EPA/600/R-09/132
October 2009

Measurement of Emissions from Produced Water Ponds: Upstream Oil and Gas Study #1

Final Report

EPA/600/R-09/132
October 2009

Measurement of Emissions from Produced Water Ponds: Upstream Oil and Gas Study #1

Final Report

by

Eben Thoma
Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
Research Triangle Park, NC 27711

National Risk Management Research Laboratory
Office of Research and Development U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

List of Appendices

List of Tables

List of Figures

List of Acronyms

AM	Alkane Mixture
CCF	Concordance Correlation Factor
DQI	Data Quality Indicator(s)
ECPB	Emissions Characterization and Prevention Branch
EPA	Environmental Protection Agency
GC-MS	Gas Chromatography-Mass Spectroscopy
MDL	Minimum detection limit
MCR	Mass Concentration Ratio
N OUT	North Pond Outlet
OAQPS	EPA Office of Air Quality Planning and Standards
OP-FTIR	Open-Path Fourier Transform Infrared
ORD	Office of Research and Development
ORS	Optical Remote Sensing
OTM 10	EPA ORS Test Method OTM 10
PAC	Path averaged concentration
PI	Principal Investigator
PIC	Path integrated concentration
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RSD	Relative Standard Deviation
S	South
S OUT	South Pond Outlet
SNMOC	Speciated non-methane organic compounds
SOP	Standard Operating Procedures
SP IN	Skim Pond Inlet
SP OUT	Skim Pond Outlet
SSE	Sum of Squared Errors
AM	Alkane Mixture
TAM	Time Averaging Method
TO	Toxic Organic
UOGEM1	Upstream Oil and Gas Emission Measurement study, Phase 1
VOA	Volatile Organics Analysis
VOC	Volatile Organic Compound
VRPM	Vertical Radial Plume Mapping

This page intentionally left blank.

Executive Summary

Significant uncertainty exists regarding air pollutant emissions from upstream oil and gas production operations. Oil and gas operations present unique and challenging emission testing issues due to the large variety and quantity of potential emission sources. To improve emission knowledge for this sector, a project team with representatives from United States Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards (OAQPS), EPA Office of Research and Development (ORD) and their contractors, EPA Region 8, and the states of Colorado and Wyoming was formed and is working to define and execute a multi-phased research effort. This report summarizes Phase I of the effort, which helps address an immediate need of EPA Region 8 and states to improve understanding of volatile organic compound (VOC) emissions from oil and gas produced water evaporation ponds. Phase I field measurements focused on a subset of VOCs that are commonly found in oil and gas production operations and are quantifiable using area source measurement method EPA OTM 10 (EPA, 2006) and related techniques. This subset includes mixture of alkanes, benzene, toluene, xylenes, methanol, and methane.

This report presents emission flux estimates from the holding evaporation ponds at the Williams Rulison and EnCana Benzel facilities in Western Colorado acquired August 6-9 and 12-15, 2008, respectively. The primary measurement approach was EPA OTM 10 using two open-path Fourier transform infrared (OP-FTIR) instruments deployed around the ponds to provide mass emission flux estimates for an alkane mixture (AM) by spectroscopic analysis of the infrared absorption features in the C-H stretch spectral region around 2900 cm^{-1}. The AM was chosen for analysis since it was robustly quantifiable by the utilized methodology whereas other species of interest were frequently below detection limits of the OP-FTIRs so could not be used for standard OTM 10 flux measurements. Estimates of emission flux for select VOCs, which were quantifiable by OP-FTIR using time averaging techniques, were also produced. These estimates utilized a VOC to AM mass concentration ratio calculation determined when the AM concentrations were relatively high.

Table E-1 presents a summary of the AM emission flux results from the two sites. The values in the table represent the average of all valid 20-minute AM flux estimates calculated over a four-day period at each site with standard deviation in parenthesis and number of values indicated. The uncertainty estimate for the individual flux measurements comprising this average is estimated at ± 40%. The uncertainty in the overall average is likely driven by the temporal variability in the source emissions.

Table E-1. Summary of AM Emission Flux Results from William Rulison and EnCana Benzel Sites

Site	Source	Average AM Flux [g/s]	Number of Values
Williams	Evaporation Pond	0.20 (0.33)	27
Williams	Skim Pond	0.90 (0.58)	15
EnCana	Evaporation Pond	0.07 (0.06)	65

Table E-2 presents a summary of emission flux estimates for select VOCs produced using a mass concentration ratio technique. For this estimate, the compound to AM mass concentration ratio and AM emission flux results for similar time periods were utilized to produce the emission rates estimate. The values of Table E-2 include underlying uncertainty in AM flux measurement average in addition to significant VOC to AM concentration ratio uncertainty so the values should be considered estimates.

Table E-2. Summary of Estimated select VOC Emission Rates from William Rulison and EnCana Benzel Sites

Site	Source Area	Benzene (g/s)	Toluene (g/s)	m-Xylene (g/s)	o-Xylene (g/s)	p-Xylene (g/s)	Methanol (g/s)	Methane (g/s)
Williams	Evaporation Pond	0.018	0.040	0.016	0.040	0.020	0.001	0.017
Williams	Skim Pond	0.078	0.181	0.072	0.182	0.088	0.006	0.074
EnCana	Evaporation Pond	0.029	0.023	0.017	0.014	0.014	0.002	0.007

To provide supporting information, the concentration of the AM and select VOCs were determined using one-hour SUMMA canister sampling deployed at positions around the ponds. The canisters were analyzed with EPA Method TO-15 and SNMOC analysis and were compared to OP-FTIR measurements for similar time periods. Additionally, water samples were taken during the campaign and these results are included as supporting information.

Note that the emission estimates presented in this report represent a snapshot in time consisting of day-time observations over consecutive four-day periods at each facility during the month of August. Diurnal and seasonal effects in addition to changing process variables were not evaluated as part of this study. Since these variables may have a significant effect on emissions, extrapolation of the results contained in this report involves significant uncertainty. As a specific example, methanol-water concentrations are known to vary seasonally so the emission data contained in this report is may not be typical.

1. Introduction

1.1 Background

EPA Region 8 and, in particular the State of Colorado, is home to numerous oil and gas production operations (also called upstream operations). In recent years, Colorado has seen ozone levels that exceed national ambient air quality standards with levels increasing at several sites. It is thought that emissions of volatile organic carbon (VOC) ozone precursor compounds from upstream oil and gas operations may contribute in part to these exceedance episodes. With the continued increase in oil and gas production operations coupled with new lowered ozone standards, the potential for exceedance episodes may increase. Emissions of VOCs including hazardous air pollutants (HAPS) is a general concern to the public and press prompting regular inquiries to the affected state agencies and Region 8. In addition to air quality issues, emissions from upstream oil and gas operations include a significant proportion of methane which is a potent greenhouse gas and could become a key concern if regulating agencies moves to greenhouse gas emissions quantification, reporting and control.

Significant uncertainty exists regarding air pollutant emissions from upstream oil and gas production operations which start with well completion and work-over activities, to well-site operations through to midstream production and waste handling. Models exist to estimate emissions from some of these emission sources such as: amine units, glycol dehydrators and oil/condensate storage tanks. These modeled emissions represent only a fraction of the emissions and may underestimate these emissions from oil and gas production activities. The Texas Commission on Environmental Quality is currently conducting a project to compare modeled emissions from condensate tanks to actual emission measurements. Development and application of tools to quantify both VOC and methane emissions would help the regulatory community, citizens, and industry better assess emission contributions from upstream oil and gas operations in Colorado, the other states in Region 8, and in Region 6 which also has the same concerns. Data collected in our field testing can be used to develop a more robust inventory of oil and gas operation emissions from which mitigation options can be quantified and compared. This can ultimately lead to more effective control of ozone precursors and greenhouse gases and protection of air quality.

Oil and gas fields provide very unique and challenging testing issues due to their large variety and quantity of emissions sources. For example, one 30 mile by 15 mile section of Garfield County in Colorado contains over 3,000 well sites and Weld County in Colorado contains over 20,000 well sites. Producing oil or gas well sites each require various combinations of supporting process equipment such as separators, dehydrators, generators, natural gas powered pneumatic devices, injection wells, heaters, compressors/engines, storage tanks, land farms, and produced water ponds. In addition to all these potential emissions sources, there are also a variety of activities such as well drilling, well completion, well work-over, and loading/unloading of oil/produced water into trucks which have the potential to generate organic emissions. There is little or no data regarding the emissions from most of these sources and activities.

A project team with representatives from EPA OAQPS, EPA ORD and their contractors, EPA Region 8, and the states of Colorado and Wyoming are working to define and execute a multi-phased research effort to address this important issue. Phase I of the of the upstream oil and gas emissions measurement program (UOGEM1) helps address the immediate need of Region 8 and states to improve understanding of VOC emissions from oil and gas produced water evaporation ponds (produced water generally refers to water that this co-emitted with oil and gas as part of the production process). These emissions data will help stakeholders increase understanding regarding the accuracy of their emission inventories and further residual risk knowledge and potential environmental impact of this source category. This report may also provide a basis for future protocols for testing this source category.

1.2 Phase 1 Project and Report Description

Phase I of UOGEM1 involved a two-week testing project designed to improve understanding of VOC emissions from oil and gas produced water evaporation ponds. The field campaign was conducted at the Williams Rulison and EnCana Benzel facilities in Western Colorado from August 6-9 and 12-15, 2008 respectively. The measurement campaign focused on a subset of VOCs that are commonly found in oil and gas production operations and are quantifiable using EPA area source method OTM 10 and related techniques. This subset includes mixture of alkanes, benzene, toluene, xylenes, methanol, and methane.

This report presents emission flux estimates from the holding evaporation ponds at the Williams Rulison and EnCana Benzel facilities in Western Colorado acquired August 6-9 and 12-15, 2008, respectively. The primary measurement approach was OTM 10 using two open-path Fourier transform infrared (OP-FTIR) instruments deployed in a four corners configuration to provide mass emission flux estimates for an alkane mixture (AM) by spectroscopic analysis of the infrared absorption features in the C-H stretch spectral region around 2900 cm^{-1}. The AM, further described in Appendix A, was chosen for analysis since it was robustly quantifiable by the utilized methodology whereas other species of interest were frequently below detection limits of the OP-FTIRs so could not be used for standard OTM 10 flux measurements. Estimates of emission flux for select VOCs, which were quantifiable by

OP-FTIR using time averaging techniques, were also produced. These estimate utilized a VOC to AM mass concentration ratio calculation based on the AM flux data for similar time periods. These estimates were produced when AM concentrations were relatively high. To provide supporting information, the concentration of an estimated AM along with select speciated VOCs were determined using SUMMA canister sampling with EPA Method TO-15 and SNMOC analysis. These results were compared to the OP-FTIR measurements to help inform overall results. Water samples from the ponds were also acquired and analyzed to help support the overall study.

Section 2 of the report provides a description of the Williams Rulison and EnCana Benzel facilities, information of the measurement methods used, and the location of the measurement configurations used at each site. Section 3 presents the results of the OTM 10 AM flux surveys conducted at each site along with supporting canister and water sampling information. Section 4 presents a summary of the findings, and Section 5 discusses quality assurance/quality control of the measurements and uncertainty extimations.

Appendix A presents information on the AM calculation and the OTM 10 measurements collected during the campaign. Appendix B contains the results of the SUMMA canister analysis and Appendix C contains the results of the water analysis.

The Phase 1 project was conducted by ARCADIS U.S., Inc. (ARCADIS), Durham, NC, under EPA ORD contract No. EP-C-04-023, Work Assignment No. 4-49. ARCADIS executed the field campaign, analyzed the OP-FTIR and OTM 10 data, and produced data tables and descriptions in Section 3.2, 3.3 and 3.4 and AM concentration data tables in Appendix A. ARCADIS provided parts of Section 5, contributed to the descriptions in Section 2, and provided wind direction summaries included Section 3.5. The Summa canister laboratory analysis contained in Appendix B was performed by Eastern Research Group Inc., Morrisville, NC under subcontract to ARCADIS.

EPA Personnel were primary authors on the body and summary sections of the report, produced the canister and water data summary analyses and comparative descriptions and graphs of Section 3.5 and 3.6, the uncertainty discussion and simulations in Section 5, and the AM descriptions and graphs in Appendix A. The water analysis contained in Appendix C was performed by EPA Region 8.

This report has been reviewed by the Office of Research & Development, U.S. EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the agency nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This page intentionally left blank.

2. Description of Test Sites and Measurement Methods

The following section describes the two test sites and the utilized measurement methods. Section 2.1 describes the Williams Rulison and EnCana Benzel facilities and shows the layout of each site. Section 2.2 describes the EPA OTM 10, Vertical Radial Plume Mapping (VRPM) method used to assess mass emission flux of the alkane mixture (AM) from the sites. Section 2.3 describes emission flux estimates for select VOCs that were quantifiable by OP-FTIR using extended time averaging techniques. Section 2.4 describes the supporting SUMMA canister concentration measurements made at each of the ponds. Section 2.5 describes supplemental water sampling activities conducted on site. Detailed information on OTM 10 averaging periods and data analysis and OP-FTIR spectral analysis is contained in Sections 3 and Appendix A.

2.1 The Williams Rulison and EnCana Benzel Test Sites

The two test sites chosen for this study were selected based on logistical and access factors. The first site, the Williams Rulison Facility, was tested from August 6-9, 2008 and is shown in Figures 2-1 and 2-2. The second site, the EnCana Benzel Facility, was tested from August 12-15, 2008 and is shown in Figure 2-3.

The Williams Rulison facility had a complex layout compared to the EnCana Benzel Facility, and Figure 2-2 identifies the details that surround the large evaporation apron and the two evaporation holding ponds. As explained by Williams personnel, water from the oil and gas production operations is delivered by truck or a small pipe line to Tank A where the first stage of oil-water separation occurs, then to Tank E for the second stage of separation). Oil from both stages is pumped to Tank B, oil sales. The water is passed through to the Tank G at then enters the skim pond. The water passes through the skim pond operation and then into the north evaporation pond (North Pond) where aeration is employed to assist aerobic bio-treatment of the water. Water exits the North Pond at its west side and enters the South Pond. At the east side of the South Pond, water is pumped back into the North Pond. Some water from the South Pond is also pumped to Tank C, the frac water loadout. This water is trucked back to the field to be used again in drilling operations. The large evaporation apron to the north of the North Pond is used to evaporate water through misting sprayers. This process occurs infrequently and was not performed during the test period. Since the misting operation was not used during the study, no estimate of emission from this potential source could be made. The evaporation apron had shallow pockets of standing water (likely to be rain water). Note the figures presented below are stock satellite images and are not representative of site conditions during the study. For example, there was very little standing water in the evaporation apron during the study.

Figure 2-1. Williams Rulison Facility

Location:	Approximately 2 miles north of Rulison, CO (Lat: 39.508858; Long: -107.918335). The magnetic declination was calculated to be -15.8525º.
Site Process Description:	Water is trucked into the facility. The receiving tanks are heated to induce separation. Then the water flows to heated polishing tanks before entering the oil-water separators. At the outlet of the oil-water separators, the water is injected with aerobic bacteria to reduce hydrocarbons. There is extensive separation prior to ponds.
Dimensions of Ponds:	There are two ponds at the site. The exact dimensions of the ponds are not known. However, we estimated that the first pond has a surface area about of 3.1 acres, and the second pond has a surface area of about 2.7acres.

Figure 2-2 Details of the Site Layout for Williams Rulison Facility

Figure 2-3. EnCana Benzel Facility

<u>Location</u>:	Approximately 10 miles south of Rifle, CO. (Lat: 39.500149; Long: -107.739334). The magnetic declination was calculated to be -15.6575º.
<u>Site Process Description</u>:	Water is piped into facility via a pipeline. There will be some separation prior to the facility. There is only one stage of separation using chemical demulsifying agents prior to the pond. Minimal separation prior to ponds.
<u>Dimensions of Pond</u>:	There is one pond at the site with dimensions of 350' x 150' and a surface area of 1.2 acres.

The daily incoming flow (volume) for the Williams facility for August 6, 7 and 8, 2008 was 4700, 6400, and 4900 barrels per day, respectively, into Building A as shown in Figure 2-2. On each day of testing, ARCADIS personnel also took a number of flow measurements from the meter located outside of Building A. The flow rates were highly variable, and ranged as follows: August 6, from a reverse flow reading at one point to 6.2 barrels/min; August 7, from 2.3 to 15.5 barrels/min; and August 8, from 1.7 to 14.9 barrels/min.

The second site, the EnCana Benzel Facility, was tested from August 12-15, 2008 and is shown in Figure 2-3. Water is piped into tanks on the northern side of the pond, which can be seen under the red line connecting the scissor jack and the EPA FTIR (ID E123). These tanks are where the one-stage separation using chemical demulsifying agents occurs prior to the water bring pumped into the pond. The brown areas north of the pond and tanks are racks of used pipes, another likely source of hydrocarbons. A neighboring facility can be seen north of the pipe racks. No in coming flow information was available to be recorded during monitoring at the Benzel facility. EnCana later provided an estimate of ~285 barrels per day average throughput during the week of the study.

2.2 Description of EPA OTM 10 Measurements

The estimate of alkane mixture (AM) mass emission flux from facility sources was produced using EPA method OTM 10 with open-path Fourier transform infrared (OP-FTIR) spectroscopy deployed in a four corner configuration. The measurement approach includes two steps: (1) acquisition and analysis of path-integrated concentration (PIC) data of air pollutants along multiple plane-configured optical paths using OP-FTIR, and (2) the analytical approach which calculates the mass emission flux estimate for the upwind source. The approach utilizes the vertical radial plume mapping (VRPM) plane-integrating computer algorithm with the acquired multi-path PIC data and wind vector information as primary inputs.

The acquisition of PIC data was accomplished using a three-beam OTM 10 setup for each flux plane. Utilizing both the ARCADIS (A) and EPA (E) OP-FTIR instruments, a four corner configuration was set up around the pond sources (Figure 2-4). In this configuration, 4 flux planes provide continuous measurement coverage under changing wind directions. The flux planes are labeled with a letter (A or E) representing the OP-FTIR system along with the beam paths (123 or 456) to form unique identifiers. Alternating scans were made between the two VRPM planes of each OP-FTIR. The red lines in Figures 2-1 and 2-3 show the actual placement of this configuration at the William Rulison and EnCana Benzel facilities, respectively. At both facilities, the position of the VRPM planes were chosen to maximize the capture of emissions from the ponds taking into account the suspected source locations and site constraints.

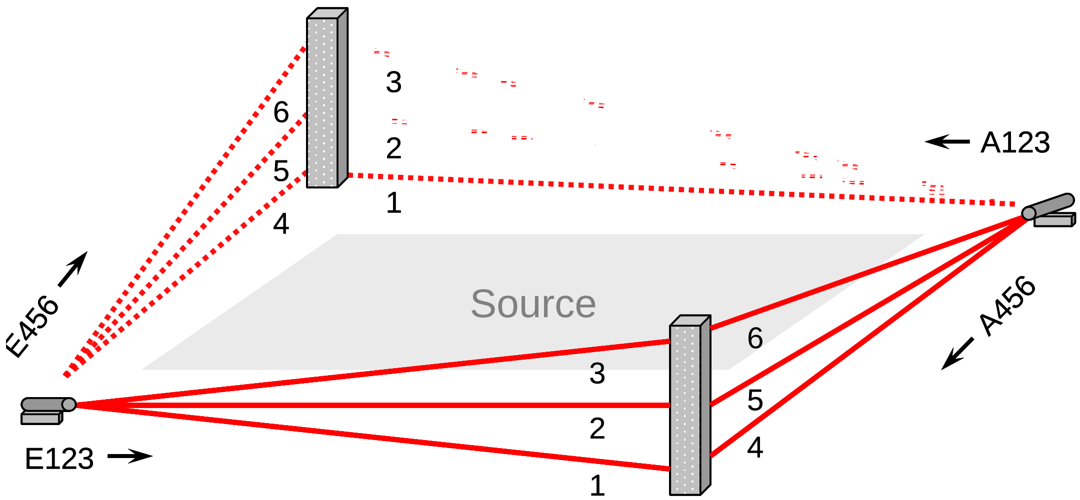

Figure 2-4. Four Corner Configuration

Tables 2-1 and 2-2 present details of the placement of the optical components for the four corner configurations at the Williams and EnCana Benzel facilities.

The acquired OP-FTIR data must be analyzed to produce a PIC value. For this project, OP-FTIR data reduction focused on the PIC values of the AM by spectroscopic analysis of the infrared absorption features in the C-H stretch spectral region around 2900 cm^{-1}. The AM is composed of a variety of hydrocarbons but the infrared signature for fuel base mixtures is usually dominated by C-4 to C-8 alkanes (butane, pentane, hexane, heptane, octane). The AM analysis was executed for a combined group of compounds since performing spectral analysis of each individual species was not possible due to the similarity in the shapes of their absorption bands. The spectral analysis of the AM is further described in Appendix A. The AM was chosen for analysis since it was robustly quantifiable whereas other species of interest were frequently below detection limits of the OP-FTIRs so could not be used for standard OTM 10 flux measurements. Estimates of emission flux for select VOCs, which were quantifiable by OP-FTIR using extended time averaging were also produced and is described in Section 2.3.

Table 2-1. Optical Configuration Details for the Williams Facility Setup

Mirror Number	OP-FTIR to Retroreflector Distance (m)	Approximate Retroreflector Height (m)	Optical Path Angle from North (deg)
A1	142.3	1	148.5
A2	142.0	4.8	148.8
A3	142.8	8.6	148.5
A4	185.3	1	32.4
A5	187.6	2.9	32.3
A6	187.2	8.1	33.3
E1	148.3	1	232.2
E2	150.2	4.4	232.5
E3	149.7	8.2	232.3
E4	219.1	1	328.2
E5	220.3	3.5	328.4
E6	220.6	8.7	328.5

Table 2-2. Optical Configuration Details for the EnCana Facility Setup

Mirror Number	OP-FTIR to Retroreflector Distance (m)	Approximate Retroreflector Height (m)	Optical Path Angle from North (deg)
A1	128.4	1	334.2
A2	129.3	3.7	333.9
A3	129.9	9.3	334.1
A4	109.7	1	54.4
A5	109.7	5.2	54.4
A6	110.1	9.5	54.9
E1	104.1	1	268.2
E2	104.1	3.9	268.2
E3	104.4	9.4	268.8
E4	74.0	1	154.2
E5	80.2	4.2	154.6
E6	81.2	8.2	154.9

The OTM 10 analytical procedure was used to produce the AM flux estimate by inputting the multi-beam AM PIC values along with wind information and configuration data into the VRPM algorithm. The VRPM method is generally discussed in EPA OTM 10 *"Optical remote sensing for emission characterization from non-point sources"* which describes direct measurement of pollutant mass emission flux from area sources using ground-based optical remote sensing (ORS). The VRPM computer algorithm uses a smooth basis function minimization routine of a bivarate Gaussian function to generate mass emission flux information from species concentration and wind data. For this measurement campaign, the VRPM configuration utilized a three-beam configuration which leads to a reduced form of the bivarate Gaussian in polar coordinates (*r, θ*). The standard deviation in the crosswind direction was set at one half the length of vertical plane (r_1) for this project.

$$G(A,\sigma_z,m_z) = \frac{A}{2\pi(4r_1)\sigma_z}\exp\left\{-\frac{1}{2}\left[\frac{(r\cdot\cos\theta - \tfrac{1}{2}r_1)^2}{(4r_1)^2} + \frac{(r\cdot\sin\theta - m_z)^2}{\sigma_z^2}\right]\right\} \qquad (2\text{-}1)$$

Where:

A	=	*normalizing coefficient, adjusts for the peak value of the bivariate surface;*
m_z	=	*peak location in Cartesian coordinates;*
σ_z	=	*vertical standard deviation in Cartesian coordinates;*
r_1	=	*length of VRPM plane;*

A, m_z, and σ_z are the unknown parameters to be retrieved by the fitting procedure. An error function (SSE) for minimization is defined as:

$$SSE(A,\sigma_z,m_z) = \sum_i\left(PAC_i - \int_0^{r_i} G(r_i,\theta_i,A,\sigma_{m_z})dr/r_i\right)^2 \qquad (2\text{-}2)$$

Where PAC_i is the measured path-averaged concentration (PAC) value for the i^{th} beam. The SSE function is minimized using the Simplex method to solve for the three unknown parameters. This process is for determining the vertical gradient in concentration. It allows an accurate integration of concentrations across the vertical plane as the long-beam ground level PAC provides a direct integration of concentration at the lowest level.

Once the parameters of the function are found for a specific run, the VRPM procedure calculates the concentration values for every square elementary unit in a vertical plane. Then, the VRPM procedure integrates the values, incorporating wind speed data at each height level to compute the flux. This enables the direct calculation of the flux in grams per second (g/s), using wind speed data in meters per second (m/s). Further information on the VRPM method for area source emission measurements in general can be found in Hashmonay and Yost 1999, Thoma et al. 2005, U.S. EPA 2006, U.S. EPA 2007 with specific details of this deployment in U.S. EPA 2008. An analysis of OTM 10 measurement uncertainty for this project is contained in Section 5.3.

Table 2-3 describes the instrument operation time periods for the OTM 10 measurements for this study. The instrument operational times represent those periods when instrumentation was operating within acceptable limits. Note that valid flux data time periods represent a subset of instrument operation time periods when data acceptance criteria were met. Valid flux data time periods are detailed in Appendix A. As it requires 1 to 2 hours to get the equipment set up and operational each day, the start time for operation was usually in the mid morning. The end time was dictated primarily by site access limitation (no night work) or by weather events (8/9). Additional information on equipment operational requirements and data quality indicators is contained in Section 5 and Appendix A.

Table 2-3. Instrument Operation Time Periods for the EPA OTM 10 Method

	Date	Start Time	End Time
Williams Rulison	8/6/2008	14:20	16:40
	8/7/2008	10:20	17:40
	8/8/2008	10:20	16:40
	8/9/2008	11:40	15:00
EnCana Benzel	8/12/2008	12:00	18:20
	8/13/2008	10:20	17:40
	8/14/2008	9:20	16:20
	8/15/2008	9:40	14:20

2.3 OP-FTIR VOC Analysis and Calculation of Estimated VOC Flux

As discussed in previous sections, the AM was chosen for flux analysis since it was present at high enough concentrations to be quantified at standard OTM 10 time resolution (30 second integration time) whereas other species of interest were frequently below the OP-

FTIR detection limits on one or more optical paths so could not be used for OTM 10 flux measurements. Using a time-averaging approach, many of these compounds could be quantified and estimates of emission flux for select VOCs were produced using a mass concentration ratio calculation based on the AM flux data for similar time periods.

Analysis of the OP-FTIR data was performed to determine concentrations of benzene, toluene, m-xylene, o-xylene, p-xylene, methanol, and methane. The select VOC analysis was done for time periods when relatively high alkane mixture (AM) emissions were detected. Table 2-4 presents a summary of the time periods when the analysis was performed. The table also indicates the measurement path from which the data was collected. Here the term VOC represents one or more of the target compounds listed above and is not inclusive of all VOCs. Note that methane did not require the time averaging method.

Table 2-4. Periods of OP-FTIR VOC Analysis

Measurement Path	Site	Compound Analyzed	Start Time (MDT)	End Time (MDT)
EPA-806_1353-M4	Williams	Methane	8/6/2008 16:00	8/6/2008 16:40
EPA-807_1356-M4	Williams	VOC	8/7/2008 14:01	8/7/2008 15:59
ARC-807_1102-M4	Williams	VOC/methane	8/7/2008 14:02	8/7/2008 14:58
EPA-807_1022-M4	Williams	Methane	8/7/2008 16:01	8/7/2008 17:40
EPA-808_1153-M4	Williams	VOC/methane	8/8/2008 13:27	8/8/2008 14:24
ARC-808_1004-M4	Williams	VOC	8/8/2008 16:00	8/8/2008 16:46
EPA-808_1153-M4	Williams	VOC/methane	8/8/2008 16:01	8/8/2008 16:50
ARC-808_1004-M1	Williams	VOC	8/8/2008 16:02	8/8/2008 16:49
ARC-812_1513-M4	EnCana	VOC/methane	8/12/2008 17:02	8/12/2008 18:16
ARC-812_1513-M1	EnCana	VOC/methane	8/12/2008 17:04	8/12/2008 18:27
ARC-813_0922-M4	EnCana	VOC/methane	8/13/2008 11:08	8/13/2008 12:05
ARC-813_0922-M4	EnCana	Methane	8/13/2008 13:20	8/13/2008 14:30
ARC-813_0922-M4	EnCana	VOC	8/13/2008 15:00	8/13/2008 15:26
EPA-813_1021-M1	EnCana	VOC	8/13/2008 15:25	8/13/2008 16:13
ARC-813_1536-M4	EnCana	VOC/methane	8/13/2008 15:52	8/13/2008 16:51
ARC-814-0908-M4	EnCana	VOC/methane	8/14/2008 10:22	8/14/2008 11:19
ARC-814-0908-M4	EnCana	Methane	8/14/2008 15:00	8/14/2008 16:10
ARC-814-0908-M4	EnCana	VOC/methane	8/14/2008 15:59	8/14/2008 16:56
ARC-815-0918-M4	EnCana	Methane	8/15/2008 13:00	8/15/2008 14:00

The VOC analysis was done using the time-averaging method (TAM), which is a post-measurement analysis technique for determining multi-hour concentration averages and detection limits. This method may facilitate comparison with time-integrated point-sample collection techniques (such as one-hour canister samples). The method can produce significantly lower instrument detection limits and can be applied to any ORS measurement technology that produces a set of response-signal (single-beam) spectra. As discussed, analysis of the OP-FTIR data for select VOC using a standard averaging period (30 seconds) resulted in minimum detection limits too high to robustly quantify the target VOC compounds.

The TAM consists of two steps. The first step is performed once for all target compounds that are analyzed in a single measurement set. This procedure involves determining, for each target compound, the individual measurements in the measurement set in which the spectra indicate background or zero levels of the target species. These measurements are averaged to produce a specific time-averaged background spectrum for each compound.

The second step involves performing a Classical Least Squares analysis on the single-beam spectrum that is the average of the entire measurement set covering the time-averaging period, and the background single beam spectrum selected in the first step of the procedure for the target compound. The analysis is repeated for each target compound using the respective co-added background determined in step one. The resulting concentration determination is the time-averaged result, and the detection limit is determined from the standard error of the regression fit.

Table 2-5 provides a comparison of estimated minimum detection limits (MDL) of OP-FTIR for select VOC compounds measured in this study. The first column presents typical MDL using a 1-minute averaging time, while the second column shows typical MDL using the TAM with 30-minute time resolution.

Table 2-5. Detection Limits for Optimal OP-FTIR Setup with Clean, Fully Populated Retroreflector Arrays

Species	MDLs, 200 meters 1 minute (ppb)	MDLs, 200 meters 30 minute Avg. (ppb)
Benzene	60	12
Toluene	80	16
m-Xylene	44	12
o-Xylene	40	12
p-Xylene	64	16
Methanol	12	3

The results of the VOC concentration analysis, which can be found in Section 3.4 of this document, were used with the measured average alkane mixture emissions fluxes from the Williams and EnCana sites to calculate an estimated emissions flux for each VOC. More information on this calculation, as well as the estimated VOC flux values, can be found in Section 3.4.

Additional concentration analysis of the OP-FTIR data for benzene, toluene, m-xylene, o-xylene, and p-xylene was performed for six time periods that SUMMA canisters were deployed near the OP-FTIR measurement path. This analysis was done to compare the concentration determinations from the two measurement methods. Table 2-6 presents a summary of the six SUMMA canister deployment periods used for this comparison. The results of this comparison are presented in Section 3.4 of this document. Section 3.5 contains a detailed comparison of the OP-FTIR AM and SUMMA canister AM data along with sampling location information and wind summaries.

Table 2-6. Periods of SUMMA Canister/ OP-FTIR VOC Analysis

SUMMA ID	Site	Date	Start Time (MDT)	End Time (MDT)
TNAPC11	Williams	8/7/2008	16:13	17:13
926,648	Williams	8/8/2008	13:25	14:25
ER047	Williams	8/9/2008	14:00	15:00
TNAPC20	EnCana	8/13/2008	15:52	16:52
ER069, ER064	EnCana	8/14/2008	10:32	11:32
988,3248	EnCana	8/14/2008	16:09	17:09

2.4 Description of SUMMA Canister Measurements

In addition to EPA OTM 10 flux and related open-path measurements, evacuated SUMMA canister samples were collected at both sites to provide supporting information on the AM and select VOC concentration levels in areas near the observing OTM 10 planes. Time-integrated (1 hour) SUMMA canister samples with EPA TO-15 and SNMOC analysis were utilized since this approach yields lower method detection limits (MDL) for most compounds compared to the in situ path-integrated measurements acquired with OP-FTIR using standard 30 second time integration, thus providing useful information on concentrations of trace VOCs. A manual sample collection system was used with canister placement at an approximate 1 m height in many cases near the location of the lowest beam paths of the respective VRPM planes (paths 1 or 4 shown in Figure 2-4). Three samples were collected at a time: two canisters were co-located near the midpoint of the downwind VRPM plane, and one canister was deployed near the midpoint of the upwind VRPM plane. On some days, two sets of samples were collected, one in the morning and one in the afternoon. A total of 28 canister samples were collected between the two sites.

The exact locations along the optical path were decided at the time of deployment by field personnel, and an attempt was made to initiate sampling when the meteorological conditions were most conducive to representative plume capture (i.e., when the wind was blowing across the open path beam at or near 90°). The vertical placement of the sample inlet and inlet funnel was one meter above ground level, approximately equal to the height of the ground level OP-FTIR optical beams. In some cases the position of the canisters were separated by from the location of OP-FTIR planes. The exact placement of the canisters along with wind information for the sampling time period is contained in Section 3.5.

Air was drawn into the evacuated canister using a calibrated critical orifice that is between the inlet and canister. The critical orifices were chosen to allow only a specified amount of air to enter the can over a given time. To avoid losses of VOCs to condensed water in the canisters, the pressure of the air sample in the canister did not exceed atmospheric pressure. The samples were analyzed by TO-15 and SNMOC with data presented in Appendix B. Table 2-7 shows the date, sampling time, and identification (ID) for the canister measurements.

2.5 Description of Water Sampling

Water sampling was conducted at the Williams Rullison site during August 7 and 8, 2008. These samples were collected at four different sites around the water treatment facility: Skim Pond Inlet (SP IN), Skim Pond outlet to the North Pond (SP OUT), North Pond outlet o the South Pond (N OUT) and South Pond outlet to the North Pond (S OUT). Figure 2-5 shows the location of each sampling point. For each sample, a Williams employee took a large grab sample directly from each header pipe exit. From each grab sample, two VOA (Volatile Organics Analysis) sample containers were filled with a minimum amount of head space. The sample containers were 40 ml amber glass with a teflon/silcon septa. The samples were then immediately put on ice. The samples were shipped over-night to the EPA R8 lab in Denver for analysis of volatile organics by EPA SW-846 Method 8260 “Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (capillary column technique). The dates and times of the sampling along with a results summary are contained in Section 3.6.

Table 2-7. SUMMA Canisters Deployed at the Williams Rulison and EnCana Benzel Facilities

Site	Date Deployed	Start Time	End Time	Summa ID
Williams Rulison	8/7/2008	16:13	17:13	TNAPC-17[1] 243[1], 973[1]
	8/7/2008	16:13	17:13	TNAPC-11
	8/8/2008	13:25	14:25	3639A
	8/8/2008	13:25	14:25	926, 648
	8/9/2008	~14:00	15:00	ER001,ER038
	8/9/2008	~14:00	15:00	ER047
EnCana Benzel	8/12/2008	~11:00	~12:00	ER029
	8/12/2008	~11:00	~12:00	659, 167604
	8/13/2008	11:07	12:07	3255
	8/13/2008	11:07	12:07	ER043, 444
	8/13/2008	15:52	16:52	TNAPC20
	8/13/2008	15:52	16:52	167601, 3254
	8/14/2008	10:33	11:33	ER061
	8/14/2008	10:33	11:33	ER069, ER064
	8/14/2008	16:09	17:09	15280
	8/14/2008	16:09	17:09	988, 3248
	8/15/2008	11:09	12:09	ER021
	8/15/2008	11:09	12:09	ER085, ER114

[1]Invalid due to zero final pressure in the canister

Figure 2-5. Location of Water Sampling Points at the Williams Facility

Water sampling was conducted at the Williams Rullison site during August 12 through August 14, 2008. These samples were collected at four different sites around the evaporation pond: grass mesa inlet to the pond (Grass), west side of pond (W), south side of pond (S), and east side of pond (E). Figure 2-6 shows the location of each sampling point. For W, S, and E locations, a peristaltic pump was used to pull sample from approximately 2 to 6 inches below the surface of the water. Two VOAs sample containers were filled directly from the peristaltic tubing exit for each point. For the Grass sample point, an EnCana employee took a large grab sample directly from each header pipe exit. From the grab sample, two VOA sample containers were filled with a minimum amount of head space. The samples were then immediately put on ice. The samples were shipped over-night to the EPA R8 lab in Denver for analysis of volatile organics by EPA SW-846 Method 8260 “Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (capillary column technique). The dates and times of the sampling along with a results summary are contained in Section 3.6.

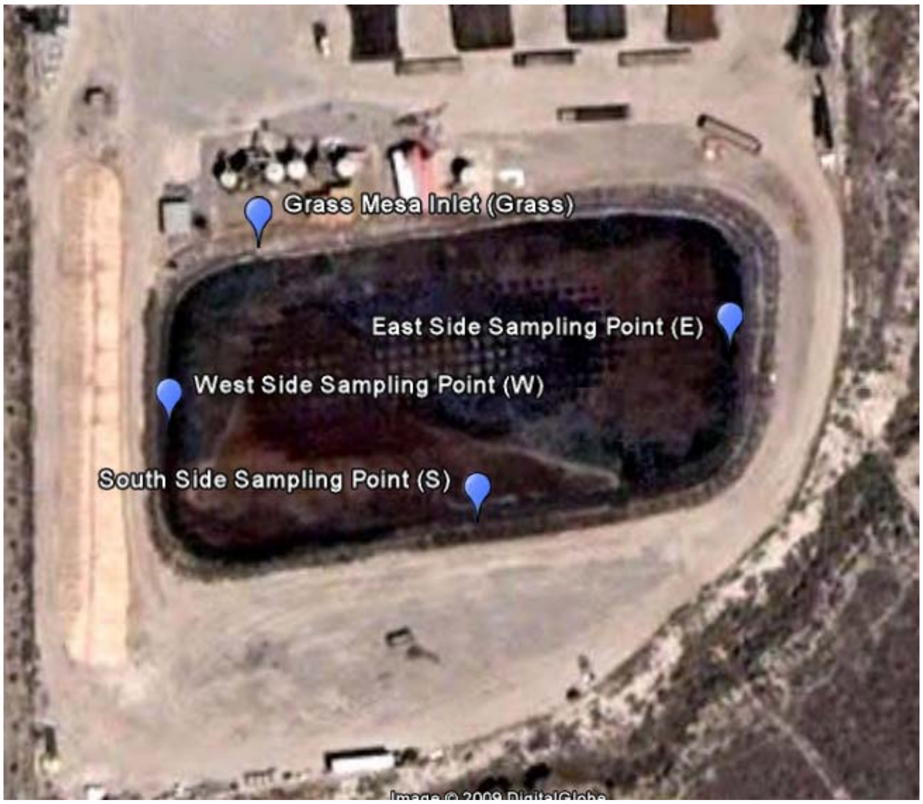

Figure 2-6. Location of Water Sampling Points at the EnCana Facility

3. Results and Discussion

3.1 Results Summary Approach

For this study, the OTM 10 VRPM calculation produces a moving average AM flux value for each of the four vertical planes (Figure 2-4). Each flux value represents an average from a time interval of approximately 4 minutes. These primary flux values are summarized in Appendix A along with data quality indicators. To calculate the net flux for the source within the four vertical plane configurations, the measured fluxes for the two downwind vertical planes are added together and the fluxes of the two upwind vertical planes are subtracted as backgrounds. Since the individual flux planes for each OP-FTIR are measured sequentially and the upwind and downwind plane pairs are not time synchronized, it is necessary to average several successive primary flux values to ensure that the net flux calculation will be composed of temporally comparable results. This is accomplished by creating a 20-minute average time period for each flux plane which is used in the net flux calculation and summary tables contained in this section. For each average reported in the tables, the following information is provided: time the measurement was made (hour:minute), wind speed (m/s), wind direction with respect to north (degrees), and the AM flux value for each of the four VRPM planes (A123, A456, E123, or E456) in g/s. Additional low and high range net flux calculations and uncertainty estimates contained in the tables are described below. Note that missing values in the tables and graphs are a result of data which did not pass acceptance criteria, see Appendix A for details.

<u>Minimum Net Flux</u>
As a way to express a low-range net flux estimate, a minimum net flux calculation is given. This value is the result of adding all four of the VRPM flux values (2 upwind and 2 downwind). The upwind planes represent background conditions (ideally zero flux) and are therefore given a negative value in these calculations. The *Sum of All 4 Planes* result is entered here and represents the minimum net flux of the target area within the 4-corner configuration. In the time series graphs, the vertical bars represent the range of possible mass emission fluxes with the minimum net flux represented by the lower end of the vertical bar.

Since the upwind planes are assigned a negative value, the *Sum of All 4 Planes* may in some cases be negative if there is a strong interfering upwind source (external source). This is caused by incomplete capture of the upwind plume by the downwind planes due to plume trajectory and dilution as it moves across the cross the configuration. When this situation occurs, these are not good conditions for estimating the flux from the target source contained within the four corners configuration. When this situation occurs, the Minimum Net Flux for target source is defined to be zero since a negative value (a sink) is not physically meaningful.

Maximum Net Flux

As a way to express a high-range net flux estimate, a maximum net flux calculation is given. This value is the sum of the two downwind VRPM flux values, and therefore represents the maximum net flux possible (assuming that none of the upwind mass is captured by the downwind vertical planes). In the time series graphs, the maximum net flux values are represented by the upper end of the vertical bars.

Estimated Net Flux

This is the mean of the *Maximum Net Flux* and the *Minimum Net Flux.* When the difference between the maximum and minimum net flux is large there is a large uncertainty associated with the estimated net flux.

Combined Uncertainty

A combined uncertainty estimate was produced for each 20-minute flux measurement. This uncertainty estimate was produced by propagating individual estimates of uncertainty for each measurement plane to a combination of all four planes using an assumption of ± 20% uncertainty for each individual plane measurement. This assumption is based on tracer release OTM 10 performance data and is further described in Section 5.3. When a sum or difference of two or more independent random variables is calculated, the propagated combined absolute uncertainty is the square root of the sum of the squares of the individual absolute uncertainties.

External Flux

This represents the absolute values of the sum of the upwind plane fluxes. In cases when the minimum net flux is positive, the range of the vertical bars represents the external flux. Since the top of the vertical bar represents the flux of everything captured by the downwind VRPM configuration, and the bottom of the vertical bar represents this same flux less the background (external contributors), then the vertical bar itself represents the range of flux from external sources.

3.2 AM Flux Summary for the Williams Rulison Facility

The following tables and figures are time series graphs of the calculated mass emission fluxes for the AM during each day of sampling and at various contributing sources (evaporation versus skim pond). Tables 3-1 through 3-4 are summary tables of mass emission flux results (20-minute period averages) for the configurations used during each day of sampling at the Williams Rulison facility. These values were calculated as described in Sections 2.2 and 3.1. Figures 3-1 through 3-4 are time series graphs of calculated mass emission fluxes for the AM during each day of sampling. For each reported average in the tables, the following information is provided: time the measurement was made, wind speed, wind direction, and the flux value for each of the four VRPM planes (A123, A456, E123, or E456). Also shown are the calculated values for: minimum net flux, maximum net flux, estimated net flux, combined uncertainty and external flux.

Table 3-1 and Figure 3-1 show the first day of sampling at the Williams Rulison facility (August 6) when winds were generally steady from the SSW. All of the estimated net flux values had very small vertical bars (relatively low external flux, typically smaller than the combined uncertainty) associated with them and the combined uncertainty is slightly higher than the individual 20% assigned uncertainty. Therefore, this time period is valid for calculating the net flux from the main evaporation pond (North Pond). They ranged from about 0 g/s to 0.2 g/s, for an average of about 0.07 g/s over the 1.5 hours of valid data collection on all four VRPM planes.

Table 3-2 and Figure 3-2 show the second day of sampling (August 7). At 14:30, there is a large vertical bar when the wind shifted to a more easterly direction thus impacting the E456 VRPM plane to the west of the skim pond. These external emissions appear to be coming from the skim pond, and had an average flux of 1.1 g/s. The time period prior to 14:30 was an ideal (low combined uncertainty and external flux) time for monitoring net emissions from the North Pond, which had an average flux of 0.56 g/s.

Table 3-3 and Figure 3-3 show the third day of sampling at William Rulison (August 8). Before 11:00 am, the winds were from the SE and the flux from the skim pond was 0.24 g/s. The winds then shifted to the SW, presenting good conditions for monitoring the North Pond. The average net flux from the North Pond throughout the day was 0.10 g/s. At the end of the day, the wind shifted to the SE again for the final 20-minute averaging period, resulting in a flux of 1.8 g/s for the skim pond. Averaging the morning and afternoon fluxes for the skim pond resulted in a daily average flux of 1.1 g/s

Table 3-4 and Figure 3-4 show results from the final day of sampling at William Rulison (August 9). The prevailing winds had an easterly component during the beginning of the measurement period (up until 13:30). The winds were then from the south for the remainder of the period. The average flux for the skim pond, determined up to 13:30, was 0.56 g/s. The rest of the day showed very little influence from the skim pond and provided good conditions for monitoring the North Pond. The average flux value for the evaporation pond was 0.13 g/s.

Table 3-1. Summary Table of the Mass Emission Flux Results (g/s) for the Configuration used at the Williams Rulison Facility on August 6, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
15:10	1.7	174.8	-0.010	0.030	-0.015	0.022	0.027	0.052	0.040	0.0195	0.025
15:30	1.9	179.3	-0.020	0.028	0.000	0.178	0.186	0.206	0.196	0.0598	0.020
15:50	2.4	179.1	-0.017	0.005	0.000	0.000	0.000	0.005	0.003	0.0061	0.017
16:10	2.0	202.6	0.000	0.000	-0.005	0.052	0.047	0.052	0.050	0.0131	0.005
16:30	2.0	231.1	0.000	0.000	0.000	0.083	0.083	0.083	0.083	0.0166	0.000

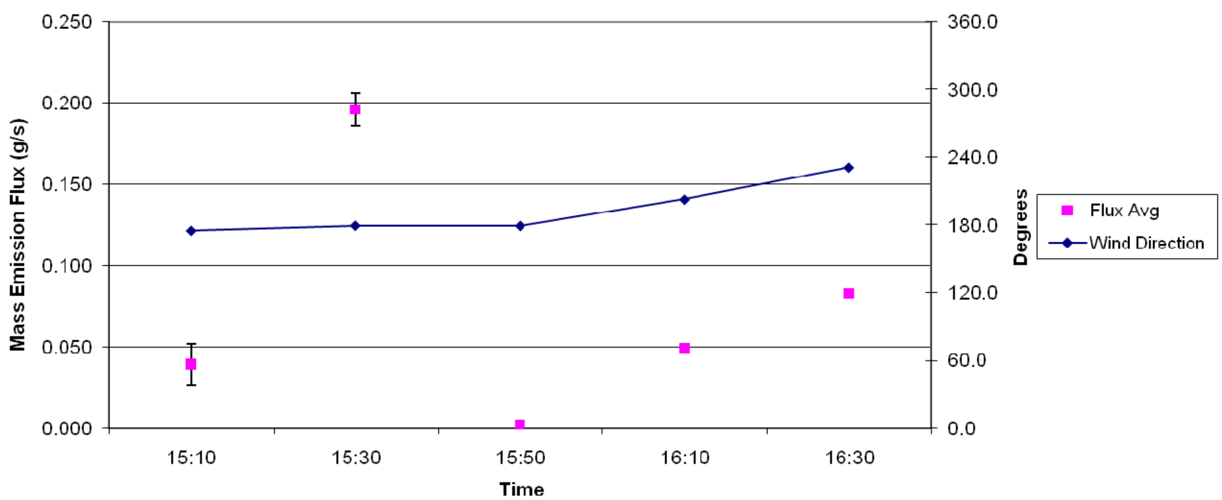

Figure 3-1. Time Series of Mass Emission Flux for August 6, 2008 at the Williams Rulison Facility

Table 3-2. Summary Table of the Mass Emission Flux Results (g/s) for the Configuration used at the Williams Rulison Facility on August 7, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
11:30	1.1	113.2	0.000	0.155	-0.003	-0.123	0.029	0.155	0.092	0.0483	0.126
12:10	1.0	95.6	0.010	0.000	-0.010	-0.440	0.000	0.010	0.005	0.0880	0.450
12:30	1.3	191.3	0.000	0.015	-0.005	0.227	0.237	0.242	0.240	0.0458	0.005
12:50	1.1	196.5	0.000	0.035	0.000	0.503	0.538	0.538	0.538	0.101	0.000
13:10	1.1	187.9	0.000	0.080	0.000	1.480	1.560	1.560	1.56	0.296	0.000
14:10	1.4	157.1	0.003	1.035	0.000	-0.200	0.838	1.038	0.938	0.279	0.200
14:30	2.4	115.9	0.080	2.637	-0.010	-1.536	1.171	2.717	1.94	0.611	1.546
15:10	1.3	34.0	0.235	-0.015	0.350	-1.088	0.000	0.585	0.293	0.233	1.103
15:30	1.3	21.0	0.242	-0.005	0.226	-0.895	0.000	0.468	0.234	0.190	0.900
15:50	1.7	60.5	0.188	0.295	0.038	-1.104	0.000	0.521	0.261	0.231	1.104
16:30	2.6	66.0	0.568	0.375	0.010	-0.265	0.688	0.953	0.821	0.146	0.265
16:50	2.8	74.3	0.306	0.470	-0.013	-0.350	0.413	0.776	0.595	0.132	0.363
17:10	1.7	60.4	0.210	0.017	0.010	-1.898	0.000	0.237	0.119	0.382	1.898
17:30	1.3	87.6	0.140	0.650	-0.030	-1.410	0.000	0.790	0.395	0.312	1.440

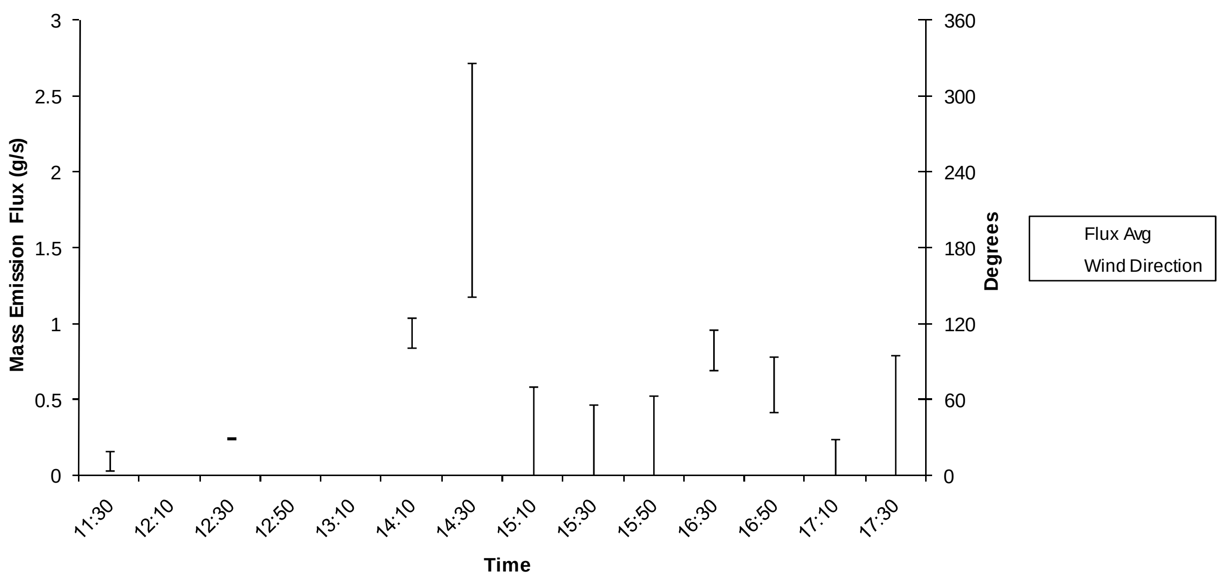

Figure 3-2. Time Series of Mass Emission Flux for August 7, 2008 at the Williams Rulison Facility

Table 3-3. Summary Table of the Mass Emission Flux Results (g/s) for the Configuration used at the Williams Rulison Facility on August 8, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
10:30	1.2	154.1	0.000	0.048	0.000	0.020	0.068	0.068	0.068	0.0104	0.000
10:50	1.1	103.2	0.020	0.092	0.000	-0.238	0.000	0.112	0.056	0.0512	0.238
11:10	1.4	170.0	0.000	0.000	-0.010	0.020	0.010	0.020	0.015	0.0045	0.010
11:30	1.7	204.9	-0.003	0.000	-0.010	0.047	0.034	0.047	0.041	0.0098	0.013
12:10	3.5	256.8	0.000	0.000	0.028	0.040	0.068	0.068	0.068	0.0099	0.000
12:30	4.3	251.5	0.000	0.000	0.005	0.078	0.083	0.083	0.083	0.0161	0.000
12:50	4.2	250.2	0.000	0.000	0.002	0.025	0.027	0.027	0.027	0.0051	0.000
13:10	4.5	245.7	0.000	0.000	0.000	0.136	0.136	0.136	0.136	0.0272	0.000
13:30	4.6	246.0	0.000	0.000	0.008	0.053	0.061	0.061	0.061	0.0108	0.000
13:50	3.8	245.9	0.000	0.000	0.010	0.108	0.118	0.118	0.118	0.0217	0.000
14:10	3.0	244.7	0.000	0.000	0.006	0.178	0.184	0.184	0.184	0.0356	0.000
14:30	2.7	226.8	0.000	0.000	-0.007	0.090	0.083	0.090	0.087	0.0181	0.007
15:10	1.9	211.1	0.000	0.000	-0.010	0.092	0.082	0.092	0.087	0.0185	0.010
15:30	2.8	228.6	0.000	0.000	-0.010	0.280	0.270	0.280	0.275	0.0560	0.010
16:30	3.5	136.5	0.237	1.757	0.000	-1.853	0.141	1.994	1.068	0.5129	1.853

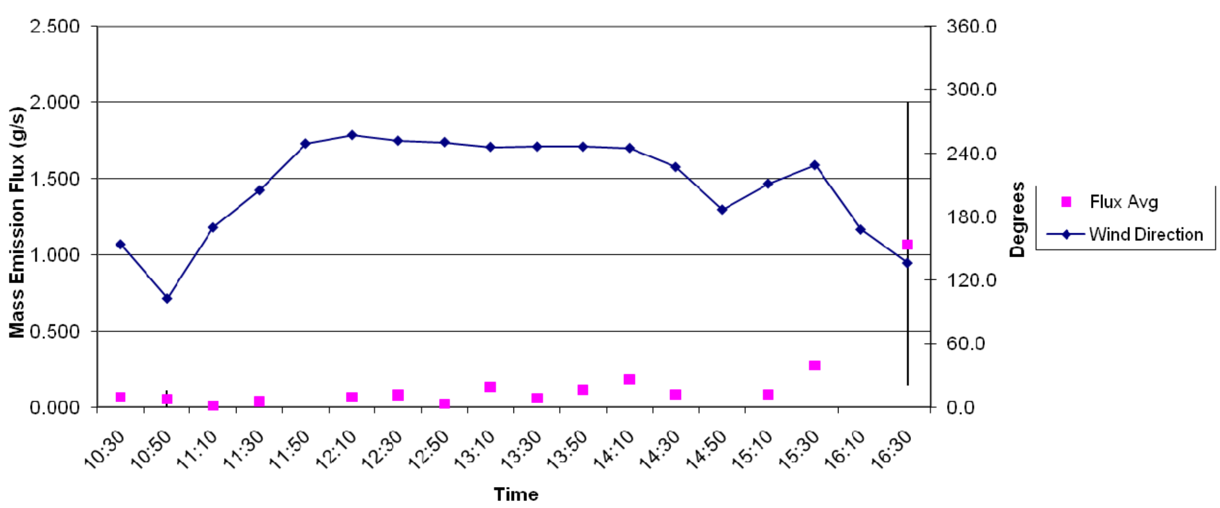

Figure 3-3. Time Series of Mass Emission Flux for August 8, 2008 at the Williams Rulison Facility

Table 3-4. Summary Table of the Mass Emission Flux Results (g/s) for the Configuration used at the Williams Rulison Facility on August 9, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
11:50	2.7	85.4	0.220	0.307	-0.012	-0.325	0.190	0.527	0.359	0.0997	0.337
12:10	2.6	92.8	0.088	0.383	0.000	-0.380	0.091	0.471	0.281	0.1093	0.380
12:30	2.5	91.2	0.045	0.158	-0.030	-0.797	0.000	0.203	0.102	0.1631	0.827
12:50	1.7	106.1	0.015	0.115	-0.025	-0.688	0.000	0.130	0.065	0.1397	0.713
13:10	1.2	93.9	0.010	0.093	-0.013	-0.525	0.000	0.103	0.052	0.1070	0.538
13:50	1.0	163.8	0.000	0.025	-0.100	0.040	0.000	0.065	0.033	0.0221	0.100
14:10	1.9	167.9	0.000	0.018	-0.038	0.094	0.074	0.112	0.093	0.0208	0.038
14:30	2.9	154.7	0.000	0.108	0.000	0.044	0.152	0.152	0.152	0.0233	0.000
14:50	3.0	144.9	0.000	0.273	0.000	-0.070	0.203	0.273	0.238	0.0564	0.070

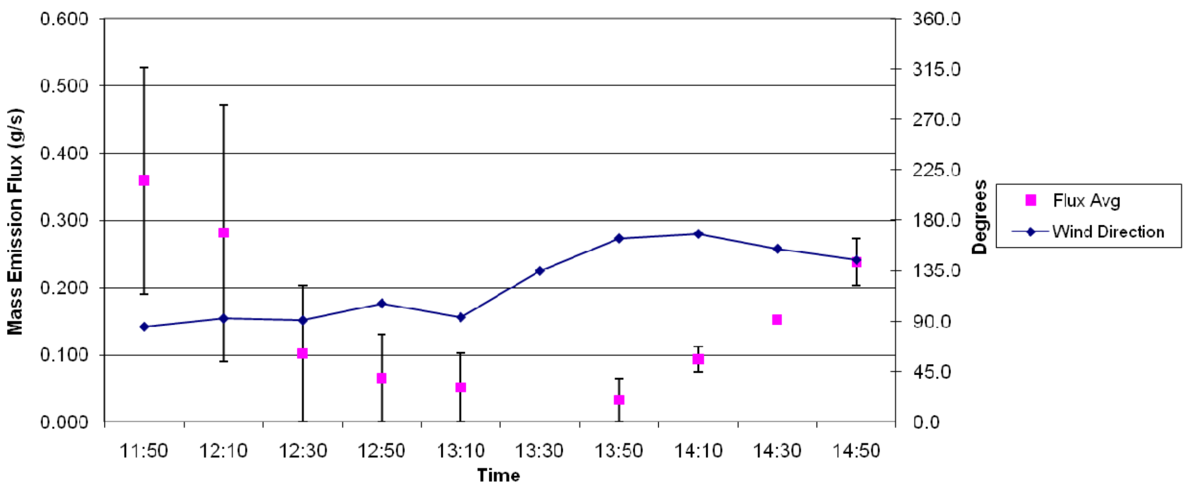

Figure 3-4. Time Series of Mass Emission Flux for August 9, 2008 at the Williams Rulison Facility

One observation made during this field campaign was that lower emissions were measured for the skim pond in the morning, than in the afternoon. Also, there was a very good correlation (Pearson correlation of 0.87) between the external flux (primarily skim pond) and the combined uncertainty. This reaffirms that in time periods with large external flux interfering with the estimation of the net flux from the north pond, the uncertainty is large.

The 4-day average flux from the evaporation pond (North Pond) was 0.20 g/s (SD of ± 0.33). The flux value for the evaporation pond was found by averaging (27) 20-minute averaged flux values over 4 days. See Section 5.3 for additional discussion on OTM 10 measurement uncertainty. The average flux value from the evaporation pond is found using the "Estimated Net Flux" values from Table 3-1 through 3-4 during the following time periods, which were ideal for characterizing emissions from the evaporation pond based on prevailing wind direction during the time of the measurements:

- August 6: 15:10 to 16:30
- August 7: 11:30 to 14:10
- August 8: 11:10 to 15:30
- August 9: 13:50 to 14:50

The 3-day average flux from the skim pond (no external sources were detected by the VRPM configuration on Day 1 of sampling) was 0.90 g/s (SD of ± 0.572). The value for the skim pond was found by averaging (15) 20-minute averaged flux values over a 3 day period. The average flux value from the Skim Pond is found using the "External Flux" value shown in Tables 3-1 through 3-4 during periods described as being ideal for characterizing emissions from the pond.

- August 6: No Measurements
- August 7: 14:30 to 17:30
- August 8: 10:30, 10:50, 16:30
- August 9: 11:50 to 13:10

Note that no valid measurements were obtained from the South Evaporation pond. Emissions from this pond are expected to be very low and this is supported by the Water sampling measurements described in Section 3.6 and Appendix C which indicate non detects for volatile organic concentrations in the ponds. For subsequent summary tables, the North Pond is referred to as Evaporation Pond.

3.3 AM Flux Summary for the EnCana Benzel Facility

Tables 3-5 through 3-8 are summary tables of mass emission flux results (20-minute period averages) for the configurations used during each day of sampling at the EnCana Benzel facility. These values were calculated as described in Sections 2.2 and 3.1. Figures 3-5 through 3-8 are time series graphs of calculated mass emission fluxes for AMs (total alkanes) during each day of sampling. For each reported average in the tables, the following information is provided: time the measurement was made, wind speed, wind direction, and the flux value for each of the four VRPM planes (A123, A456, E123, or E456). Also shown are the calculated values for: minimum net flux, maximum net flux, estimated net flux, combined uncertainty and external flux.

Table 3-5 and Figure 3-5 show the first day of sampling at the EnCana Benzel facility (August 12). Winds were northerly and there were lower emissions in the early afternoon than were seen later in the day. The conditions were good for measuring the emissions from the evaporation pond, as the background (external) emissions were small. The average flux from the evaporation pond was 0.12 g/s.

Table 3-6 and Figure 3-6 show the second day of sampling (August 13). Winds were from the NW for the majority of the day, providing good conditions for monitoring the evaporation pond. The average flux for the day from the pond was 0.06 g/s. The largest external emissions (largest vertical bars) were seen between 14:30 and 15:50, when the winds were coming from the N, indicating a possible source contribution from that direction.

Table 3-5. Summary Table of the Mass Emission Flux Results(g/s) for the Configuration used at the EnCana Benzel Facility on August 12, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
12:10	2.3	13.6	0.065	0.015	-0.020	-0.010	0.050	0.080	0.065	0.0141	0.030
12:30	2.4	5.4	0.034	0.060	-0.020	-0.015	0.059	0.094	0.077	0.0147	0.035
12:50	2.6	345.4	0.003	0.074	-0.025	-0.008	0.044	0.077	0.061	0.0158	0.033
13:10	1.8	290.3	0.000	0.033	-0.006	0.013	0.040	0.046	0.043	0.0133	0.006
13:30	2.1	302.2	0.000	0.000	-0.020	0.002	0.000	0.002	0.001	0.0040	0.020
13:50	4.3	318.5	0.000	0.000	-0.024	0.010	0.000	0.010	0.005	0.0055	0.024
14:10	3.8	297.1	0.000	0.000	-0.015	0.024	0.009	0.024	0.017	0.0057	0.015
15:30	1.9	335.8	0.017	0.070	-0.007	-0.003	0.077	0.087	0.082	0.0146	0.010
15:50	2.0	318.4	0.030	0.065	-0.015	-0.007	0.073	0.095	0.084	0.0147	0.022
16:10	1.7	11.8	0.007	0.042	-0.037	0.007	0.019	0.056	0.038	0.0114	0.037
16:30	3.4	352.9	0.096	0.085	-0.038	-0.005	0.138	0.181	0.160	0.0286	0.043
16:50	2.2	2.1	0.130	0.130	0.000	-0.010	0.250	0.260	0.255	0.0368	0.010
17:10	1.7	336.9	0.056	0.255	0.000	-0.012	0.299	0.311	0.305	0.0523	0.012
17:30	2.5	248.5	0.073	0.210	0.000	0.000	0.283	0.283	0.283	0.0445	0.000
17:50	3.0	233.9	0.158	0.068	0.000	0.000	0.226	0.226	0.226	0.0344	0.000
18:10	1.6	301.0	0.063	0.085	0.000	0.000	0.148	0.148	0.148	0.0212	0.000

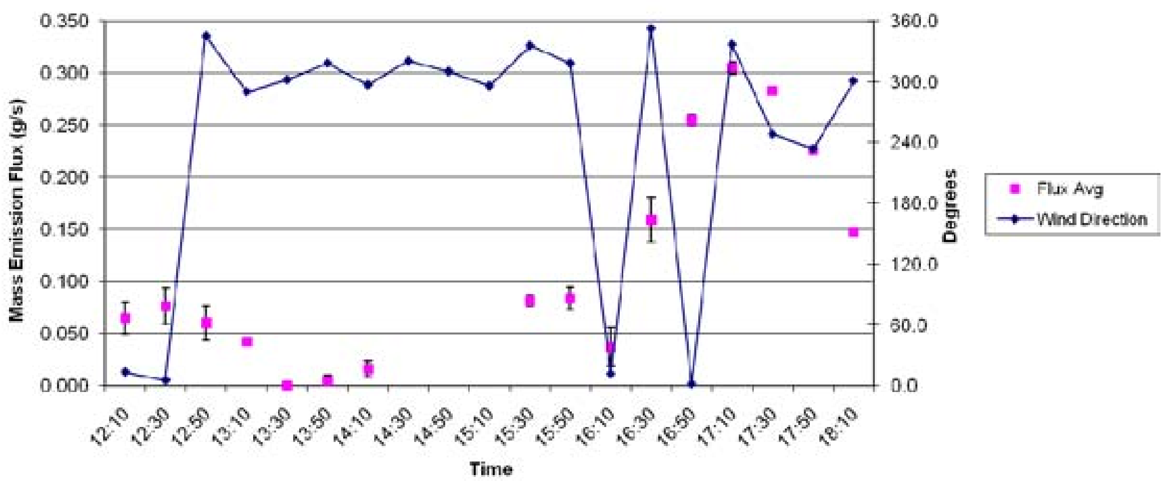

Figure 3-5. Time Series of Mass Emission Flux for August 12, 2008 at the EnCana Benzel Facility

Table 3-6. Summary Table of the Mass Emission Flux Results (g/s) for the Configuration used at the EnCana Benzel Facility on August 13, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
10:30	1.6	346.1	0.006	0.004	-0.017	-0.005	0.000	0.010	0.005	0.0081	0.022
10:50	1.6	328.3	0.005	0.038	-0.017	0.000	0.026	0.043	0.035	0.0079	0.017
11:10	1.6	314.1	0.000	0.043	-0.018	0.000	0.025	0.043	0.034	0.0063	0.018
11:30	1.7	325.1	0.000	0.040	-0.010	0.000	0.030	0.040	0.035	0.0055	0.010
11:50	1.4	335.3	0.000	0.055	-0.017	0.000	0.038	0.055	0.047	0.0115	0.017
12:30	1.3	288.5	0.020	0.020	-0.010	0.000	0.030	0.040	0.035	0.0060	0.010
12:50	1.7	303.1	0.015	0.036	-0.007	0.000	0.044	0.051	0.048	0.0081	0.007
13:10	1.3	304.9	-0.020	0.056	-0.010	0.000	0.026	0.056	0.041	0.0121	0.030
13:30	2.2	3.0	0.098	0.053	-0.014	-0.004	0.133	0.151	0.142	0.0225	0.018
13:50	2.7	8.0	0.117	0.024	-0.010	0.000	0.131	0.141	0.136	0.0241	0.010
14:10	1.4	349.6	0.080	0.020	-0.018	0.000	0.082	0.100	0.091	0.0169	0.018
14:30	2.5	19.5	0.033	0.066	-0.028	-0.008	0.063	0.099	0.081	0.0159	0.036
14:50	2.9	15.9	0.004	0.053	-0.068	-0.005	0.000	0.057	0.029	0.0173	0.073
15:10	4.0	8.1	0.007	0.035	-0.025	-0.008	0.009	0.042	0.026	0.0100	0.033
15:50	3.9	326.0	-0.010	0.014	-0.040	0.012	0.000	0.026	0.013	0.0108	0.050
16:10	4.0	304.3	0.001	0.117	-0.006	0.018	0.130	0.136	0.133	0.0239	0.006
16:30	2.5	289.5	-0.013	0.048	0.000	0.010	0.045	0.058	0.052	0.0101	0.013
17:30	1.7	250.9	0.000	0.000	0.000	0.010	0.010	0.010	0.010	0.0020	0.000

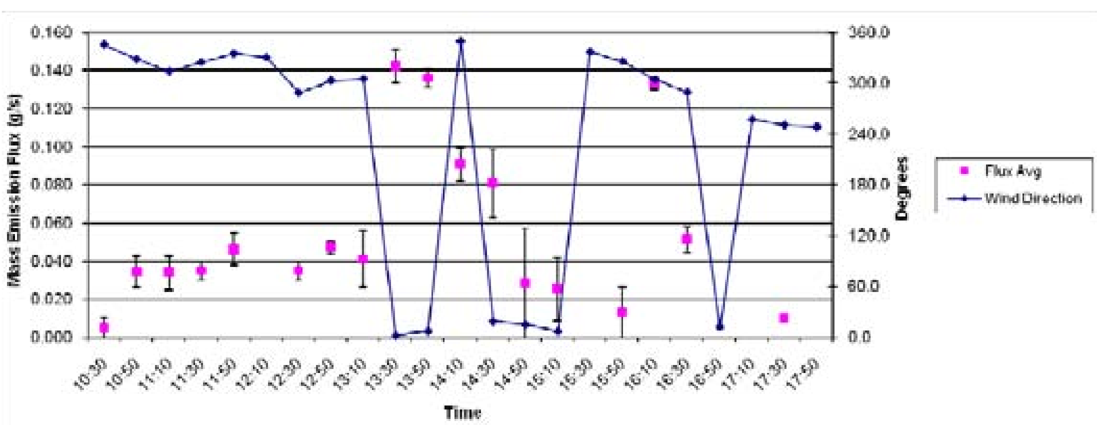

Figure 3-6. Time Series of Mass Emission Flux for August 13, 2008 at the EnCana Benzel Facility

Table 3-7. Summary Table of the Mass Emission Flux Results (g/s) for the Configuration used at the EnCana Benzel Facility on August 14, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
9:30	1.1	15.3	0.010	0.020	0.000	-0.003	0.027	0.030	0.029	0.0054	0.003
9:50	1.5	56.4	0.032	0.020	0.000	0.000	0.052	0.052	0.052	0.0075	0.000
10:10	1.8	36.3	0.013	0.040	0.000	-0.008	0.045	0.053	0.049	0.0096	0.008
10:30	1.5	349.1	0.014	0.063	-0.002	-0.007	0.068	0.077	0.073	0.0131	0.009
10:50	1.2	329.6	0.005	0.066	0.000	0.000	0.071	0.071	0.071	0.0132	0.000
11:10	1.3	328.8	0.012	0.058	0.000	-0.003	0.067	0.070	0.069	0.0119	0.003
11:30	1.7	325.4	0.014	0.075	-0.005	0.000	0.084	0.089	0.087	0.0155	0.005
11:50	1.8	332.9	0.010	0.028	-0.004	0.000	0.034	0.038	0.036	0.0061	0.004
12:10	1.5	352.9	0.018	-0.010	-0.005	-0.002	0.001	0.018	0.010	0.0043	0.017
12:30	2.2	1.7	0.065	0.000	-0.018	-0.005	0.042	0.065	0.054	0.0136	0.023
13:10	1.5	181.0	0.083	-0.023	0.003	-0.003	0.060	0.086	0.073	0.0172	0.026
13:50	1.8	99.0	0.028	0.025	-0.010	-0.016	0.027	0.053	0.040	0.0084	0.026
14:10	2.5	43.6	0.030	-0.006	-0.020	-0.025	0.000	0.030	0.015	0.0089	0.051
14:50	3.2	234.2	0.003	0.030	0.000	0.007	0.040	0.040	0.040	0.0062	0.000
15:10	2.6	274.0	-0.008	0.050	0.000	0.006	0.048	0.056	0.052	0.0102	0.008
15:30	2.5	309.1	-0.006	0.076	0.000	0.000	0.070	0.076	0.073	0.0152	0.006
15:50	1.9	318.4	0.000	0.085	0.000	0.000	0.085	0.085	0.085	0.0170	0.000
16:10	3.9	305.9	0.000	0.057	0.000	0.003	0.060	0.060	0.060	0.0114	0.000

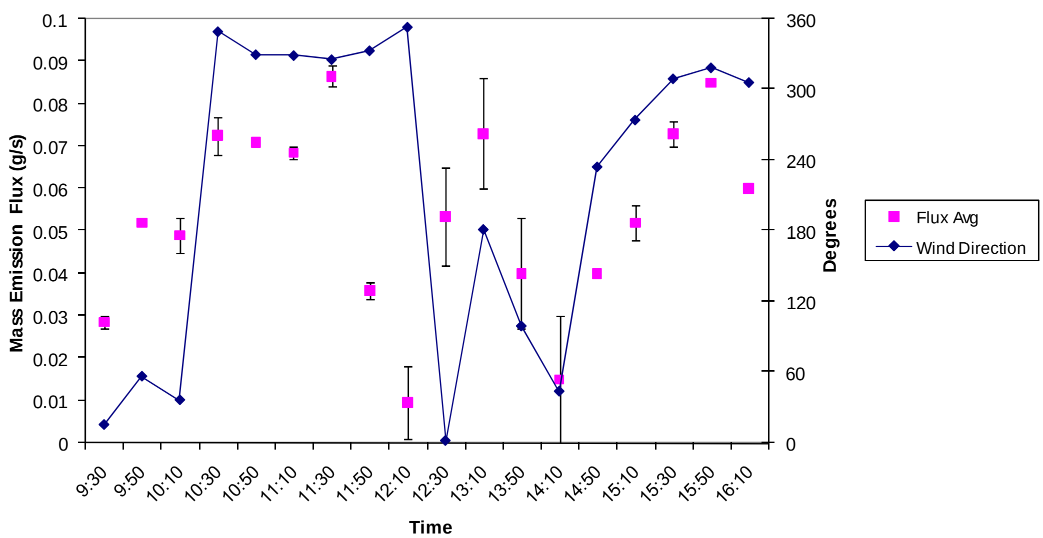

Figure 3-7. Time Series of Mass Emission Flux for August 14, 2008 at the EnCana Benzel Facility

Table 3-8. Summary Table of the Mass Emission Flux Results (g/s) for the Configuration used at the EnCana Benzel Facility on August 15, 2008

Time	Wind speed	Wind Direction	A123	A456	E123	E456	Minimum Net Flux	Maximum Net Flux	Estimated Net Flux	Combined Uncertainty	External Flux
9:50	1.9	19.0	0.057	0.000	0.000	0.000	0.057	0.057	0.057	0.0114	0.000
10:10	1.2	13.0	0.053	0.010	0.000	0.000	0.063	0.063	0.063	0.0108	0.000
10:30	1.9	27.5	0.055	0.016	0.000	-0.004	0.067	0.071	0.069	0.0121	0.004
10:50	1.5	32.5	0.056	0.004	0.000	0.000	0.060	0.060	0.060	0.0112	0.000
11:10	1.7	50.2	0.052	0.003	0.000	0.000	0.055	0.055	0.055	0.0106	0.000
11:30	2.1	30.1	0.073	0.018	0.000	0.000	0.091	0.091	0.091	0.0150	0.000
11:50	2.3	332.0	0.018	0.058	0.000	0.000	0.076	0.076	0.076	0.0121	0.000
12:10	2.2	350.0	0.007	0.056	-0.002	0.000	0.061	0.063	0.062	0.0115	0.002
12:30	2.2	351.3	0.004	0.028	-0.010	0.004	0.026	0.036	0.031	0.0069	0.010
12:50	3.1	327.6	0.000	0.036	-0.015	-0.002	0.019	0.036	0.028	0.0082	0.017
13:10	2.4	301.6	0.000	0.030	0.000	-0.002	0.028	0.030	0.029	0.0060	0.002
13:30	3.3	321.3	0.000	0.035	0.000	0.000	0.035	0.035	0.035	0.0070	0.000
13:50	3.8	301.7	0.000	0.016	0.000	0.000	0.016	0.016	0.016	0.0080	0.000

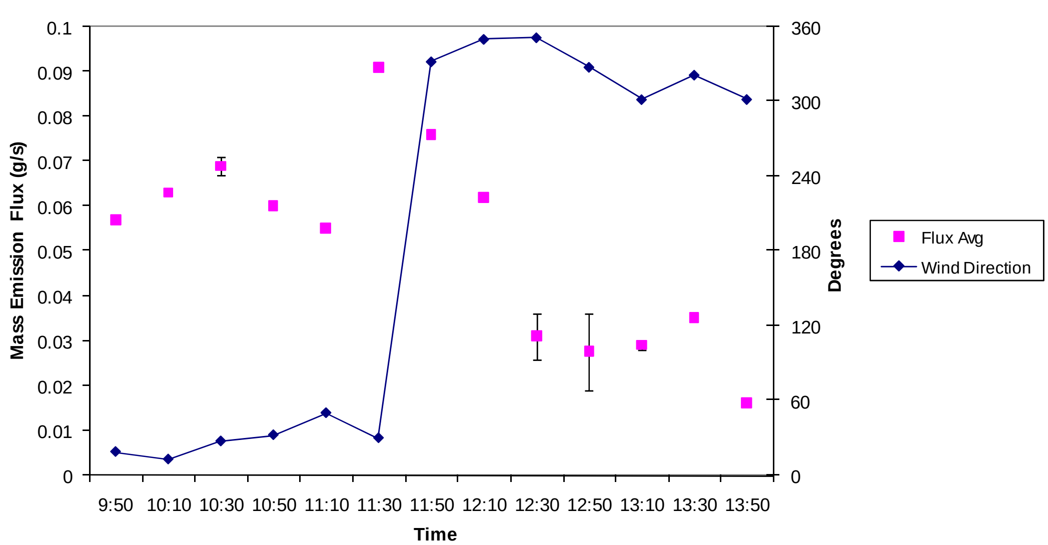

Figure 3-8. Time Series of Mass Emission Flux for August 15, 2008 at the EnCana Benzel Facility

Table 3-7 and Figure 3-7 show the third day of sampling at EnCana Benzel (August 14). Winds shifted to the east, then the south, where larger external interferences were seen. Most of the day provided good data for the evaporation pond, because even when the vertical bars were larger, they were small compared to the net flux. The average flux for the day from the pond was 0.05 g/s.

Table 3-8 and Figure 3-8 show the final day of sampling at EnCana Benzel (August 15). Although there was a wind shift from NE to NW, all winds had a northerly component and were good for estimating flux from the evaporation pond. The average flux for the day from the pond was 0.05 g/s

The 4-day average flux from the evaporation pond was 0.07 g/s (SD of ± 0.06). The flux value for the evaporation pond was found by averaging (65) 20-minute averaged flux values over the four days of measurements. The average flux value from the evaporation pond is found by averaging the “Estimated Net Flux” values in the above tales. See Section 5.3 for additional discussion on OTM 10 measurement uncertainty.

3.4 Results of OP-FTIR VOC Concentration Analysis and Estimated VOC Fluxes Using Ratio Method

As discussed in Section 2.3, analysis of the OP-FTIR data was performed using the time-averaging method (TAM) to determine the concentration of benzene, toluene, m-p-xylene, o-xylene, methanol for time periods when relatively high alkane mixture (AM) emissions were detected. This purpose of the analysis was to help estimate the select VOC emissions from the source areas. Methane was also quantified without using the TAM. Table 3-9 presents the average VOC concentration in ppb, for each analysis period. The table includes the corresponding AM concentration for each period, and the determined molecular weight of the AM, which is shown in parenthesis.

Table 3-9. Summary of OP-FTIR VOC Concentration Determinations (concentrations in ppb)

Site	Start Time	End Time	Benzene	Toluene	m-Xylene	o-Xylene	p-Xylene	Methanol	Methane	Alkane Mixture
Williams	8/6/2008 16:00	16:40	NA	NA	NA	NA	NA	NA	299	209 (114)
Williams	8/7/2008 14:01	15:59	42	250	220	ND	78	6.1	NA	2649 (114)
Williams	8/7/2008 14:02	14:58	200	230	ND	ND	ND	19	630	1086 (114)
Williams	8/7/2008 16:01	17:40	NA	NA	NA	NA	NA	NA	829	1103 (114)
Williams	8/8/2008 13:27	14:24	22	44	ND	35	21	4.5	10	85 (113)
Williams	8/8/2008 16:00	16:46	ND	160	ND	98	ND	16	NA	449 (110)
Williams	8/8/2008 16:01	16:50	70	170	130	69	49	18	21	1606 (107)
Williams	8/8/2008 16:02	16:49	ND	38	ND	36	ND	6.7	NA	210 (114)
EnCana	8/12/2008 17:02	18:16	ND	61	42	25	29	15	19	288 (106)
EnCana	8/12/2008 17:04	18:27	64	60	42	44	17	18	24	490 (111)
EnCana	8/13/2008 11:08	12:05	70	101	53	ND	ND	12	52	123 (114)
EnCana	8/13/2008 13:20	14:30	NA	NA	NA	NA	NA	NA	67	140 (111)
EnCana	8/13/2008 15:00	15:26	47	ND	ND	ND	ND	13	NA	90 (112)
EnCana	8/13/2008 15:25	16:13	82	ND	ND	31	ND	ND	NA	123 (113)
EnCana	8/13/2008 15:52	16:51	68	49	43	44	34	6.4	26	118 (113)
EnCana	8/14/2008 10:22	11:19	ND	41	ND	24	ND	8.7	110	101 (114)
EnCana	8/14/2008 15:00	16:10	NA	NA	NA	NA	NA	NA	105	134 (114)
EnCana	8/14/2008 15:59	16:56	70	ND	ND	ND	27	22	2.0	64 (114)
EnCana	8/15/2008 13:00	14:00	NA	NA	NA	NA	NA	NA	175	53 (112)

*NA denotes periods when VOC or methane concentrations were not analyzed

*ND denotes time periods that concentrations were not detected above minimum detection limits of OP-FTIR

The VOC concentrations presented above were then used with the corresponding AM concentration data from the same time period to produce a mass concentration ratio (MCR) for each VOC to AM, using the following formula:

$$MCR = \left[\frac{Conc,VOC_{FTIR}}{Conc,AM_{FTIR}} \right] \left[\frac{MW_{VOC}}{MW_{AM}} \right] \quad (3\text{-}1)$$

Where:

MCR	=	*mass concentration ratio between the VOC and the alkane mixture for a particular time period*
Conc, VOC_{FTIR}	=	*the average VOC concentration for the date and time period selected, as measured by the OP-FTIR;*
$Conc,AM_{FTIR}$	=	*the average AM concentration for the date and time period selected, as measured by the OP-FTIR;*
MW_{VOC}	=	*the molecular weight of the VOC/SNMOC;*
MW_{AM}	=	*the molecular weight of the AMs, as determined from the OP-FTIR measurements*

The results of these calculations are shown in Table 3-10.

The MCR results for the individual time periods in Table 3-10 were used to produce an average MCR for each compound for each of the two sites. Table 3-11 presents the average MCR with ± one standard deviation shown. The average excludes ND readings and the standard deviation should not be considered a robust indicator of uncertainty due to the low number of entries. It is evident that a considerable amount of variation exists in the calculated mass concentration ratios so there is a significant amount of uncertainty in the average value. The EnCana facility seems to possess a somewhat higher mass concentration ration compared to the Williams facility.

Table 3-10. Summary of OP-FTIR VOC to AM Mass Concentration Ratio Calculations

Site	Start Time	End Time	Benzene	Toluene	m-Xylene	o-Xylene	p-Xylene	Methanol	Methane
Williams	8/6/2008 16:00	8/6/2008 16:40	NA	NA	NA	NA	NA	NA	0.201
Williams	8/7/2008 14:01	8/7/2008 15:59	0.011	0.076	0.078	ND	0.028	0.001	NA
Williams	8/7/2008 14:02	8/7/2008 14:58	0.126	0.171	ND	ND	ND	0.005	0.082
Williams	8/7/2008 16:01	8/7/2008 17:40	NA	NA	NA	NA	NA	NA	0.107
Williams	8/8/2008 13:27	8/8/2008 14:24	0.179	0.422	ND	0.390	0.234	0.015	0.017
Williams	8/8/2008 16:00	8/8/2008 16:46	ND	0.299	ND	0.213	ND	0.010	NA
Williams	8/8/2008 16:01	8/8/2008 16:50	0.032	0.091	0.081	0.043	0.031	0.003	0.002
Williams	8/8/2008 16:02	8/8/2008 16:49	ND	0.146	ND	0.161	ND	0.009	NA
EnCana	8/12/2008 17:02	8/12/2008 18:16	ND	0.184	0.147	0.088	0.102	0.016	0.010
EnCana	8/12/2008 17:04	8/12/2008 18:27	0.092	0.102	0.083	0.087	0.034	0.011	0.007
EnCana	8/13/2008 11:08	8/13/2008 12:05	0.390	0.664	0.405	ND	ND	0.027	0.060
EnCana	8/13/2008 13:20	8/13/2008 14:30	NA	NA	NA	NA	NA	NA	.0692
EnCana	8/13/2008 15:00	8/13/2008 15:26	0.364	ND	ND	ND	ND	0.0413	NA
EnCana	8/13/2008 15:25	8/13/2008 16:13	0.461	ND	ND	0.239	ND	ND	NA
EnCana	8/13/2008 15:52	8/13/2008 16:51	0.398	0.339	0.346	0.354	0.273	0.015	0.031
EnCana	8/14/2008 10:22	8/14/2008 11:19	ND	0.328	ND	0.223	ND	0.024	0.153
EnCana	8/14/2008 15:00	8/14/2008 16:10	NA	NA	NA	NA	NA	NA	0.110
EnCana	8/14/2008 15:59	8/14/2008 16:56	0.749	ND	ND	ND	0.397	0.097	0.004
EnCana	8/15/2008 13:00	8/15/2008 14:00	NA	NA	NA	NA	NA	NA	0.473

*NA denotes periods when concentrations were not analyzed for a particular compound

*ND denotes time periods that concentrations were not detected above minimum detection limits of OP-FTIR

Table 3-11. Summary of the Average Mass Concentration Ratios of VOC to Alkane Mixture, for the Williams and EnCana sites

Site	Benzene	Toluene	m-Xylene	o-Xylene	p-Xylene	Methanol	Methane
Williams	0.087±0.079	0.201±0.134	0.080±0.002	0.202±0.144	0.098±0.118	0.007±0.005	0.082±0.080
EnCana	0.409±0.211	0.323±0.215	0.245±0.154	0.198±0.113	0.201±0.165	0.033±0.030	0.102±0.148

The average mass concentration ratio for each VOC from the Williams site was then multiplied by the average AM flux value from the Williams Evaporation Pond (0.20 g/s) and Skim Pond (0.90 g/s) to produce an estimated flux for each VOC for these sources. The average mass concentration ratio for each VOC from the EnCana site was multiplied by the average AM flux value from the EnCana Evaporation Pond (0.07 g/s) to produce an estimated VOC flux from this source. A summary of the estimated VOC emissions flux values from each source area are presented below in Table 3-12. It is noted that the values of Table E-2 include underlying uncertainty in AM flux measurement average and additionally VOC to AM concentration ratio uncertainty so the values should be considered estimates.

Table 3-12. Estimated Emission Flux Values (g/s) of select VOCs from the Williams and EnCana Sites

Site	Source Area	Benzene (g/s)	Toluene (g/s)	m-Xylene (g/s)	o-Xylene (g/s)	p-Xylene (g/s)	Methanol (g/s)	Methane (g/s)
Williams	Evaporation Pond	0.018	0.040	0.016	0.040	0.020	0.001	0.017
Williams	Skim Pond	0.078	0.181	0.072	0.182	0.088	0.006	0.074
EnCana	Evaporation Pond	0.029	0.023	0.017	0.014	0.014	0.002	0.007

Table 3-12 shows that the largest emission flux values for these compounds were from the Williams Skim Pond, with lower emissions found from the evaporation ponds at both sites. As discussed in the next section, the presence of these VOCs are also recorded in the SUMMA canister sampling with values near the Williams skin pond showing elevated results.

The results of Table 3-12 reflect an analysis that was conducted during times conducive to AM flux estimation. During other time periods, the concentrations of the select VOCs could be much lower, and in many cases below the detection limit of the OP-FTIR TAM method. An attempt was made to compare the concentrations determined by the OP-FTIR TAM with SUMMA canister values for the exact time periods that the canisters were acquired. Table 3-13 presents six canister results from the Williams and EnCana facilities with OP-FTIR TAM analyses conducted during the canister sampling periods. The SUMMA canister results are labeled (S) with the TO-15 analysis listed first and the SNMOC result in parenthesis. The OP-FTIR TAM result is labeled (F). The derivation of the SUMMA canister AM results is discussed in Section 3.5 and Appendix A.

Table 3-13. Comparison of Canister and OP-FTIR Results

	Canister TNAPC11 (Williams)	Canisters 926,648 (Williams)	Canister ER047 (Williams)	Canister TNAPC20 (Encana)	Canisters ER069, ER064 (Encana)	Canisters 988, 3248 (Encana)
Benzene (S)	203 (175)	88.8 (57.8)	8.1 (4.7)	1.3 (1.0)	2.3 (1.5)	2.5 (2.0)
Benzene (F)	17	23	36	(ND)	(ND)	66
Toluene (S)	1210 (993)	221 (200)	16.7 (11.4)	4.1 (3.5)	3.2 (2.9)	4.6 (4.3)
Toluene (F)	42	63	62	(ND)	42	ND
m-,o-,p-Xylene (S)	2711[1] (1916)[1]	177 (105)	15.7 (11.6)	5.1 (5.0)	1.9 (2.0)	2.6 (2.8)
m-,o-,p-Xylene (F)	91	53	79	31[2]	30[2]	40[2]
AM (S)	6654	546	164	58.2	19.4	33.5
AM (F)	536	82	509	27	86	54

[1] estimated value

[2] m-,p-Xlene below minimum detection limit of OP-FTIR TAM

(ND) below the minimum detection limits of OP-FTIR TAM

In general, it is difficult to compare the concentrations determined by the OP-FTIR TAM and SUMMA canister methods since the former integrates over an extended area, and the latter is a point sampling approach. In some cases, the canister may be located very close to the source (such as the Skim Pond at the Williams site), while the corresponding path-averaged concentration measurement from the OP-FTIR measures this area but additionally integrate clean air from both sites of the source. Conversely, at times when the concentrations measured with the OP-FTIR are larger than canister values, the canister location may not have been located within the plume but plume was captured by the spatially extended OP-FTIR measurement beam. In some cases, the canisters were not located in close enough proximity to the OP-FTIR beam to allow robust comparisons. In some cases similar concentrations are measured by the two methods but at slightly offset time periods due to changes in wind direction. For example, elevated values similar to TNAPC11 were measured by the OP-FTIR beam just before the canister was acquired (Table 3-10). These factors are further explored in Section 3.5 which compares OP-FTIR AM and SUMMA canister AM results in the context of sampling location and wind direction.

3.5 Results of Canister Measurements

As described in Section 2.4, SUMMA canister samples were collected during the field campaign to help inform the OTM 10 results. The one-hour canister samples were analyzed using U.S. EPA

Compendium Method TO-15, and speciated non-methane organic compounds (SNMOC) method. The results of the laboratory analyses are contained in Appendix B of this document.

Table 3-14 summarizes the SUMMA canisters data for several important compounds. The concentrations were determined by TO-15 except for the AM estimation which was derived from a 42 compound summation of the SNOMC results as described in Appendix A. The approximate position of the canister with respect to local source is indicated by the upwind/downwind column entry and the OP-FTIR optical path used for comparison is also shown. These comparisons are described and later in this section. Collocated canister entries represent average values of the analyses. The collocated canisters produced the same concentrations to within 10% with the exception of the ER085, ER114 pair which differed by approximately 40%.

It can be seen that the upwind canisters reflect generally lower values than the downwind canisters. The Williams canisters recorded higher concentrations than the EnCana canisters but this was primarily due to the location of the Williams canisters in very close proximity to the skim pond source and inlet to the North pond. These factors are further discussed later in this section.

Figures 3-9 and 3-10 summarize 42 of the most prevalent species measured by SNMOC analysis of the downwind canisters. Figure 3-9 (Williams facility) presents the average of four downwind canisters (TNAPC-11, 648, 926, ER047) with the average of three upwind canisters (3639A, ER038, ER001)subtracted. Figure 3-10 (EnCana facility) presents the average of six downwind canisters (3248, 988, 3254, 167601, 444, ER043) with the average of three upwind canisters (ER061, 3255, ER029) subtracted. Figure 3-10 is included for completeness but should not be emphasized since the upwind versus downwind canister signal levels at the EnCana facility were extremely low (single digit ppb) so the results are less certain especially with regard to the low mass compounds which can be affected disproportionately by background variation. An optimized subset of canisters was employed for the EnCana analysis in an attempt to increase signal levels. Overall, the Williams distribution (Figure 3-9) has a much higher degree of certainty due to the higher concentration levels and is likely similar to the actual distribution at the EnCana facility

In addition to providing speciation information, the SUMMA canister samples can be compared to the OP-FTIR measurements along selected paths to help inform the study. In the following figures, OP-FITR time series graphs of AM concentrations for ground-level beam paths are presented along with SUMMA canister AM estimates based on SNMOC analysis (described in Appendix A). The comparisons of OP-FITR and SUMMA canister are summarized in Table 3-14. The approximate location of the SUMMA canisters and OP-FTIR beam paths are noted in the associated images and the wind rose for the 1 hour SUMMA canister sampling period is also presented.

Table 3-14. Summary Canister Summary from the Williams and EnCana Sites

Site	Date	Sampling Mid-point (hr:min)	Summa ID	Upwind / Downwind	Benzene (ppbv)	Toluene (ppbv)	m-,o-,p-Xylene (ppbv)	Octane (ppbv)	AM Estimate (ppbv)	OP-FTIR Plane
Williams Rulison	8/7	16:43	TNAPC-11	d	203	1210	2711[3]	1160	6654	E4
	8/8	13:55	3639A	u	1.4	4.8	3.1	0.5	47.5	A1
	8/8	13:55	926, 648	d	88.8	221	177	72.6	546	E4
	8/9	14:30[1]	ER001, ER038	u	0.6	1.1	0.7	0.4	27.5	A1
	8/9	14:30[1]	ER047	d	8.1	16.7	15.7	11.6	164	E4
EnCana Benzel	8/12	11:30[1]	ER029	u	0.5	1.1	1.2	0.6	15.6	E1
	8/12	11:30[1]	659, 167604	d	2.3	3.7	2.3	0.9	28.5	--
	8/13	11:37	3255	u	0.3	0.7	0.7	0.4	21.4	E1
	8/13	11:37	ER043, 444	d	2.2	5.7	6.5	2.0	50.6	A4
	8/13	16:22	TNAPC20	u[2]	1.3	4.1	5.1	2.0	58.2	E1
	8/13	16:22	167601, 3254	d	1.5	5.2	8.5	2.8	60.0	A4
	8/14	11:03	ER061	u	0.3	0.4	0.2	0.1	10.7	E1
	8/14	11:03	ER069, ER064	d	2.3	3.2	1.9	0.4	19.4	A4
	8/14	16:39	15280	u[2]	1.1	2.0	1.2	0.4	26.0	E1
	8/14	16:39	988, 3248	d	2.5	4.6	2.6	0.8	33.5	A4
	8/15	11:39	ER021	u[2]	4.3	7.3	2.7	0.6	85.1	A1
	8/15	11:39	ER085, ER114	d	1.9	3.4	2.1	0.4	28.6	A4

[1] approximate time

[2] upwind affected by source, see detailed description

[3] estimated value

A1- ARCADIS OP-FTIR beam 1 (of A123)

A4 - ARCADIS OP-FTIR beam 4 (of A456)

E1 - EPA OP-FTIR beam 1 (of E123)

E4 - EPA OP-FTIR beam 4 (of E456)

All results above 50 ppb required dilution of SUMMA canister.

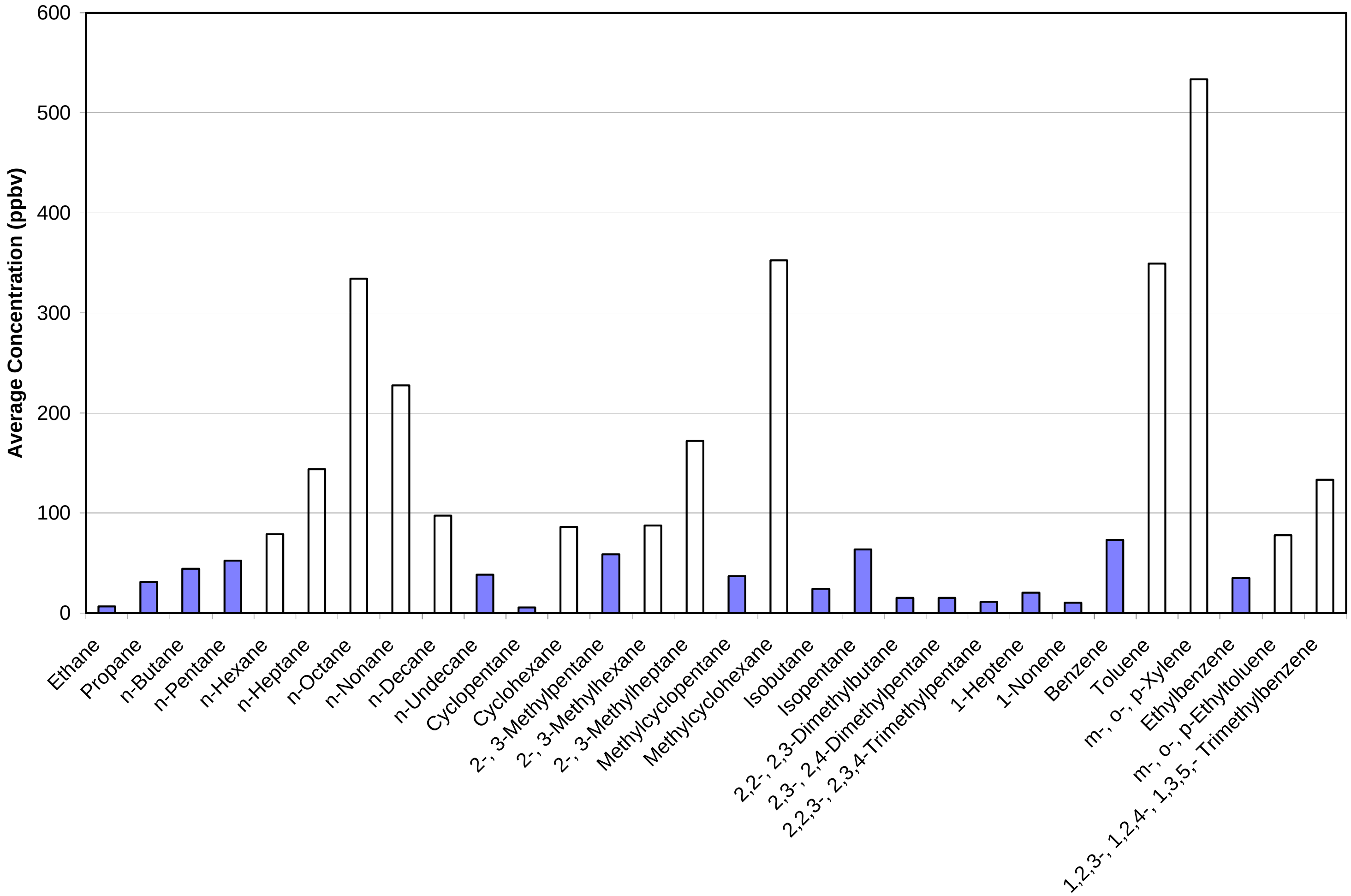

Figure 3-9. Summary of Downwind Canisters SNMOC Analysis for the Williams Facility

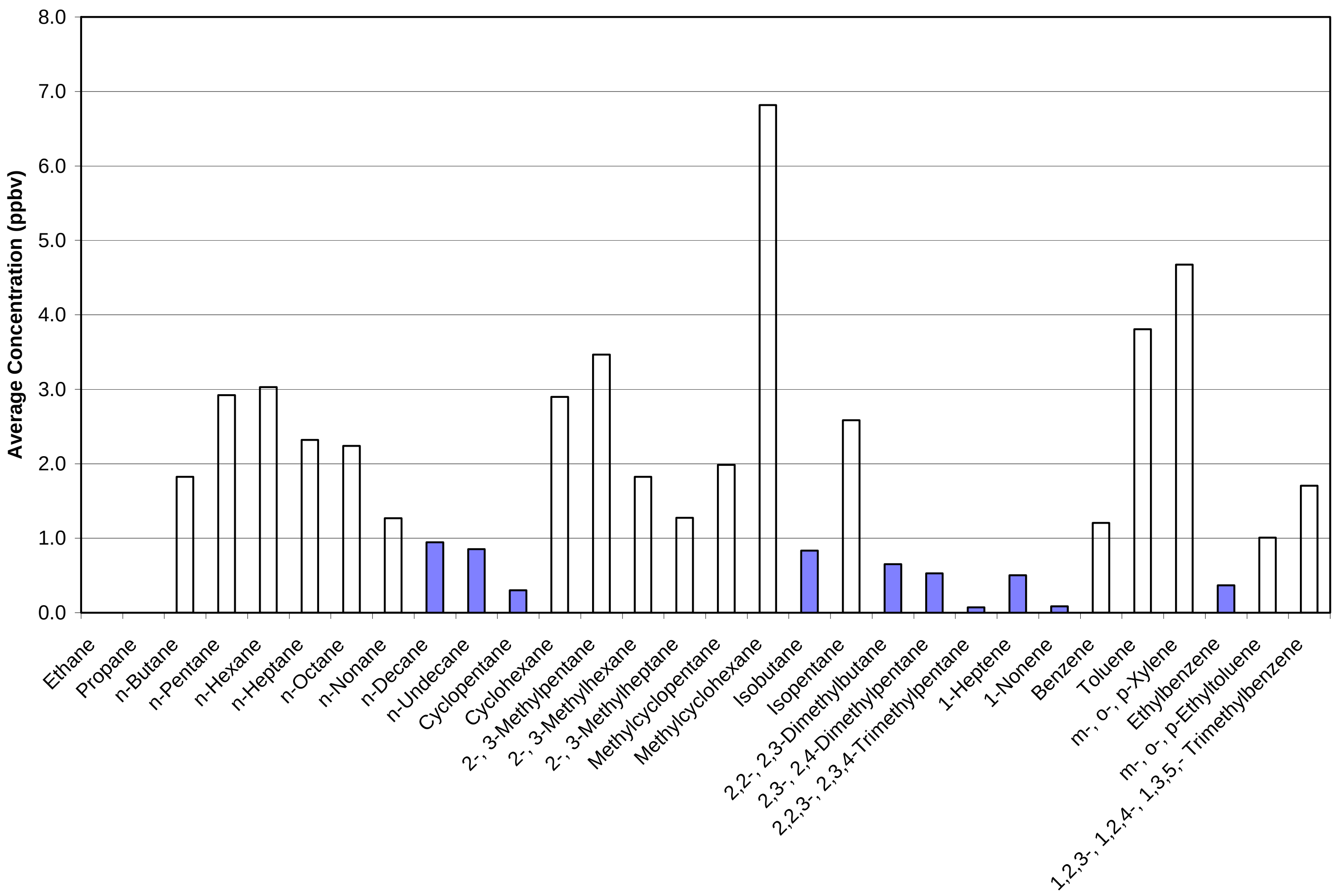

Figure 3-10. Summary of Downwind Canisters SNMOC Analysis for the EnCana Facility

Figure 3-11 shows canister TNAPC11 in close proximity to the skim pond and inlet of the skim pond into the North evaporation pond. The close proximity of the canister sample to large sources can yield highly variable results small changes in wind direction can greatly affect measured concentrations. Although E4 is significantly lower than TNAPC11 during the canister sampling period, E4 registered similar concentrations at neighboring time periods. Concentrations during this time period were amongst the highest recorded during the study.

In a similar fashion to Figure 3-11, Figure 3-12 shows elevated concentrations for 648, 926 compared to OP-FTIR path E4 for the sampling time period, believed to be due to the proximity of the canister to the pond inlet (local source). Under slightly different wind conditions after 15:00, the E4 path is elevated. In comparisons, the upwind canister 3639A is in good agreement with neighboring OP-FTIR plane (A1). It is noted some number of the A1 points are below MDL.

In Figure 3-13, wind is from the SE resulting in reduced sampling of the previously discussed strong sources for the canister which is slightly NW of this position. The wind direction in this case provided enhanced average concentrations measured by OP-FTIR path E4 with high temporal variability noted as the wind direction changes over short timer periods. The upwind canisters ER038 and ER001 are in good agreement with OP-FTIR path A4.

In Figure 3-14 presents the only available comparison from the EnCana facility on 8/12/08. This represents primarily and upwind comparison and shows good agreement between the canister and OP-FITR result.

Figure 3-15 presents the first of two comparisons from 8/13/08 and shows relatively good agreement in both upwind and downwind concentrations. As opposed to the previous Williams results, the temporal profile of the downwind OP-FTIR results is more stable indicating more developed plumes which aids in the comparison of canister to OP-FTIR.

Figure 3-16 presents the second comparison from 8/13/08. In this case the upwind and downwind canister show very similar results. This is explained by the fact that the TNAPC20 upwind canister is located too close to the pond edge and under these wind conditions, is being significantly impacted by emissions from the pond. The variability in wind conditions is also evident in the OP-FTIR data.

Figure 3-17 presents the first of two comparisons from 8/14/08. This is an informative case which shows good agreement for the upwind case however the downwind canisters ER064 and ER069 significantly lower than OP-FTIR A4 result. The inlet to the pond at the EnCana is located toward the North West portion of the Pond (Section 2.5) and is expected to be a high contributor to the overall source signature. Under the indicated wind directions and canister placements, this portion of the source is not effectively sampled by the canisters but is robustly captured by the OP-FTIR.

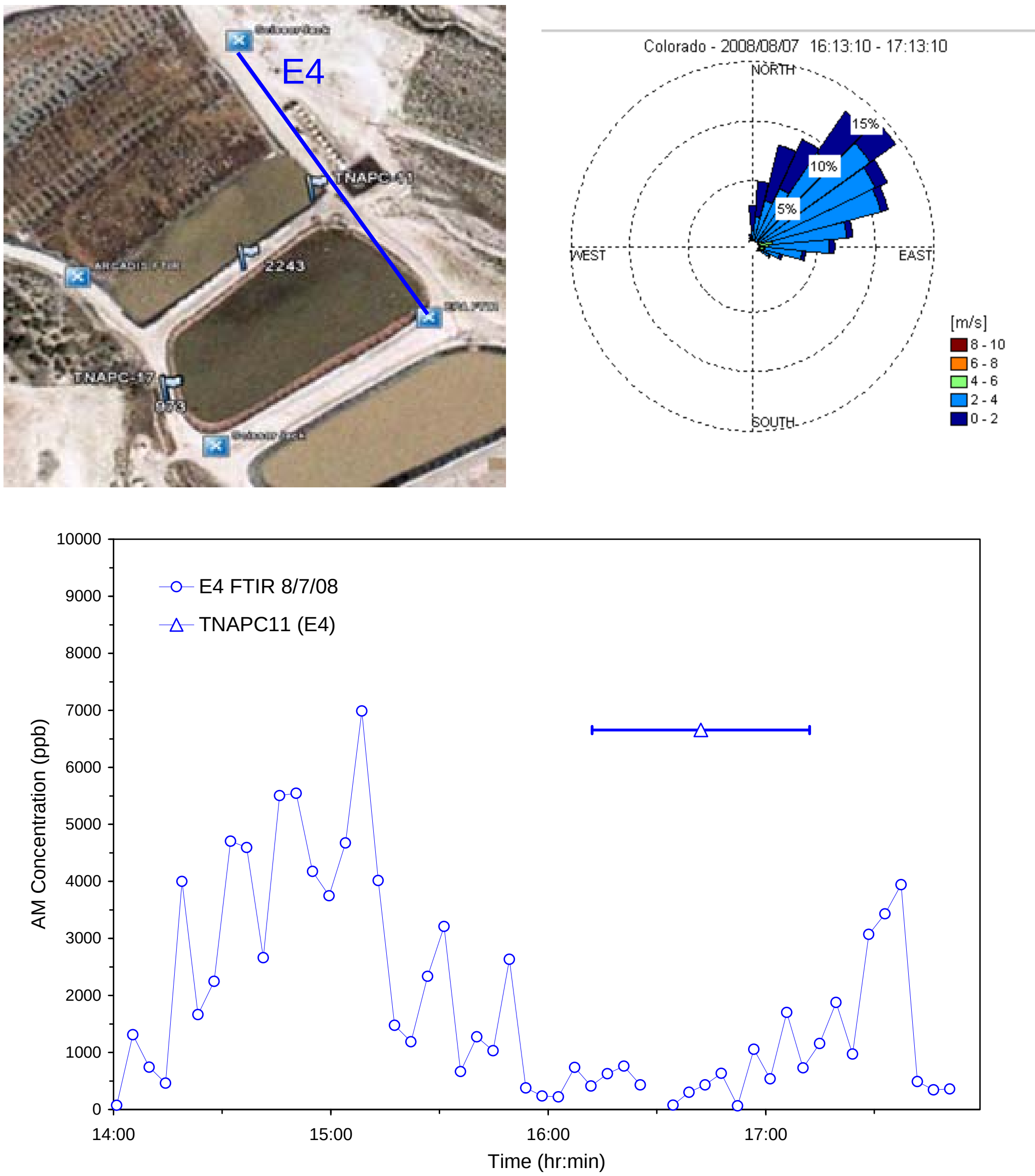

Figure 3-11. Williams 8/7/08, Canister TNAPC11 and OP-FTIR Path E4.

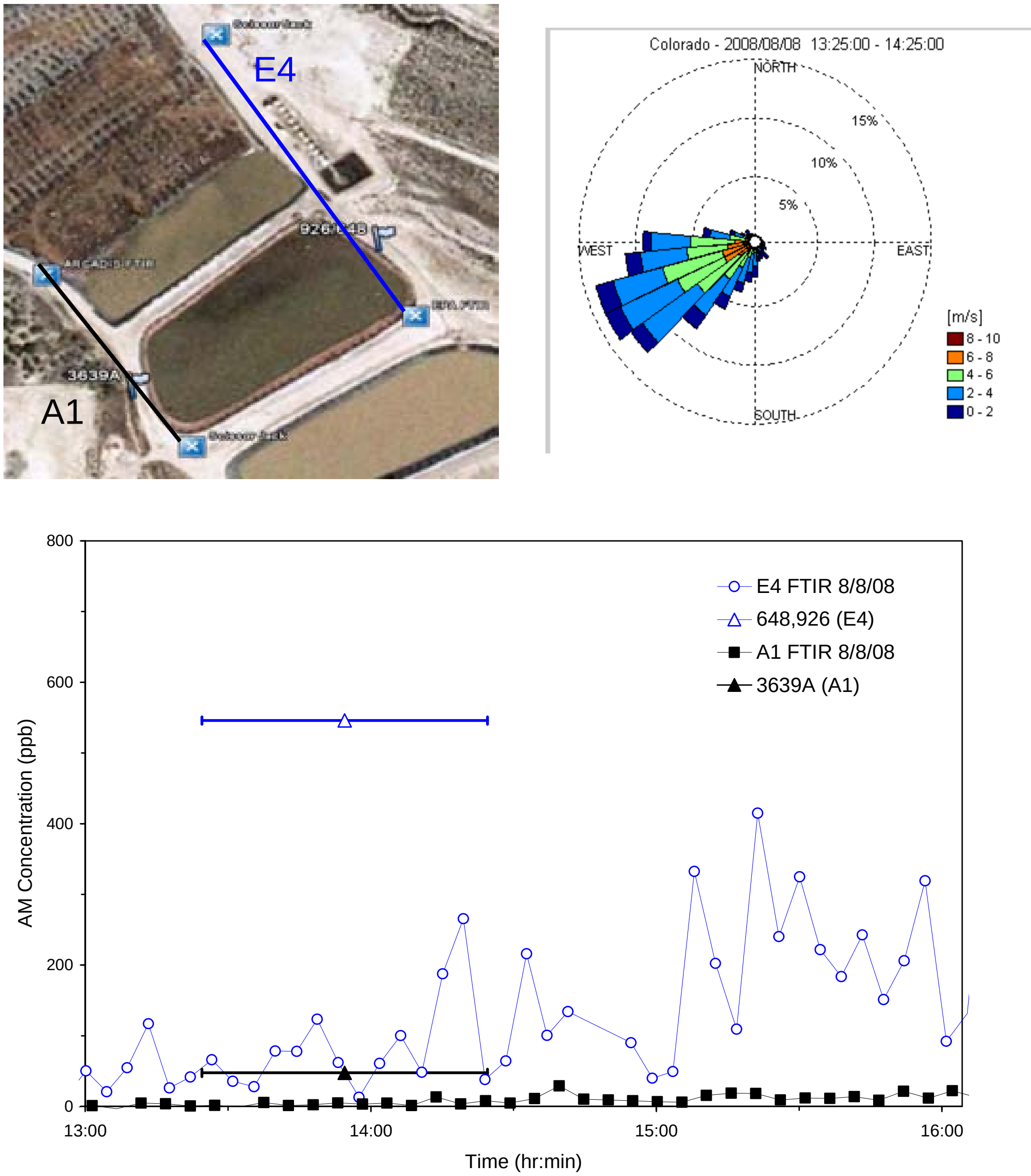

Figure 3-12. Williams 8/8/08, Canisters 648 and 926 Compared to OP-FTIR Path E4 and Canister 3639A Compared to OP-FTIR Path A1

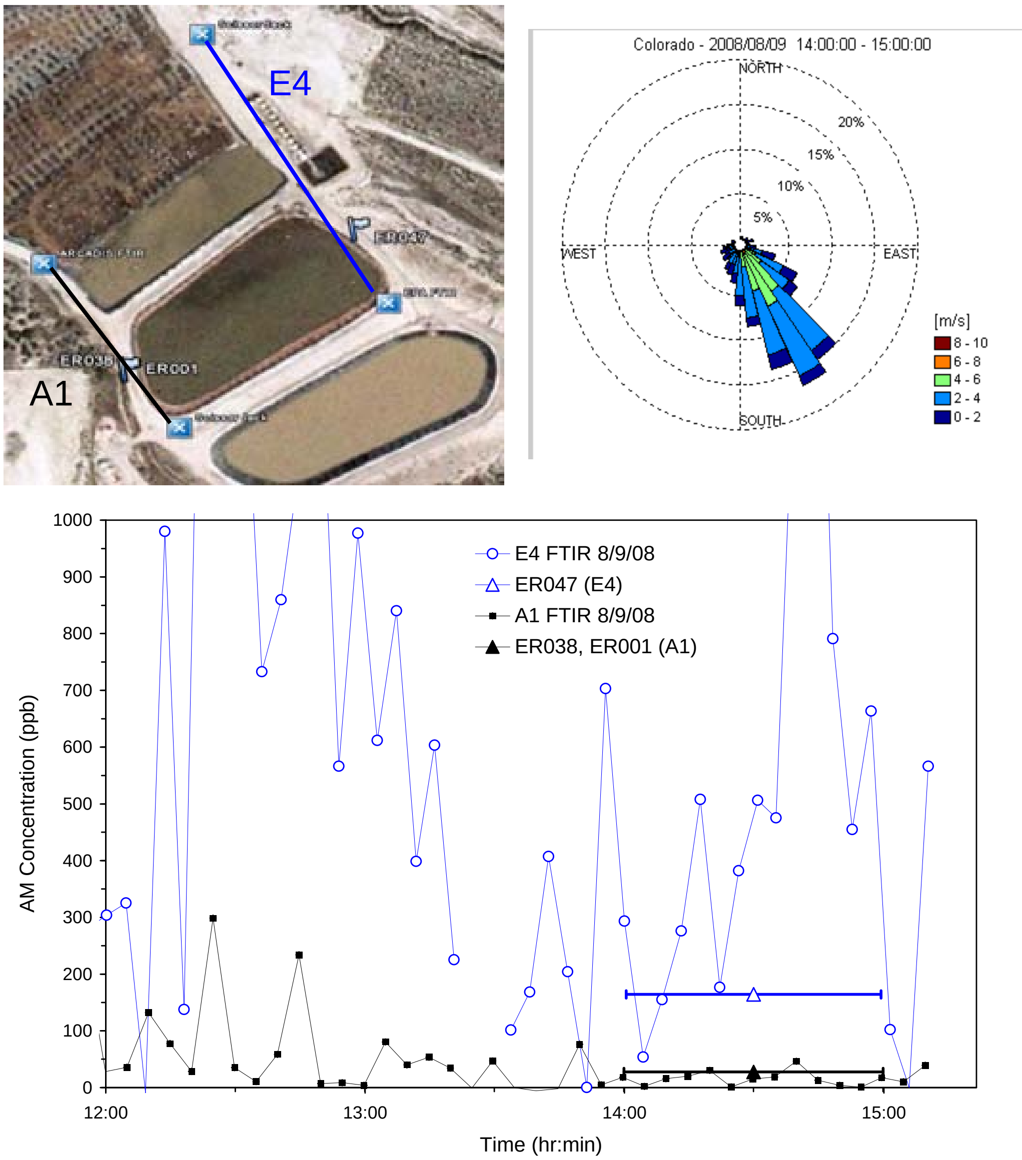

Figure 3-13. Williams 8/9/08, Canister ER047 Compared to OP-FTIR Path E4 and Canisters ER038 and ER001 Compared to OP-FTIR Path A1

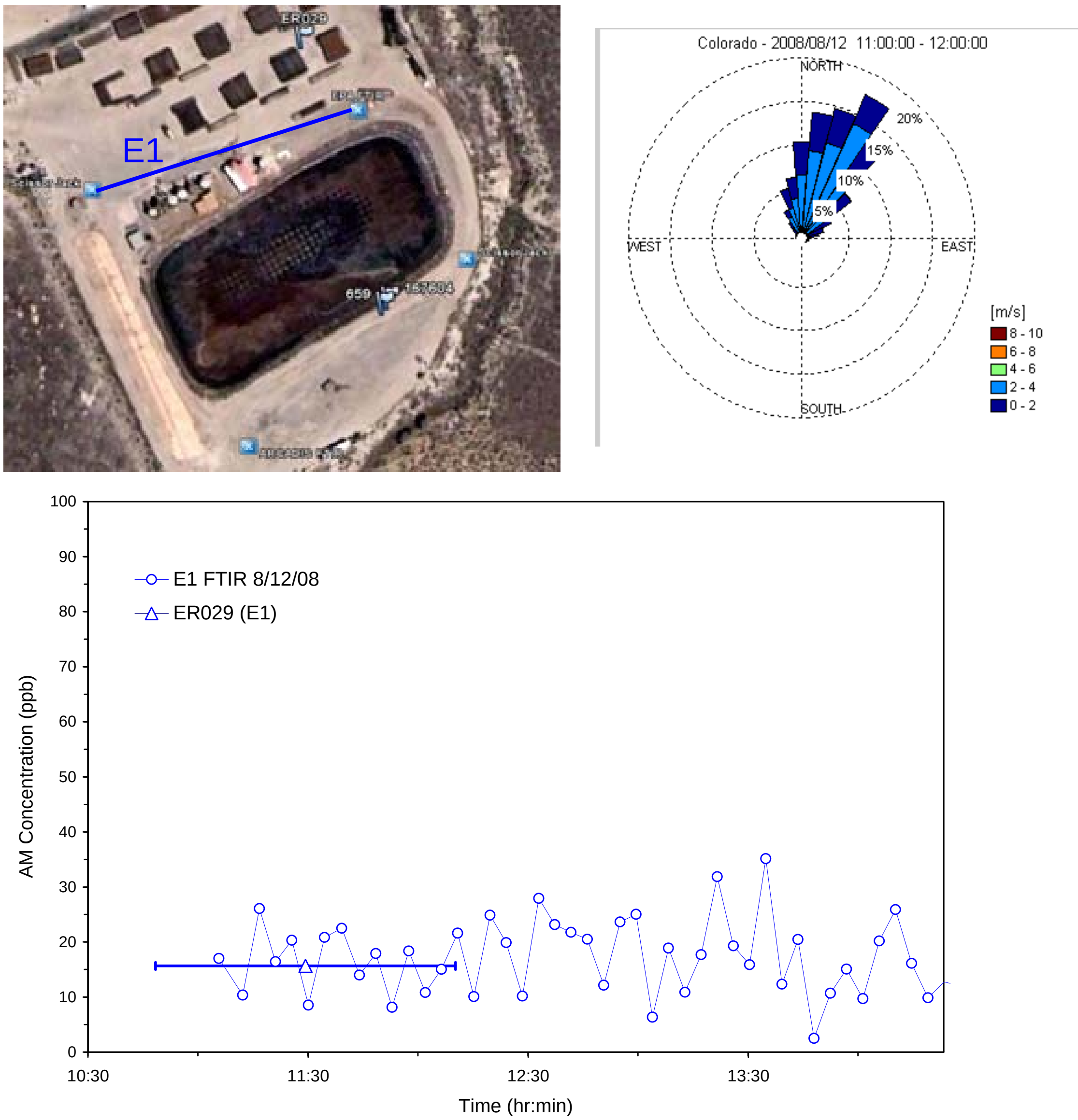

Figure 3-14. EnCana 8/12/08, Canister ER029 Compared to OP-FTIR Path E1

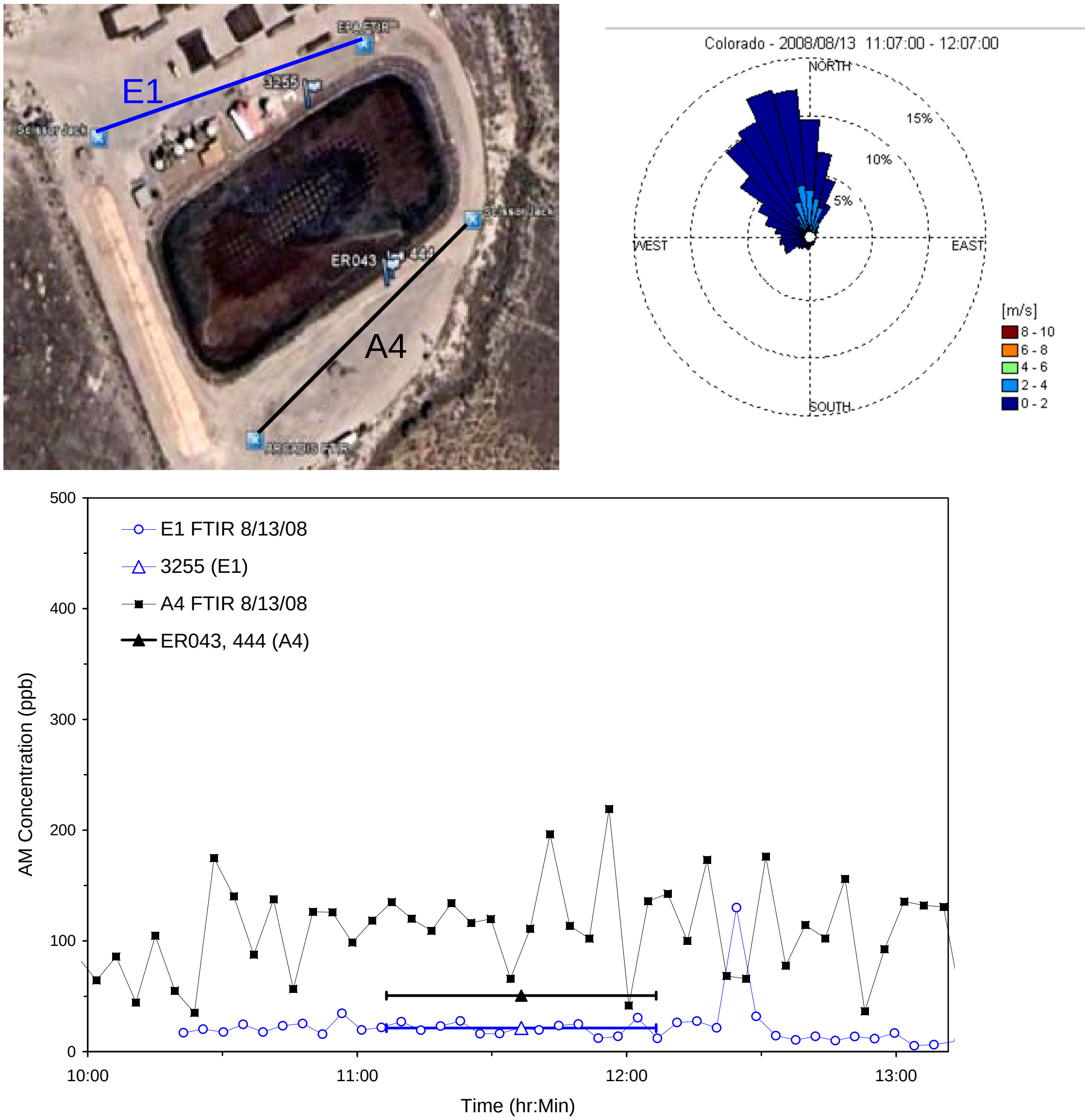

Figure 3-15. EnCana 8/13/08, Canister 3255 Compared to OP-FTIR Path E1 and Canisters ER043 and 444 Compared to OP-FTIR Path A4

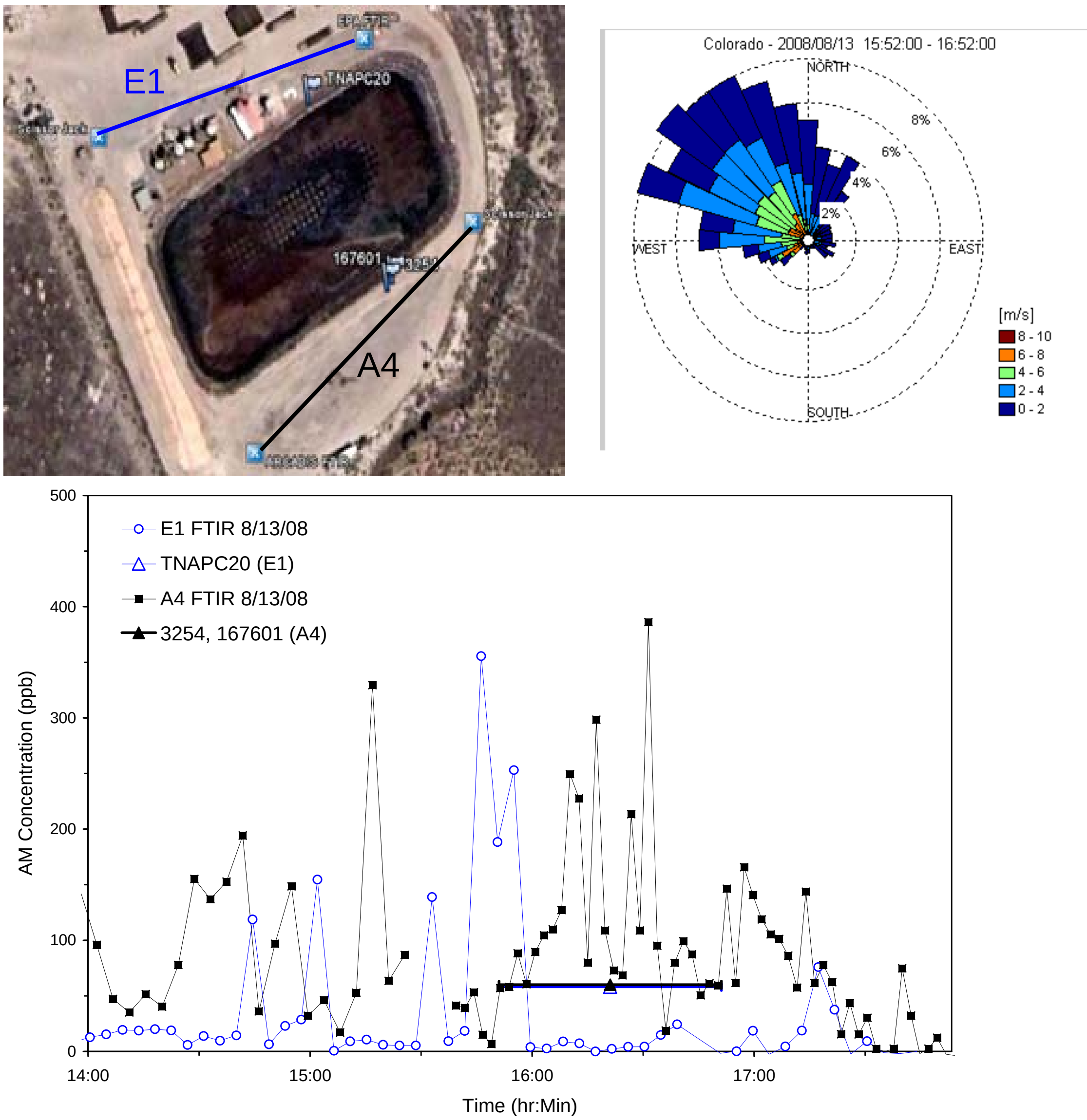

Figure 3-16. EnCana 8/13/08, Canister TNAPC20 Compared to OP-FTIR Path E1 and Canisters 3254 and 167601 Compared to OP-FTIR Path A4

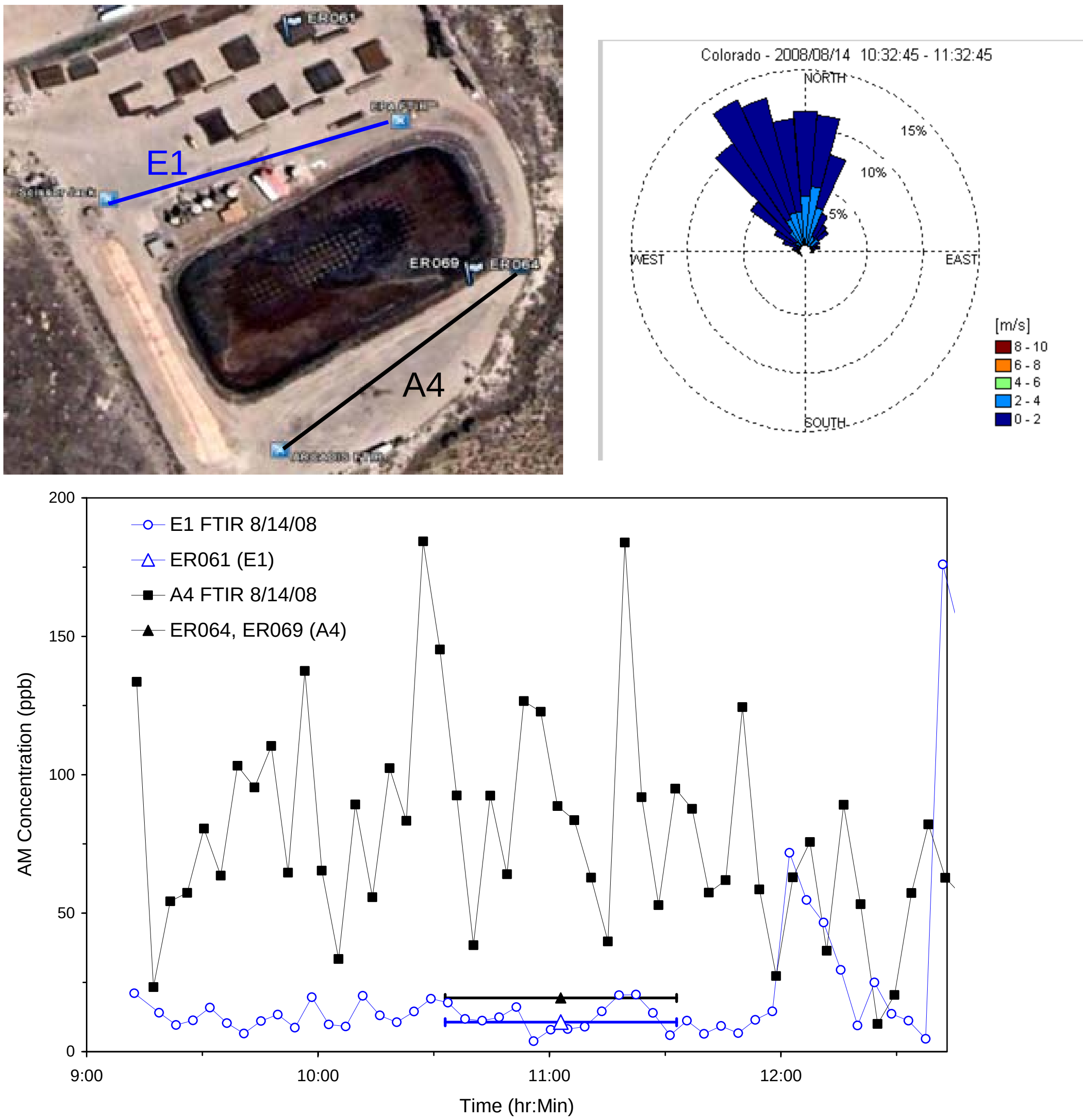

Figure 3-17. EnCana 8/14/08, Canister ER061 Compared to OP-FTIR Path E1 and Canisters ER064 and ER069 Compared to OP-FTIR Path A4

Figure 3-18 presents the second comparison from 8/14/08. Note the change in canister placements and wind conditions compared to Figure 3-17. Here the OP-FTIR A4 path registers similar concentrations to Figure 3-17 prior to canister sampling and reduced values comparable to the canister as winds obtain SW components. At this time signal begins to appear of the E1 path.

Figure 3-19 presents a comparison from 8/15/08. In this case the canister ER021 is in close proximity to the pond inlet and is clearly impacted by a local source so is not a true upwind canister. It is noted that E1 OP-FTIR beam path (not shown) was characteristically low for this time period. The ER021 canister is most easily compared to the A1 OP-FTIR path under this wind direction and relatively good agreement is evident. Agreement is relatively good for the A4 path and it is interesting the note the how the concentration changes between the A4 and A1 paths as a consequence of wind direction variations over time.

3.6 Summary of Water Analysis Results

As discussed in Section 2.5, water samples were taken and analyzed to provide supporting information for the study. The results are presented in Tables 3-15 and 3-16 for the Williams and EnCana Facilities respectively. All samples were analyzed for volatile organics by EPA SW-846 Method 8260 "Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (capillary column technique)". Due to the high levels of VOCs in the Skim Pond Inlet and Outlet samples, some of the compounds exceeded the calibration range. Further information on the analysis can be found in Appendix C.

Table 3-15 shows a summary of the results for the three highest concentration compounds for the skim pond inlet and exit. All results presented in Table 3-15 exceeded the calibration range and are considered estimates. For samples taken from the north and south pond outlet headers, all compounds analyzed were under the detection limit (<2.5 µg/L).

Table 3-16 shows a summary of the results from the EnCana facility for the three highest concentration compounds for the evaporation pond inlet and subsurface samples. All results presented in Table 3-16 exceeded the calibration range and are considered estimates.

At both sites, a strong gradient in concentration from the inlet to outlet (or pond edges) is evident. The three highest compounds (benzene, toluene, and m-, p-xylenes were also found in relatively high concentrations compared in the other analyses.

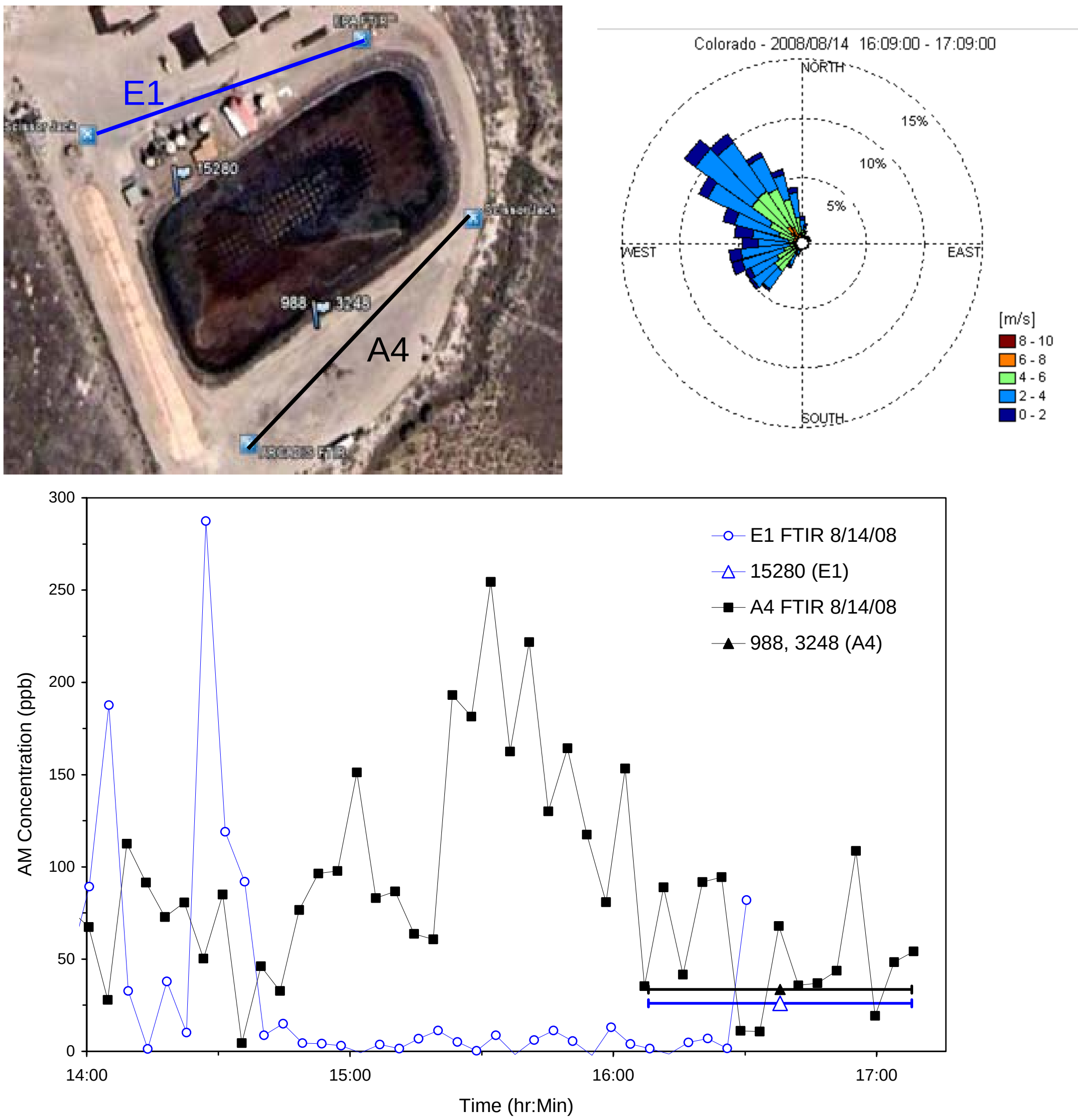

Figure 3-18. EnCana 8/14/08, Canister 15280 Compared to OP-FTIR Path E1 and Canisters 988 and 3248 Compared to OP-FTIR Path A4

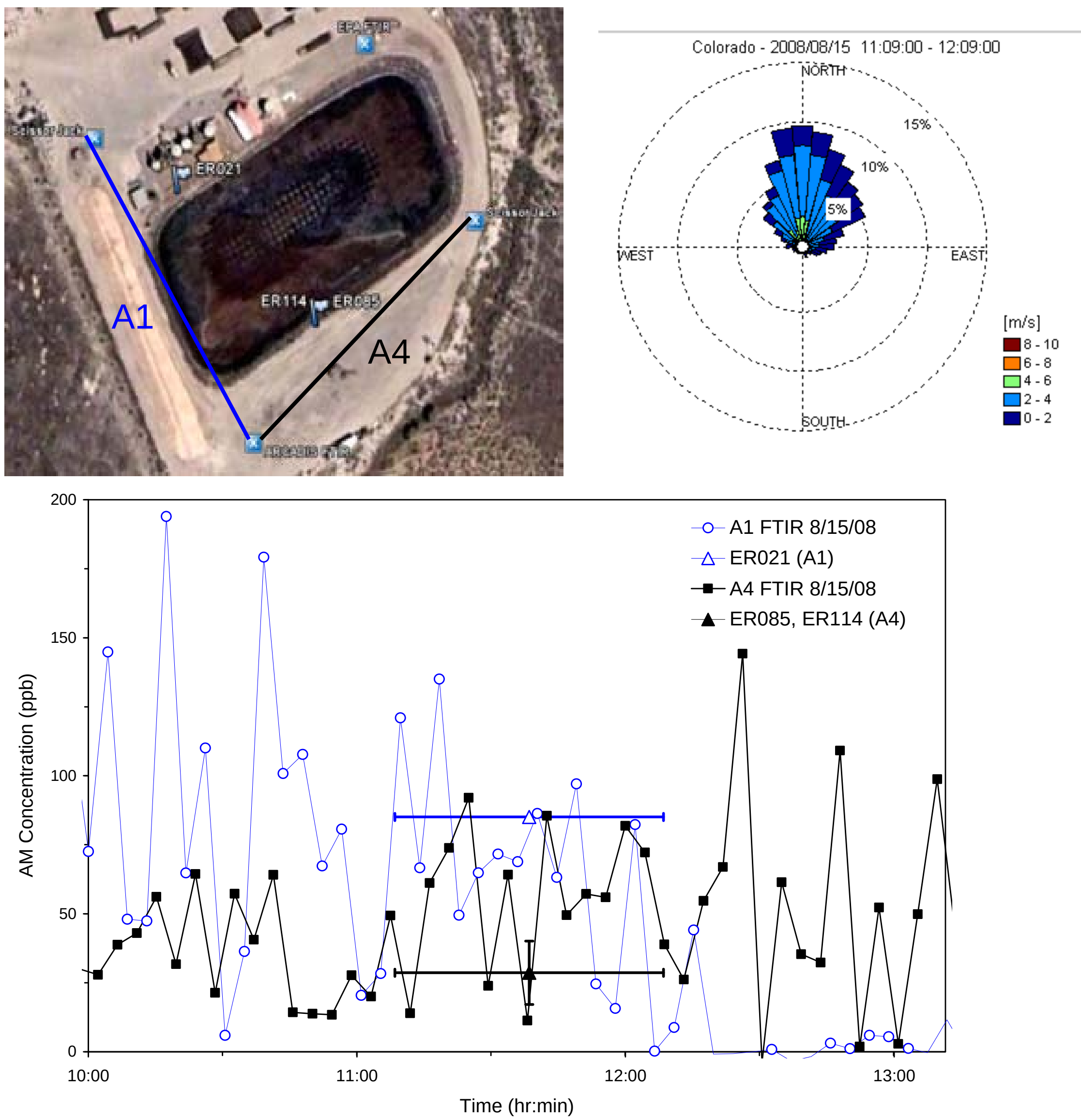

Figure 3-19. EnCana 8/15/08, Canister ER021 Compared to OP-FTIR Path A1 and Canisters ER085 and ER114 Compared to OP-FTIR Path A4

Table 3-15. Summary Water Analysis from the Williams Site

Sample No	Date	Time (hr:min)	Benzene (µg/L)	Toluene (µg/L)	m,p-Xylene (µg/L)
Skim Pond Inlet					
SP IN-1	8/7/2008	13:34	19,000	50,000	40,400
SP IN-2	8/8/2008	11:02	16,200	29,400	16,300
Skim Pound Outlet					
SP OUT-1	8/7/2008	13:45	15,000	33,400	24,100
SP OUT-2	8/8/2008	11:04	7,470	16,200	8,850
SP OUT-2 Dup	8/8/2008	11:04	10,700	21,900	11,000
SP OUT-3	8/8/2008	11:35	11,300	23,600	11,900
SP OUT-4	8/8/2008	11:51	12,000	27,400	16,100

Table 3-16. Summary Water Analysis from the EnCana Site

Sample No	Date	Time (hr:min)	Benzene (µg/L)	Toluene (µg/L)	m,p-Xylene (µg/L)
Grass Mesa Inlet					
Grass-1	8/12/2008	16:30	13,700	36,400	22,500
Grass-2	8/13/2008	16:50	7,930	18,500	8,180
Grass-3	8/14/2008	10:45	12,500	30,900	18,300
West Side					
W-1	8/12/2008	14:45	642	1,370	756
W-2	8/13/2008	15:30	564	1,430	933
W-3	8/14/2008	11:15	694	1,710	1,000
W-3 Dup	8/14/2008	11:15	729	1,800	1,070
South Side					
S-1	8/12/2008	15:20	382	716	314
S-2	8/13/2008	15:15	804	1,920	1,100
East Side					
E-1	8/12/2008	15:40	605	1,320	689
E-2	8/13/2008	14:50	550	1,340	804

This page intentionally left blank.

4. Summary

A measurement campaign was conducted at the Williams Rulison and EnCana Benzel facilities in Western Colorado from August 6-9 and 12-15, 2008, respectively. The purpose of the study was to increase knowledge of VOC emissions form the produced water ponds at the facilities. The measurement approach used EPA method OTM 10 with two OP-FTIRs deployed in a four corners configuration to provide mass emission flux estimate of measurements for an alkane mixture. Table 4-1 presents a summary of the AM emission flux results from the two sites. The values in the table represent the average of all valid 20-minute AM flux estimates calculated over a four-day period at each site with standard deviation in parenthesis and number of values indicated. The uncertainty estimate for the individual flux measurements comprising this average is estimated at ± 40% (section 5.3). The uncertainty in the overall average is likely driven by the temporal variability in the source emissions.

Table 4-1. AM Emission Flux Results from William Rulison and EnCana Benzel Sites

Site	Source	Average AM Flux [g/s]	Number of Values
Williams	Evaporation Pond	0.20 (0.33)	27
Williams	Skim Pond	0.90 (0.58)	15
EnCana	Evaporation Pond	0.07 (0.06)	65

The results show that the major AMs emissions source from the Williams facility was from the Skim Pond. The emissions from the Skim Pond were on average about 5 times the emissions from the Evaporation Pond. The results also show that the emissions from the Evaporation Ponds at the two sites were comparable (0.20 g/s and 0.07 g/s for the Williams and EnCana sites, respectively).

The OP-FTIR TAM data were used to estimate concentrations of select VOC at the sites. The VOC concentrations were ratioed to AM concentrations and measured fluxes from the same time period to produce an estimate of the VOC emissions from the sites. Table 4-2 presents the results of these calculations. The values of Table 4-2 include underlying uncertainty in AM flux measurement average in addition to significant VOC to AM concentration ratio uncertainty so the values should be considered estimates

In addition to the OP-FTIR measurements, VOC concentrations were determined using SUMMA canister samples and EPA Method TO-15 and SNMOC analysis. These values were compared to the OP-FTIR data to provide supporting information for the study. Water samples were also acquired and analyzed to help support the study. These data showed a strong concentration gradient between the inlet on outlet (or pond edges) for both facilities.

Table 4-2. Summary of Estimated VOC Emission Rates (in grams per second) from William Rulison and EnCana Benzel Sites

Site	Source Area	Benzene (g/s)	Toluene (g/s)	m-Xylene (g/s)	o-Xylene (g/s)	p-Xylene (g/s)	Methanol (g/s)	Methane (g/s)
Williams	Evaporation Pond	0.016	0.036	0.014	0.036	0.018	0.001	0.015
Williams	Skim Pond	0.078	0.181	0.072	0.182	0.088	0.006	0.074
EnCana	Evaporation Pond	0.029	0.023	0.017	0.014	0.014	0.002	0.007

The overall AM emission rate estimates for the produced water pond sources at the Williams facility was ~16 times higher than for the EnCana facility. The incoming flow estimates were ~5300 barrels per day for the Willams facility and ~ 300 barrels per day for the EnCana facility, a factor of ~18. Combining the emission estimates of benzene, toluene and m-,o-,p-xylene, the Williams facility was ~ 7.5 times higher than the EnCana, although these estimates contain additional uncertainty. Differences in emissions between the facilities could be due to many variables including: differences produced water input to the ponds, pond size and aeration differences, transportation and water treatment differences etc.

Note that the emission estimates presented in this report represent a snapshot in time consisting of day-time observations over consecutive four-day periods at each facility during the month of August. Diurnal and seasonal effects in addition to changing process variables such as (concentration of hydrocarbons in the waste water, use of spray operations, changes in separation and biotreatment, etc.) were not evaluated as part of this study. Since these variables may have a significant effect on emissions, extrapolation of the results contained in this report would include significant uncertainty. As a specific example, methanol water concentrations are known to vary seasonally so the emission data contained in this report is may not be typical.

5. Quality Assurance/Quality Control

This document reports the results from Phase I of a multi-phase research effort to identify and quantify select VOC and methane emissions from oil and gas field operations. These data are not intended for direct use in enforcement activities, litigation, or human studies. These data were collected in conformance with the quality requirements of NRMRL QA Category III.

The basic objective of this phase of the project was to improve knowledge of emission rates produced water evaporation ponds. The approach used EPA Method OTM -10 in conjunction with canister sampling. The following sections describe the procedures used to ensure that the data met the project data quality indicators (DQI) and was acceptable for use in meeting these study objectives.

5.1 Instrument Calibration

As stated in the *ECPB Optical Remote Sensing Facility Manual* (USEPA, 2004), all equipment is calibrated annually and or cal-checked as part of standard operating procedures. Certificates of calibration are kept on file. Maintenance records are kept for any equipment adjustments or repairs in bound project notebooks that include the data and description of maintenance performed. Instrument calibration procedures and frequency are listed in Table 5-1 and further described in the text.

5.2 Assessment of DQI Goals

The critical measurements associated with this project and the established data quality indicator (DQI) goals in terms of accuracy, precision, and completeness are listed in Table 5-2. More information on the procedures used to assess DQI goals can be found in Section 10 of the *ECPB Optical Remote Sensing Facility Manual* (USEPA, 2004).

Table 5-1. Instrumentation Calibration Frequency and Description

Instrument	Measurement	Calibration Date	Calibration Detail
IMACC, Inc. OP-FTIR	Analyte PIC	Pre-deployment and in-field checks	MOP-6802 and 6823 of the ECPB Optical Remote Sensing *Facility Manual*
AIL, Inc. OP-FTIR	Analyte PIC	Pre-deployment and in-field checks	MOP-6802 and 6823 of the ECPB Optical Remote Sensing *Facility Manual*
R.M. Young Meteorological Head	Wind Speed in miles/hour	July 21, 2008	APPCD Metrology Lab Cal. Records on file
R.M. Young Meteorological Head	Wind direction in degrees from North	July 21, 2008	APPCD Metrology Lab Cal. Records on file
Topcon Model GTS-211D Theodolite	Distance Measurement	June 17, 2008	Calibration of distance measurement. Actual distance=43.105 ft Measured distance= 42.5 ft
Topcon Model GTS-211D Theodolite	Angle Measurement	June 17, 2008	Calibration of angle measurement. Actual angle= 360º Measured angle= 358º58'48" Measured angle= 359º00'20" Measured angle= 359º01'08"

Table 5-2. Measurement Quality Objectives for the Project

Measurement Parameter	Analysis Method	Accuracy	Precision	Detection Limit	Completeness
Analyte PIC	OP-FTIR: Nitrous Oxide Concentrations	± 25%,15%, 10%a	± 10%	See Table 4-2 of QAPP (EPA, 2008)	90%
Cannister Measurements	TO-15/ SNMOC	± 30 of audit	± 25	See Tables 4-3 and 4-4 of QAPP (EPA, 2008)	90%
Ambient Wind Speed	R.M. Young Met heads post-deployment calibration in EPA Metrology Lab	± 1 m/s	± 1 m/s	0.2 m/s	90%
Ambient Wind Direction	R.M. Young Met heads post-deployment calibration in EPA Metrology Lab	±10º	± 10º	5 deg	90%
Distance Measurement	Theodolite- Topcon	± 1m	±1 m	0.1 m	100%
Prevailing Wind Direction	R.M. Young Met heads	N/A	N/A	N/A	NA

a. The accuracy acceptance criterion of ±2 5% is for pathlengths of less than 50m, ± 15% is for pathlengths between 50 and 100m, and ± 10% is for pathlengths greater than 100m.

5.2.1 DQI Check for Analyte PIC Measurement

The precision and accuracy of the concentration data may be checked by looking at the analyzed nitrous oxide concentrations. The known atmospheric background nitrous oxide concentration is around 315 ppbv (this is an average value, as the value exhibits a slight seasonal variation). The acceptable range of nitrous oxide concentrations is 315 ppb ± 25% for pathlengths of less than 50m, 315 ppb ± 15% for pathlengths between 50 and 100m, and 315 ppb ± 10% is for pathlengths greater than 100m. Verifying this background concentration provides a good QC check of the data collected. Obviously, this method is not valid for data collected at a site that is a source of nitrous oxide.

The precision of the analyte PIC measurements was evaluated by calculating the relative standard deviation (RSD) from one data subset collected near the surface of the suspected source. A subset is defined as the data collected along one particular path length during one particular survey in one survey sub-area.

The accuracy of the analyte PIC measurements was evaluated by comparing the calculated nitrous oxide concentrations from one data subsets to the background value of 315 ppb. The number of calculated nitrous oxide concentrations that failed to meet the DQI accuracy criterion was recorded.

Overall, a total of two datasets were analyzed for each OP-FTIR instrument. Based on the DQI criterion set forth for precision of ± 10%, all of the data subsets from the ARCADIS OP-FTIR were found to be acceptable, for a completeness of 100%. The range of calculated relative standard deviations for the data subsets was 1.8 to 3.2 ppb, which represents 0.57 to 1.02% RSD. Based on the DQI criterion set forth for precision of ± 10%, all of the data subsets from the EPA OP-FTIR were found to be acceptable, for a completeness of 100%. The range of calculated relative standard deviations for the data subsets was 3.6 to 3.7 ppb, which represents 1.14 to 1.17% RSD.

Each data point (calculated nitrous oxide concentration) in the data subsets was analyzed to assess whether or not it met the DQI criterion for accuracy of ± 10% (315 ± 32 ppb), as the path lengths used for measurements were greater than 100 meters. A total of 138 data points were analyzed from the ARCADIS OP-FTIR, and 138 of the points met the DQI criteria for accuracy for a completeness of 100%. A total of 136 data points were analyzed from the EPA OP-FTIR, and 89 of the points met the DQI criteria for accuracy for a completeness of 65%. It should be noted that all of the analyzed data points from the EPA OP-FTIR were within ± 14% of the DQI criterion for accuracy of 315 ppb (range of analyzed nitrous oxide concentrations was 335 to 357 ppb).

5.2.2 DQI Checks for TO-15 Can Measurements

A field audit (Technical Systems Audit) was conducted by EPA quality staff from OAQPS at the start of the Williams Rulison sampling campaign. An audit report was not generated.

The QC data associated with the ERG TO-15 and SNMOC analyses of these samples were evaluated according measurement audit goals: accuracy ± 30 percent; precision ± 25 percent; and 90 percent completeness. The accuracy could not be assessed since laboratory control sample results were not included in the ERG laboratory reports. A number of field duplicate analyses were conducted by the laboratory, with a resulting precision of more than 98 percent. All samples were analyzed and reported, resulting in 100 percent completeness.

5.2.3 DQI Checks for Ambient Wind Speed and Wind Direction Measurements

The meteorological head DQIs are checked annually as part of the routine calibration procedure. The R.M. Young Meteorological heads used in the current study were calibrated by the EPA Metrology Lab on July 21, 2008. Due to field studies requiring the equipment, a post calibration assessment of the R.M. Yong Meteorological heads by the EPA Meteorology lab could not be performed. Both heads did successfully pass a post deployment certified calibration test performed by the manufactures (R.M. Young) conducted on May 13, 2009.

Additionally, a couple of reasonableness checks were performed in the field on the measured wind direction data. While data collection was occurring, the field team leader compares wind direction measured with the heads to the forecasted wind direction for that particular day. Another reasonableness check involved confirming a magnetic north reading by manually setting the vane to magnetic north using a hand held compass. The output wind direction during this manual test should be very close to 360º.

The Wind Sonic anemometer was used in place of the 10-meter R.M. Young Meteorological head when the wireless transmitter failed on the last day at the Williams Rulison facility. This instrument was intended only as an emergency back-up and was therefore not calibrated prior to the field campaign. There are no moving parts in this anemometer, nor is there an auto northing feature. There is a yellow dot on the Wind Sonic that must be pointed north. Prior to use, the theodolite compass was used to verify that the instrument was pointing to magnetic north.

5.2.4 DQI Checks for the Topcon Theodolite

A calibration check was performed before the field campaign on June 17, 2008. The calibration of distance measurement was done at the EPA facility using a tape measure. The actual distance was 43.105 feet, and the measured distance was 42.5 feet. The results indicate accuracy and precision fall well within the DQI goals. The calibration of angle measurement was also performed. The actual angle was 360°, and the measured angles were 358°58’48”, 359°00’20” and 359°01’08”. The results indicate accuracy and precision fall well within the DQI goals.

Additionally, there are several internal checks in the theodolite software that prevent data collection from occurring if the instrument is not properly aligned on the object being measured, or if the instrument has not been balanced correctly. When this occurs, it is necessary to re-initialize the instrument to collect data.

5.2.5 QC Checks of OP-FTIR Instrument Performance

Several diagnostic checks were performed on the OP-FTIR instrumentation prior to deployment to the field, and during the duration of each field campaign. These checks involve assessing the electronic noise of the instrument, the strength of the instrument signal, and features in the collected data spectrum. The results of these tests are used to determine whether or not the instrument is functioning properly. More information on the diagnostic checks that are performed as part of a typical ORS field campaign can be found in MOP 6802 and 6823 of the *ECPB Optical Remote Sensing Facility Manual* (USEPA, 2004).

In addition to the QC checks performed on the OP-FTIR, the quality of the instrument signal (interferogram) was checked constantly during the field campaigns. This was done by ensuring that the intensity of the signal is at least 5 times the intensity of the stray light signal (the stray light signal is collected as background data prior to actual data collection, and measures internal stray light from the instrument itself). In addition to checking the strength of the signal, checks were done constantly in the field to ensure that the data were being collected and stored to the data collection computer. During the campaign, a member of the field team monitored the data collection computer to make sure these checks were completed.

Prior to instrument deployment, a series of QC checks were performed on the IMACC OP-FTIRs to assess the instrument performance. The single beam ratio, baseline stability, noise equivalent absorbance, ZPD stability, saturation, random baseline noise, and stray light diagnostic tests were performed at the EPA facility. The results of the tests indicated that the ARCADIS and EPA OP-FTIR instruments were operating within the acceptable criteria range.

5.2.6 Difficulties Encountered

During the two-week measurement campaign, the project encountered some problems with instrumentation and data telemetry. As mentioned in Section 3.2, the R.M. Young meteorological station was employed to collect wind data until mid-morning (10:30 a.m.) on August 9, 2008. At that time, the wireless transmitter failed in the 10-meter head and the emergency backup Wind Sonic anemenometer was put in place. A compass was used to establish magnetic north (there is no auto north feature on the Wind Sonic) and the software was modified for use in the field.

During this time, an R.M. Young meteorological station was employed to collect wind data until mid-morning (10:30 a.m) on August 9, 2008. At that time, the 10-meter head transmitter failed and a Wind Sonic anemometer was put in place and was used for the remainder of the sampling.

There were some seal integrity issues with both the EPA and ARCADIS OP-FTIR instruments. For the EPA OP-FTIR, the liquid nitrogen would run out much sooner than expected. The field protocol was modified to ensure that the liquid nitrogen was checked more frequently.

During the evening of August 10, 2008, unexpected and severe wind gusts (estimated at 70-80 mph) knocked over the OP-FTIR and orbital scanner. On the morning of August 11, 20 minutes of data was collected and analyzed to ensure that the instrument was working properly before being deployed to the EnCana Benzel site.

5.3 Estimate of Uncertainty for OTM 10 Emission Measurements

There are four primary sources of uncertainty for OTM 10 emissions estimates from the produced water pond sources for this project: (1) baseline flux measurement uncertainty for the combination of multiple measurement planes discussed in Section 3.1 (Combined Uncertainty); (2) uncertainty due to assignment of interfering sources; (3) additional uncertainty associated with 3-beam OTM 10 configuration; and (4) uncertainty due to the variability of source. These sources of uncertainty will be discussed in this section.

<u>Combined Flux Uncertainty</u>
As discussed in Section 3.1, a combined uncertainty estimate was produced for each 20-minute flux measurement. This uncertainty estimate was calculated by propagating individual estimates of uncertainty for each OTM 10 measurement plane to a combination of all four planes using a base assumption of ± 20% uncertainty for each plane. The ± 20% total uncertainty number is an estimate on previous tracer release studies of OTM 10 performance in a close-coupled area source measurement scenario. For this project, the average calculated combined uncertainty expressed as a percentage of the net flux value were typically in the 20% to 30% range however several values exhibited very high values of uncertainty. For example, Williams 8/7/09 12:10 shows a very low net flux (0.005 g/s) with a large combined uncertainty (0.0880 g/s) due to a high external flux from the interfering source (0.450 g/s). There is a similar value for EnCana 8/12/09 13:30 which shows a very low net flux (0.001 g/s) with a large combined uncertainty (0.004 g/s) due to a high external flux (0.02 g/s). Excluding these two outlier values, a meaningful metric of uncertainty can be produced by taking the average value of the combined uncertainty expressed as a percentage of the individual flux measurements value for each facility. For the Williams Evaporation Pond this value is

32.7% and for the EnCana facility this value is 26.8%. Note that the skim pond facility is expressed as the external source so this calculation cannot be done for this source however due its strength, it is less affected by interfering sources so a 25% to 30% combined uncertainty assumption would seem reasonable.

Uncertainty Due to Assignment of Interfering Sources

As discussed in the combined uncertainty section above and also in the text and graphs of Section 3, interfering sources can cause significant uncertainty with regard to emission flux estimates. This is especially true when the interfering source is strong in comparison to the source being evaluated. An example of this would be evaluation of the Williams North pond with potential interference from the skim pond. To first order, interfering sources are accounted for in the combined uncertainty estimation however there are cases were assignment of the interfering source can come into question due to uncertainties in wind direction. An example of this would be the 13:10 value from 8/7/09 which shows a high value for emissions from the North Pond (1.56 g/s) compared to the overall average (0.20 g/s) and was produced during a period when the direction was changing. In this particular case, this effect may have been exaggerated due to the close proximity of the skim pond source and the relatively strong source associated with the inlet to the North pond from the skim pond. It is difficult to estimate the overall uncertainty associated with this effect however it is partially reflected in the standard deviation of the results of the combined average.

Uncertainty Due to 3-beam OTM 10 Approach

As discussed in Section 2, the OTM 10 measurement configurations for this project consisted of three measurement paths which extended from the OP-FTIR instrument to the scissor lift. The 3-beam OTM 10 approach was chosen for this project since it was decided that it was more important to obtain a larger number of measurement cycles as opposed to fewer number of cycles with a five beam approach since the horizontal spatial location of the plume was not of primary importance. Due to the convergence of the optical beams at the instrument location, the use of a 3-beam measurement approach can introduce additional uncertainty in the flux if the emission zone is relatively small and located near the ends of the configuration. For this project the key suspected emission areas are thought to provide relatively well-developed plumes from spatially and were generally well-centered on the optical configuration (i.e. location of Williams skim pond), however a discussion of general uncertainty associated with the three beam approach is warranted.

To produce this uncertainty discussion, we used the *VRPM Fit Explorer* program (described by Abichou et al., 2009) to run a series of simulations to assess the variability in flux results from the OTM 10 method as a result of assuming different σ_y and peak plume concentration locations. In this simulation program, a downwind concentration field is generated from an area source using EPA ISC Gaussian dispersion model and then analyzed using OTM 10 algorithms and optical beam geometries.

In analyzing the PIC data using the 3-beam approach, the peak plume concentration was assumed to be centered along the crosswind axis of the OTM 10 configuration, and the σ_y parameter (horizontal dispersion coefficient) of the measured plume was assumed to be equal to ½ the length of the OTM 10 configurations. It was necessary to make these assumptions because the 3-beam OTM 10 approach does not include two intermediate surface beam paths which are used to obtain information on the horizontal location and dispersion of the plume.

To investigate the effect of assuming fixed σ_y and lateral plume size parameters in the OTM 10 VRPM calculation, as simulation was performed which presented three different plume size scenarios using *VRPM Fit Explorer* program. For this simulation, the OTM 10 plane configuration parameters were set near the average values used in this study (plane length = 140 m, retroreflector heights 1m, 4m, 9m). The plume size parameter in the OTM 10 calculation was fixed at 70 m and the σ_y parameter was varied (7m, 70 m, and 700 m). The simulated plumes were centered on the configuration with the upwind location of the source set to 50 m and stability class set to three with winds normal to the plane. The results are shown in Table 5-3 for three different staring plume sizes with values compared to 1.0 for a perfect reconstruction of the simulated flux.

Table 5-3. Results of Flux Values Calculated by the *VRPM Fit Explorer* Program With a Fixed Peak Plume Concentration Location and Varying Values of the σ_y Parameter

σ_y Value	40 m × 40 m	70 m × 70 m	100 m × 100 m
σ_y = 7 m	0.97	0.92	0.86
σ_y = 70 m	1.03	0.99	0.93
σ_y = 700 m	1.04	1.00	0.94

The results of the simulation show that the OTM 10 calculation is relatively insensitive to the choice of the σ_y parameter and that the choice of setting this parameter to ½ the value of the OTM 10 plane length is a reasonable assumption and likely will not lead to a large source of error.

As discussed previously, a potentially larger source of error when using the three-beam OTM 10 approach occurs in situations where the plume is relatively small in comparison to the OTM 10 plane and passes through the plane near its edges. At the position of the OP-FTIR, the three optical beam paths are close together forming the vertex of the OTM 10 triangle. At the position of the retroreflectors, the beams are the separated by the largest amount. The flux estimate for plumes intersecting the OTM 10 plane near the OP-FTIR instrument will be overestimated. The flux estimate for plumes intersecting the OTM 10 plane near the scissor lift and retroreflectors will be underestimated.

Table 5-4 presents the results of a second simulation which investigates variation of the plume center location as it intersects the OTM 10 plane with the σ_y parameter assumed to be 70 m and other parameters the same as the previous simulation.

Table 5-4. Results of Flux Values Calculated by the VRPM Fit Explorer Program with a Fixed σ_y Parameter and Varying Peak Plume Concentration Locations

Peak Plume Concentration Location (m)	40 m × 40 m	70 m × 70 m	100 m × 100 m
30	2.01	N/A	N/A
50	1.44	1.318	N/A
70	1.03	0.99	0.93
90	0.77	0.76	N/A
110	0.60	N/A	N/A

N/A- Simulation results not included because plume would not be located within the confines of the OTM 10 configuration plane

The results of the simulation show that the 3-beam OTM 10 calculation is dependent upon the peak plume concentration location along the OTM 10 configuration plane. For the smallest plume size at a location close to the OP-FTIR instrument and convergence of the measurement paths (peak concentration location at 40 m), the OTM 10-derived flux values from the simulation was 200% higher than simulated values. The simulation shows underestimation of results as the 40 m x 40 m plume intersects the OTM plane closer to the scissor lift (up to 40 % underestimation). The OTM 10-derived flux values from the simulation agrees better with control values as the plume becomes larger and is more centered on the optical configuration.

When assessing the contribution to overall measurement uncertainty caused by using the 3-beam measurement approach, several factors must be considered. The general pond emission sources for this project are relatively large spatially with well-developed plumes (more like the 100 m by 100 m case). The Williams skim pond source would represent a smaller source however it was well-centered on the OTM 10 plane which decreases the likely hood of the near edge intersections (highly overestimated or underestimated 40 m by 40 m cases). Some of the inherent uncertainty discussed in this section is likely also evident (and accounted for) in the assumption of ± 20% single plane OTM 10 accuracy based on tracer release performance results. It is also noted that over the course of a 20 minute average measurement cycle, the plume intersection point meanders somewhat due to wind direction variation leading to an averaging effect. With these factors taken into account, the added uncertainty for a single plane measurement for this project due to use of the 3-beam approach is estimated to be within ± 20 %.

Based on this analysis and the preceding combined uncertainty analysis a reasonable estimate of the overall uncertainty in a single 20 minute OTM flux calculation for this project is estimated to be within ± 40%.

Uncertainty Due to the Variability of Source
As discussed in several sections of this report, significant variability in emissions from the assessed sources is evident and expressed as the relatively large standard deviation in emission flux results compared to the average value for the source. Some of this variability is due to uncertainty in the measurement approach but a significant amount of the variability is believed to be due to changes in emissions from the source due to changes in a number of emissions controlling variables such as make-up of the source, variable input load, meteorological conditions driving the emissions, and changes in process variables to name a few. This level of variability is evident in the standard deviation of the average results. A limitation of this data set is related to potential lack of sufficient measurement time to provide a robust estimate of average emissions.

5.4 EPA and ARCADIS Audits and Corrective Actions

Although a Technical Systems Audit (TSA) was not required for this QA Category III project, there was an attempt to perform one to help support the overall quality of the effort. Unfortunately, the trip planning and time constraints of the QA auditor was fixed near the planned project start-up at the Williams facility (August 4th – 6th 2008). Due to a transportation truck break-down enroot to the field location from the North Carolina EPA facility, the set up of the project was delayed precluding execution of a thorough audit however significant QA checks were made on August 6, 2008. The auditor did not find any issues that required corrective actions. An audit report was not generated.

6. References

Hashmonay, R.A., and M.G. Yost. (1999), Innovative approach for estimating fugitive gaseous fluxes using computed tomography and remote optical sensing techniques, *J. Air Waste Manage. Assoc*., 49, 966-972.

Thoma, E. D., Shores, R. C., Thompson, E. L., Harris, D. B., Thorneloe, S. A., Varma, R., Hashmonay, R. A.; Modrak, M. T., Natschke, D. F., Gamble, H.A.. (2005) "Open path tunable diode laser absorption spectroscopy for acquisition of fugitive emission flux data." J. Air and Waste Manage. Assoc. 55, 658-668.

U.S. EPA (2004). "*ECPB Optical Remote Sensing Facility Manual",* U.S. EPA National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, Emissions Characterization and Prevention Branch, Contract No. EP-C-04-023, Work Assignment 0-33, April 2004.

U.S. EPA (2006), EPA Test Method (OTM 10), "Optical Remote Sensing for Emission Characterization from Non-Point Sources." U.S. EPA Technology Transfer Network Emission Measurement Center, Web Site; http://www.epa.gov/ttn/emc/prelim/otm10.pdf.

U.S. EPA (2007) "Measurement of Total Site Mercury Emissions from a Chlor-alkali Plant Using Open-Path UV-DOAS" , EPA/R-07/077; U.S. Environmental Protection Agency, Office of Research and Development, Work Assignment No. 2-052, July, 2007a, available at http://www.epa.gov/ord/NRMRL/pubs/600r07077/600r07077.pdf.

U.S. EPA (2008). "*Measurement of Emissions from Produced Water Ponds: Upstream Oil and Gas Study #1"*, Category III Quality Assurance Project Plan*,* Work Assignment No. 4-49, July 2008, Version 2.0.

This page intentionally left blank.

Appendix A: OTM 10 Alkane Mixture Flux Values

This page intentionally left blank.

APPENDIX A: . OTM 10 Alkane Mixture Flux Values

This appendix contains single plane OTM 10 VRPM measurement data of alkane mixture (AM) emissions acquired in this project. These single plane values are combined to provide the total flux estimate discussed in Section 3. The acquisition description and data quality indicators leading to selection of valid Individual plane data points are described in the following text and tables. The appendix contains the following sections:

A-1: Alkane Mixture (AM) Measurement by OP-FTIR
A-2: OTM 10 Flux Measurement Sequence Description
A-3: Acceptable Data Criteria and Emission Flux Correction Factors
A-4: Individual Flux Plane Results

A-1 Alkane Mixture (AM) Measurement by OP-FTIR

To utilize the EPA Method OTM 10 measurement method, the airborne pollutants of interest must be present at sufficient concentrations to be robustly quantified by the open-path instruments. In many cases involving petroleum-base fuel mixtures, it is not possible to individually quantify specific compounds due to the convolved nature of their spectral absorption features or by the lack of sufficient concentrations to exceed minimum detection levels at standard OTM 10 time resolutions. For these cases, a special OP-FTIR analysis technique can be employed which focuses on the combined absorption of a mixture of hydrocarbons by quantifying the infrared absorbance of the in the C-H stretch infrared vibrational region around 2900 cm^{-1}. This procedure is called the alkane mixture (AM) calculation since these compounds predominantly contribute the infrared absorption profile for these sources.

The use of OTM 10 for estimation of emission fluxes requires the conversion of the volume path-integrated concentrations (VPIC) to mass path-integrated concentrations (MPICs). This conversion requires an estimate of the mean molecular weight measured gas mixture. The AM procedure described below provides a means for estimation of the average molecular weight by assuming that the mixture can be approximated by a combination of C-4, C-5, C-6, C-7, and C-8 alkanes. This assumption is further discussed later in this section.

It is first noted that the infrared absorption features many hydrocarbon species in the C-H stretch region are relatively similar. For example, Figure A-1 shows C-4 to C-8 (n-butane to n-octane) along with several other species present in fuel-base mixtures. For the n-butane to n-octane series, the similarity is greatest between the components with consecutive carbon numbers (e.g. butane and pentane) and the similarities decrease for components with greater difference in carbon numbers (e.g. C-4 and C-8, butane and octane). The similarity in band shapes of these and other hydrocarbons with significant C-H stretch signal makes it impossible to include all of the components of the mixture in the classic least squares (CLS) regression fit of measured absorbance to calibrated reference absorbance spectra to determine the concentration of the individual compounds.

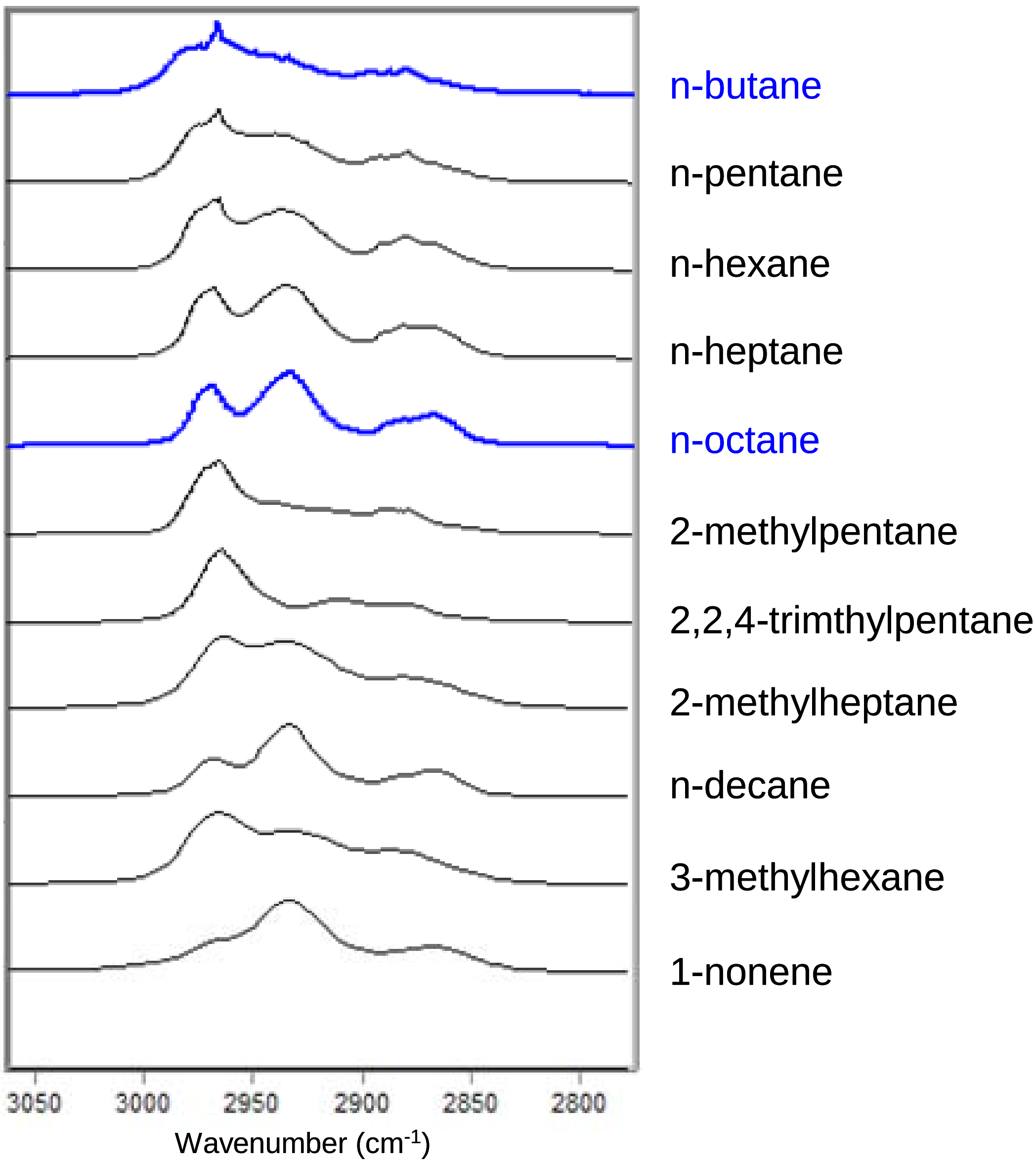

Figure A-1. Comparison of the Absorption Bands of Several Species in the C-H Stretch Region

For the AM analysis, the primary region of spectral analysis is 2804.2 to 3001.2 cm^{-1}. This region fully encumbers the main bands of the alkane mixture. To approximate the mixture, two representative analytes n-butane and n-octane (highlighted in Figure A-1) are chosen for analysis and the system is then approximated in terms of these bounding surrogates.

The mean molecular mass of the alkane mixture, $\overline{M}_{mix}$, is estimated as

$$\overline{M}_{mix} = \frac{M_{butane} \cdot {}^{V}\hat{C}_{butane}^{Arbitrated} + M_{octane} \cdot {}^{V}\hat{C}_{octane}^{Arbitrated}}{{}^{V}\hat{C}_{mix}^{Arbitrated}} \qquad \text{(A-1)}$$

where M_{butane} =58.12 g/mole (molecular mass of butane),

M_{octane} = 114.23 g/mole (molecular mass of octane),

${}^{v}\hat{C}_{butane}^{Arbitrated}$ and ${}^{v}\hat{C}_{octane}^{Arbitrated}$ are the butane and octane determinations from the analysis of the arbitration-chosen region. As explained in the in Appendix E of the QAPP, arbitration refers to the process of determining concentrations when multiple spectral regions were utilized to perform the analysis. Due to the low AM signal levels encountered for this project, only the 2804.2 to 3001.2 cm^{-1} spectral region was required for analysis.

The mass path-integrated concentration of the alkane mixture, ${}^{m}\hat{C}_{mix}$, is given as

$$ {}^{m}\hat{C}_{mix} = \frac{L(T,P) \cdot \overline{M}_{mix}}{A} \bullet {}^{v}\hat{C}_{mix}^{Arbitrated}$$

Where $L(T)$ is Loschmidt's Number at temperature, T and pressure P,

$$L(T) = 2.4793x10^{25} \bullet \frac{296K}{T} \bullet \frac{P}{1 \cdot atm} \text{ molecules/m}^3,$$

and A is Avogadro's number, $6.0220X10^{23}$ molecules/mole. The numerical solution is

$$ {}^{m}\hat{C}_{mix}[g/m^3] = 4.1171X10^{-5} \bullet \overline{M}_{mix} \left(\frac{296K}{T}\right)\left(\frac{P}{1 \cdot atm}\right) {}^{v}\hat{C}_{mix}^{Arbitrated}[ppm] \qquad \text{(A-2)}$$

The procedure for converting the volume PICs of alkane vapor mixtures from petroleum-base fuels to mass PIC is summarized by Equations A-1 and A-2. Additional information on this analysis and associated QA procedures can be found in Appendix E of the Quality Assurance Project Plan (QAPP) (EPA, 2008), *Procedure to Convert OP-FTIR Volume Concentration Determinations of Alkane Mixture that Originate from Petroleum-Based Fuels to Mass Concentrations.*

The central assumption of the AM procedure is that the complex mix of hydrocarbons emitted from the source can be approximated by the previously described two-component estimation which utilizes n-butane and n-octane as bounding surrogates. The assumption excludes alkanes with carbon numbers less than 4 (methane, ethane and propane) as these are not expected to be significant components of the airborne mixture (for this project) because these species are gases at standard atmospheric conditions would likely have separated from the liquid prior to the waste water treatment step. Alkanes with higher carbon numbers than C-8 (nonane, decane, etc.) have low vapor pressures and therefore are likely to be less prevalent in the airborne mixture. Other branched chain alkanes, and alkenes can have significant spectral contribution to the analysis band but are generally present at lower concentrations in the airborne mixture. Aromatic compounds are present at significant levels in the airborne mixture for this project but have leas spectral contribution to the 2804.2 to 3001.2 cm^{-1}analysis region.

These assumptions may be more or less valid depending on the exact nature of the source under evaluation but information can be informed by supplemental sampling such as SUMMA canister analysis (presented below) and through FTIR spectral analysis. Information regarding this assumption is present in the first level of OP-FTIR spectral analysis which, through the CLS fitting, provides an estimate of the quality of spectral match of the hydrocarbon mix to the utilized bounding reference spectra in addition to information in the fingerprint region. For petroleum-base fuel mixes there are typically a large number of hydrocarbons which posses similar broad infrared absorption features in the 2804.2 to 3001.2 cm^{-1} analysis region but in most cases, these species are present at lower levels and serve to provide an enhanced baseline to the main constituents such as octane. Aromatic compounds such as BTEX in particular have little infrared adsorption features in the primary analysis region and be individually quantified in other spectral regions if present at high enough concentrations.

A table summarizing the relative spectral contributions of a number of species prevalent in the SNMOC SUMMA canister analysis for this project is contained in Table A-1. This relative absorption factor was determined by integrating the area under the absorption curve from 2804.2 cm^{-1} to 3001.2 cm^{-1} using quality assured reference spectra or through estimation if spectra were unavailable. The table was normalized to n-octane.

Table A-1. Relative Absorption Factor (AF) of Select Hydrocarbon Species in the 2804.2 cm^{-1} to 3001.2 cm^{-1} Spectral Range (values are normalized to n-Octane)

Species	AF	Species	AF
Methane	0.032	2,4-Dimethylpentane[2]	0.715
Ethane	0.244	2,3-Dimethylpentane[2]	0.715
Propane	0.425	Methylcyclohexane[3]	0.766
n-Butane	0.553	2-Methylheptane[2]	0.971
n-Pentane	0.680	3-Methylheptane[2]	0.971
n-Hexane	0.779	2,2,4-Trimethylpentane	0.924
n-Heptane	0.888	2,2,3-Trimethylpentane[1]	0.924
n-Octane	1.000	2,3,4-Trimethylpentane[1]	0.924
n-Nonane[2]	1.093	1-Heptene	0.596
n-Decane[2]	1.195	1-Nonene[2]	0.613
Isobutane	0.536	Benzene	0.004
Isopentane	0.637	Toluene	0.093
Cyclopentane[2]	0.715	m-Xylene	0.192
2-Methylpentane	0.753	o-Xylene	0.204
3-Methylpentane	0.737	p-Xylene	0.212
2,2-Dimethylbutane	0.729	Ethylbenzene	0.230
2,3-Dimethylbutane[1]	0.729	1,3,5-Trimethylbenzene	0.296
Cyclohexane	0.853	1,2,3-Trimethylbenzene[1]	0.296
Methylcyclopentane[3]	0.766	1,2,4-Trimethylbenzene[1]	0.296
2-Methylhexane[2]	0.868	o-Ethyltoluene	0.323
3-Methylhexane[2]	0.868	m-Ethyltoluene[1]	0.323

[1] estimate based on AF value of close isomer

[2] estimate based on uncalibrated spectra (NIST Database)

[3] estimate not based on spectra (significant uncertainty)

Calculated values from DOE/PNNL Infrared Spectral Library R9, 2005

As described in Section 3.5, the summa canister SNMOC analysis provides an approximate distribution of hydrocarbons with the Williams analysis being the most robust due to good signal levels. Figure A-2 and A-3 estimate the contribution of the various species to the AM analysis region by presenting the SNMOC analysis (Figure A-2) and the same distribution multiplied by the AF value for each compound from Table A-1. It can be seen in Figure A-3 that the contribution to the AM band from benzene, toluene, and m-, o-, p-xylenes are limited even though they are preset at high levels in the airborne mixture. Note that there is significant uncertainty in estimate regarding methylcyclohexane due to lack of reference spectra.

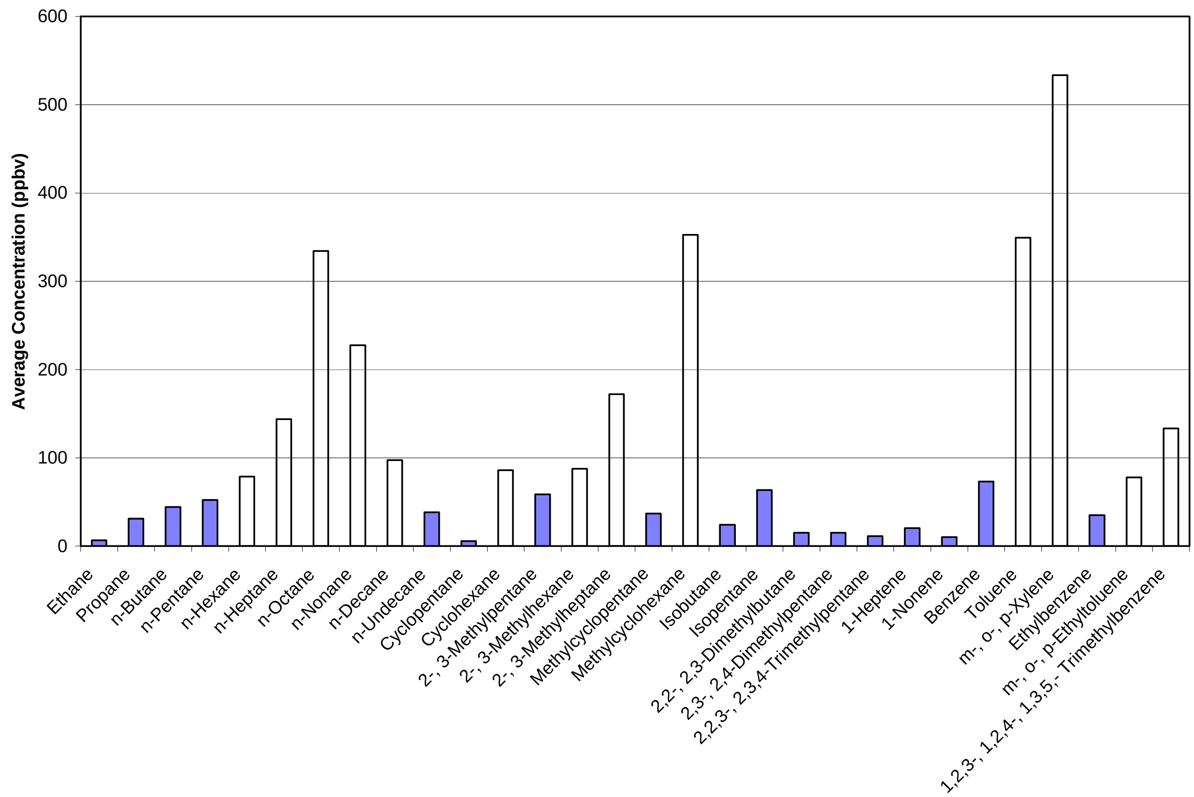

Figure A-2. Summa Canister SNMOC Analysis Showing Compound Distribution (Section 3.5)

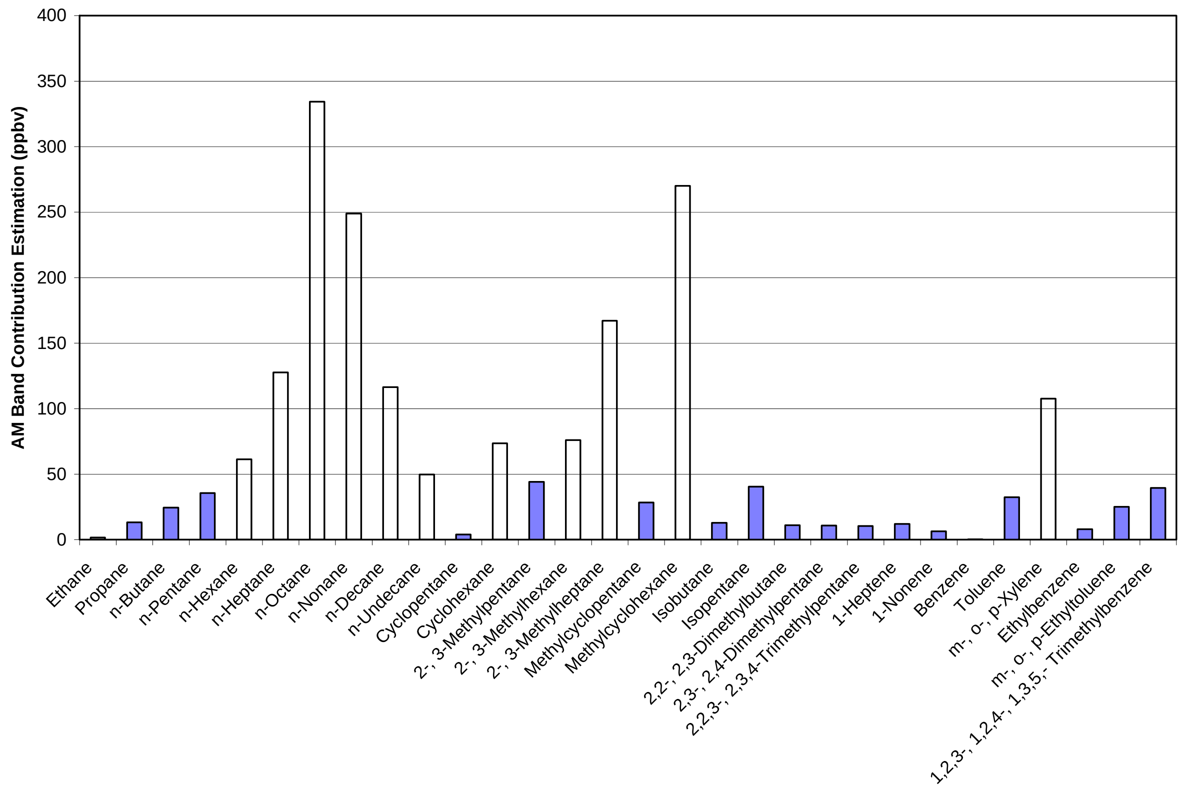

Figure A-3. Estimation of Contribution to AM Band, SNMOC Result Multiplied by AF

For purpose of comparison with OP-FTIR AM data, a summation of the 42 compounds modified by the AF factor was produced for each canister and this constitutes the SNMOC AM estimation utilized in Section 3.5 of the report. The molecular weight estimates from the OP-FTIR processing were very close to the octane values. For the time periods of downwind canister sampling, the average MWs by OP-FTIR AM method was 111 amu and 113 amu for the Williams and EnCana facilities respectively. The average MW using the distribution of A-2 was 103 amu and taking into account the AF as in Figure A-3, the average MW was 108 amu. Figure A-4 illustrates the latter by plotting the normalized concentration vs. molecular weight.

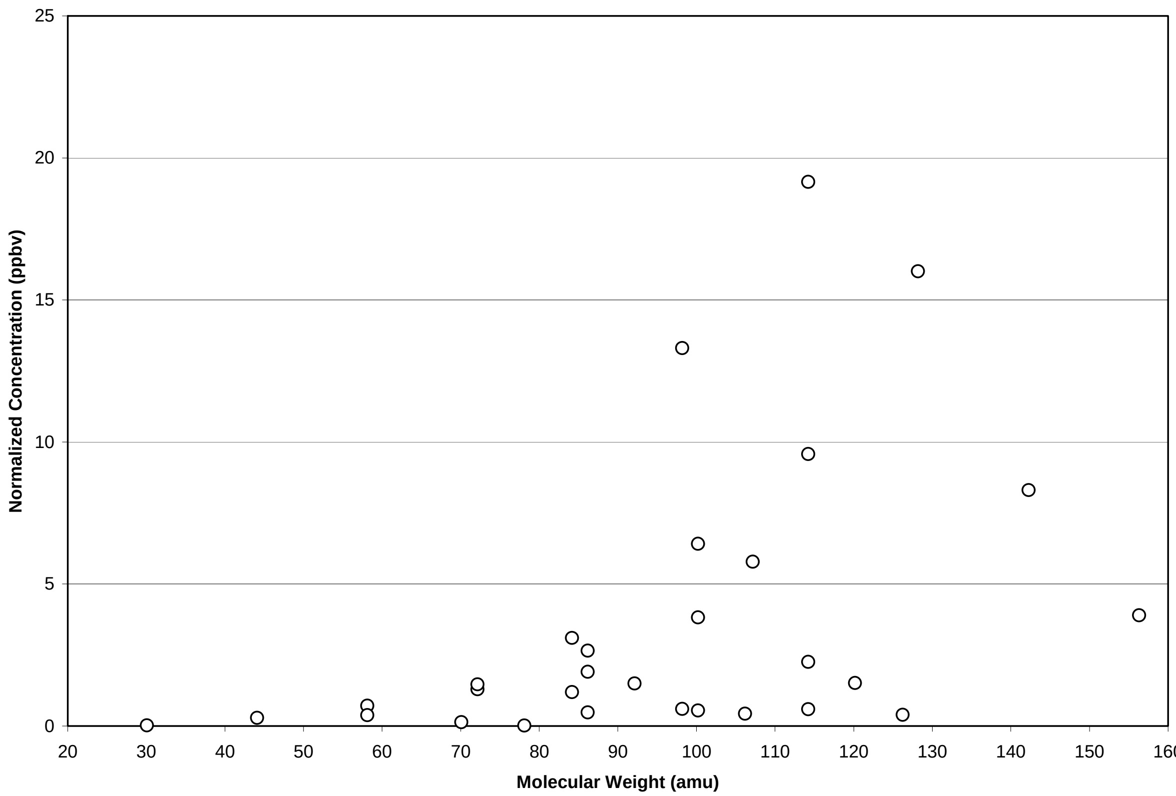

Figure A-4. Normalized Concentration vs. Molecular Weight for the Distribution of Figure A-3

A-2 OTM 10 Measurement Sequence Description

The 3-beam OTM 10 setup used for this project is described in Section 2 of this report. The OP-FTIR system acquires data on a single measurement path using a 30 second integration time starting with the lowest path (path 1) and then sequentially moving to the middle path (path 2) and highest path (path 3) completing the flux plan. The OP-FITR then rotates 90˚ to produce the measurement on the adjacent plan (paths 4,5,6) before returning to the 1,2,3 plane and repeating. There are two OP-FTIRs utilized each producing two of the four measured planes. The OP-FITRs are labeled (E) for EPA unit and (A) for the ARCADIS unit leading two a unique identifier for each of the four paths (E123, E456, A123, A456)

As a standard OTM procedure to reduce analytical noise, each flux calculation presented consists of an average of five consecutive flux plane measurements for an individual measurement plane.

To create this five-cycle value, individual beam PIC data for each path is averaged and processed as a single VRPM calculation using the average wind data for the measurement time period. A default value of five cycles is used however some data points contain a lower number of averages due to consecutive point data availability.

The OP-FTIR data and meteorological data had a measurement averaging time of 30 seconds. A single plane measurement requires approximately two minutes to complete. This includes a 30 second integration time for OP-FTIR (and meteorological data) each of the three measurement paths and time for the scanner to reposition the OP-FTIR to a new path. Since each OP-FTIR measured two separate three-beam flux planes in an interwoven fashion (e.g., A123 then A456, then A123 etc.), an approximate 20 minute time period is required to complete a five-cycle individual plane measurement. The data is displayed as a moving average. In this procedure, a subsequent five-cycle average contains four of the five values form the preceding average, excluding the earliest cycle and replacing it with the most recent cycle.

The fundamental units of emission flux produced by the EPA OTM 10, VRPM method are grams per second. In order to calculate the total alkane mixture (AM) flux values for a given plane, the FluxCalc VRPM software calculated the average AM molecular weight of the three beams as an input variable.

A-3 Acceptable Data Criteria and Emission Flux Correction Factors

The total AM mass emission flux was calculated when (1) the criteria for valid target compound detection and OP-FTIR Data Quality Indicators (DQIs) were met; and (2) the vertical capture criteria were met. When these criteria were met, all total flux calculations are reported. In some instances, failure to meet these criteria does not necessarily indicate an inaccurate flux calculation. When such exceptions are made, the flux calculations are reported and are flagged accordingly. Only data which met all of the following criteria were deemed acceptable and included in the data presented:

1. Prevailing wind speed ≥ 1 m/s but ≤ 8 m/s. Sections 3.2. and 3.3 present the summary tables of calculated flux values for each VRPM plane during each day of sampling at the Williams Rulison and EnCana Benzel facilities, respectively. Flux values for data collected during periods where the prevailing wind speed was ≤ 1 m/s or ≥ 8 m/s were not calculated and are shaded as follows in those tables:

   Medium orange.

2. Assessment of valid target compound detection

Prior to inputting the concentration data into the flux calculation software, the average concentration along each beam path was compared to the instrument minimum detection limit (MDL). For this project, the general definition of the term “minimum detection limit (MDL)” for OP-FTIR data is based around the uncertainty in the quantification of the measured species as determined by standard classical least squares (CLS) spectral analysis procedures. The standard error (σ) in the regression fit of the measured spectrum to the calibrated reference spectrum forms a basis for the defined MDL. Some multiple of σ is used a as threshold for quantification depending on the type of analysis used in this project. For example, for single-path time averaging method (TAM) estimation of trace VOC concentrations, we define an MDL threshold of 6σ. This means that the determined concentration must exceed six times the standard error in the CLS to be counted. For AM concentrations associated with the five cycle rolling average AM flux determination, the average measured concentration for all three optical paths must exceed eight times the average standard error for the paths in order for the flux plane ensemble concentration to be judged valid allowing an AM flux calculation to be executed.

If this measured concentration was not above the MDL (meaning that the ratio of the average concentration to the MDL of the OP-FTIR instrument was < 1), the flux was not calculated and are shaded as follows in those tables:

Dark orange.

In the vast majority of cases, the reason for “below MDL” determinations is due to lack of sufficient AM concentration, usually occurring on the upwind background measurement planes (no source signal present). In these instances there is negligible AM flux through the planes and values of zero flux have been assigned to these entries to aid in calculation of the four plane estimate. The moving average flux values presented in Tables 3-1 through 3-8 of the report include periods of zero flux values in the averaging. The values in these tables were used to calculate the average AM flux value from each source presented in Table 4-1. Additional calculations were performed to evaluate the average AM flux value from each source after removing the zero flux values from the calculations. The results showed that the average AM flux value from each source did not change significantly when zero flux values were not included in the calculations.

3. Vertical capture criteria

   There are two instances in which vertical integration of the concentration was limited to the height of the scissor jack (i.e., no extrapolation occurred above the scissor jack). If the average concentration on the top beam (beams # 3 or # 6, depending on the VRPM plane) was higher than the average concentration of the middle beam (beams # 2 or # 5) – indicating that the plume was not being captured by the plane − the concentrations along those two top beams were switched to allow the software to calculate the flux. These flux values are in **green font** in the summary tables of calculated flux values in Sections 3.2 and 3.3.

   The second case where integration of the concentration was limited to the height of the scissor jack occurred when all three beam concentrations were very similar. This indicated that the plume was homogeneous and very diluted vertically. These flux values in the tables in Sections 3.2 and 3.3 are in **red font**.

   For the remaining data, the vertical gradient was extrapolated to a height where the extrapolated concentration was zero (as described in EPA OTM 10).

4. The CCF $\geq$ 0.80.

The Concordance Correlation Factor (CCF) is used in the VRPM method to represent the level of fit for the reconstruction in the path-integrated domain (predicted versus measured PAC). However, a poor CCF value (CCF< 0.80) at the end of the fitting procedure does not necessarily indicate an inaccurate flux calculation. Therefore, hydrocarbon flux values were reported when then corresponding CCF value of the reconstruction was greater than 0.80 and are shaded as follows in the summary tables of calculated flux values in Sections 3.2. and 3.3:

Light orange.

A-4: Individual Flux Plane Results

This section presents individual plane AM flux estimates for the test campaigns conducted at the Williams Rulison facility (Tables A-2 through A-17) and the EnCana Benzel facility (Tables from August 12-15. Each table presents the time (hr:min:sec), AM flux value (g/sec), wind direction (w.r.t. N), rotated wind direction (w.r.t VRPM plane), wind speed (m/s), and Concordance Correlation Factor (CCF). As described in Section A-3, AM flux values were calculated for data which met a series of quality control criteria pertaining to valid target compound detection and vertical plume capture, and instrument DQIs. That section also described the flags that were added to flux values that did not meet the optimal data criteria, but that could still prove useful in understanding the source and magnitude of hydrocarbon emissions being generated from these sites.

Table A-2. Summary Data Table of VRPM Plane A123 for August 6, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
15:15:02	-0.01	156.2	97.2	2.0	0.97
15:20:48	-0.01	150.6	91.6	2.0	0.84
15:25:35	-0.01	150.0	91.0	1.9	0.91
15:30:23	-0.01	155.1	96.1	1.9	0.59
15:35:06	-0.03	170.6	111.6	1.8	0.86
15:39:47	-0.04	173.6	114.6	2.3	0.41
15:44:31	-0.04	176.3	117.3	2.4	0.40
15:49:18	-0.02	170.1	111.1	2.4	0.00
15:54:02	-0.01	167.5	108.5	2.4	0.44
15:58:50		162.9	103.9	2.3	0.00
16:03:32		169.4	110.4	2.1	0.00
16:08:11		177.1	118.1	2.0	0.00
16:12:52		203.5	144.5	1.7	0.00
16:17:30		224.7	165.7	1.6	0.00
16:22:11		224.8	165.8	1.8	0.00
16:26:52		214.9	155.9	1.6	0.00
16:31:30		223.2	164.2	1.4	0.00

Table A-3. Summary Data Table of VRPM Plane A456 for August 6, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
15:18:25	0.03	152.5	29.5	2.0	1.00
15:23:09	0.03	147.9	24.9	1.9	0.85
15:27:57	0.04	152.4	29.4	1.9	0.81
15:32:42	0.02	164.4	41.4	1.6	0.99
15:37:26	0.02	173.9	50.9	2.1	0.63
15:42:09		176.8	53.8	2.4	0.00
15:46:54	0.02	172.3	49.3	2.3	0.05
15:51:40		170.2	47.2	2.5	0.00
15:56:26		164.1	41.1	2.4	0.00
16:01:10		166.0	43.0	2.2	0.00
16:05:51		172.2	49.2	1.9	0.00
16:10:32		187.6	64.6	1.8	0.00
16:15:11		215.8	92.8	1.6	0.00
16:19:54		224.3	101.3	1.7	0.00
16:24:33		221.5	98.5	1.6	0.00
16:29:13		216.4	93.4	1.4	0.00
16:33:47		201.6	78.6	1.2	0.00

Table A-4. Summary Data Table of VRPM Plane E123 for August 6, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:37:26		198.2	236.2	2.5	0.00
14:41:54		183.4	221.4	2.7	0.00
14:46:23		183.4	221.4	2.7	0.00
14:50:53	-0.01	185.4	223.4	2.4	1.00
14:55:21	-0.01	199.0	237.0	2.0	1.00
14:59:49	-0.02	173.5	211.5	1.6	1.00
15:04:18	-0.02	170.3	208.3	1.8	1.00
15:08:51	-0.02	166.9	204.9	1.6	1.00
15:13:23	-0.02	158.9	196.9	2.0	0.97
15:17:51		152.7	190.7	2.1	0.00
15:22:22		148.6	186.6	1.9	0.00
15:26:54		150.0	188.0	1.9	0.00
15:31:24		163.9	201.9	1.7	0.00
15:35:56		172.7	210.7	1.9	0.00
15:40:26		173.6	211.6	2.3	0.00
15:44:53		176.3	214.3	2.5	0.00
15:49:21		169.7	207.7	2.4	0.00
15:53:48		165.6	203.6	2.5	0.00
15:58:15		162.8	200.8	2.3	0.00
16:02:43		166.2	204.2	2.1	0.00
16:07:09	-0.01	176.9	214.9	2.0	0.97
16:11:36	-0.01	188.9	226.9	1.7	0.87
16:16:02	0.00	221.1	259.1	1.5	0.93
16:20:31	0.00	225.7	263.7	1.7	0.94
16:24:59	0.00	221.5	259.5	1.6	0.62
16:29:28	0.00	216.4	254.4	1.4	0.02

Table A-5. Summary Data Table of VRPM Plane E456 for August 6, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:39:41	0.18	189.0	311.0	2.5	0.99
14:44:10	0.13	183.4	305.4	2.7	0.98
14:48:38	0.09	177.5	299.5	2.7	0.99
14:53:08	0.07	192.0	314.0	2.2	0.97
14:57:35	0.10	178.9	300.9	1.6	0.73
15:02:04	0.09	172.0	294.0	1.7	0.83
15:06:36		168.2	290.2	1.7	0.00
15:11:06		160.1	282.1	2.0	0.00
15:15:38		153.9	275.9	2.1	0.00
15:20:08		151.8	273.8	2.0	0.00
15:24:37	0.21	148.3	270.3	1.8	0.13
15:29:09	0.32	153.9	275.9	1.9	0.08
15:33:42	0.36	164.5	286.5	1.7	0.02
15:38:12		176.7	298.7	2.2	0.00
15:42:39		177.0	299.0	2.4	0.00
15:47:08		171.3	293.3	2.3	0.00
15:51:34		168.9	290.9	2.5	0.00
15:56:02		165.0	287.0	2.4	0.00
16:00:30		164.7	286.7	2.3	0.00
16:04:58	0.06	170.2	292.2	2.0	0.92
16:09:24	0.05	181.8	303.8	1.8	0.97
16:13:51	0.07	209.7	331.7	1.9	0.95
16:18:18	0.08	225.8	347.8	1.7	0.61
16:22:46	0.13	223.8	345.8	1.7	0.81
16:27:15	0.07	215.1	337.1	1.5	0.84
16:31:44	0.05	223.6	345.6	1.4	0.95

Table A-6. Summary Data Table of VRPM Plane A123 for August 7, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:13:19	0.00	91.9	32.9	0.4	0.00
11:18:12	0.00	100.1	41.1	0.7	0.00
11:23:01	0.00	100.6	41.6	0.6	0.00
11:27:54	0.00	98.5	39.5	0.9	0.00
11:32:45		107.3	48.3	1.1	0.00
11:37:37		101.0	42.0	1.2	0.00
11:42:29		99.5	40.5	1.2	0.00
11:47:26	0.01	90.9	31.9	1.1	0.75
11:52:26		92.9	33.9	1.2	0.00
11:57:23	0.01	91.7	32.7	1.3	-0.01
12:02:15	0.01	82.4	23.4	0.8	-0.01
12:07:14	0.00	83.0	24.0	0.6	0.00
12:12:13	0.00	111.9	52.9	0.6	0.00
12:17:03	0.00	150.4	91.4	0.5	0.00
12:21:55	0.00	163.7	104.7	0.7	0.88
12:26:47	0.00	159.6	100.6	1.1	0.90
12:31:44	0.00	167.9	108.9	1.2	0.98
12:36:37		184.3	125.3	1.0	0.00
12:41:22		181.6	122.6	1.0	0.00
12:46:18		180.5	121.5	1.0	0.00
12:51:14		192.4	133.4	1.0	0.00
12:56:07		168.8	109.8	1.0	0.00
13:01:01		159.6	100.6	1.1	0.00
13:05:58		163.9	104.9	0.9	0.00
13:10:55	0.00	152.0	93.0	0.8	0.00
13:15:53	0.00	154.1	95.1	0.8	0.00
13:20:50		161.4	102.4	0.9	0.00
13:25:48		166.0	107.0	1.0	0.00
13:30:46		179.1	120.1	1.1	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:35:44		170.2	111.2	1.4	0.00
13:40:45		184.0	125.0	1.4	0.00
13:45:47		196.5	137.5	1.5	0.00
13:50:48		192.6	133.6	1.3	0.00
13:55:49		197.7	138.7	1.0	0.00
14:00:53		194.5	135.5	1.1	0.00
14:05:56		177.0	118.0	1.1	0.00
14:11:01		135.8	76.8	1.2	0.00
14:16:10	0.01	126.7	67.7	2.0	0.43
14:21:20	0.02	114.1	55.1	2.5	0.76
14:26:26	0.03	105.1	46.1	2.7	0.72
14:31:27	0.08	102.4	43.4	2.7	0.51
14:36:29	0.19	83.3	24.3	1.6	0.99
14:41:35	0.17	64.0	5.0	1.3	1.00
14:46:33	0.13	0.8	301.8	1.7	1.00
14:51:31	0.13	0.8	301.8	1.7	1.00
14:56:29	0.10	353.6	294.6	2.0	0.99
15:01:29	0.06	345.0	286.0	1.6	0.06
15:06:22	0.13	18.9	319.9	0.9	0.00
15:11:19	0.33	18.3	319.3	1.1	0.00
15:16:21	0.42	19.5	320.5	1.1	-0.01
15:21:19	0.45	21.3	322.3	1.2	0.01
15:26:17	0.31	7.6	308.6	1.2	0.00
15:31:14	0.14	351.3	292.3	1.2	0.95
15:36:12	0.07	348.5	289.5	1.2	0.93
15:41:12	0.05	347.7	288.7	1.2	0.51
15:46:06	0.11	25.1	326.1	1.1	0.19
15:51:02	0.28	54.3	355.3	1.5	0.11
15:55:57	0.31	67.8	8.8	2.0	-0.01
16:00:52	0.47	68.4	9.4	2.2	-0.01

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:05:47	0.57	65.9	6.9	2.2	0.98
16:10:42	0.65	46.8	347.8	1.9	0.74
16:15:36	0.61	29.7	330.7	1.8	0.92
16:20:31	0.66	27.5	328.5	1.9	0.93
16:25:26	0.56	39.7	340.7	2.1	0.94
16:30:20	0.60	52.4	353.4	2.2	0.99
16:35:16	0.45	65.2	6.2	2.5	0.97
16:40:13	0.35	63.9	4.9	2.5	1.00
16:45:06	0.22	64.2	5.2	2.5	1.00
16:50:02	0.21	61.7	2.7	2.3	0.93
16:54:57	0.37	61.5	2.5	2.3	0.92
16:59:55	0.38	55.3	356.3	2.1	0.78
17:04:50	0.26	54.0	355.0	1.7	1.00
17:09:43	0.19	42.4	343.4	1.4	0.53
17:14:38	0.18	30.1	331.1	1.0	0.00
17:19:34	0.00	25.5	326.5	0.8	0.00
17:24:33	0.00	39.9	340.9	0.8	0.00
17:29:28	0.14	68.1	9.1	1.1	0.00

Table A-7. Summary Data Table of VRPM Plane A456 for August 7, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:15:44	0.00	105.2	342.2	0.5	0.00
11:20:35	0.00	99.6	336.6	0.8	0.00
11:25:26	0.00	99.9	336.9	0.7	0.00
11:30:19	0.12	105.3	342.3	1.1	0.54
11:35:09	0.19	102.8	339.8	1.1	0.03
11:40:03	0.18	100.9	337.9	1.2	0.04
11:44:57	0.21	92.8	329.8	1.3	0.05
11:49:58	0.11	89.1	326.1	1.0	0.40
11:54:56	0.22	92.8	329.8	1.4	0.04
11:59:48	0.08	88.6	325.6	1.1	0.99
12:04:41	0.00	75.0	312.0	0.7	0.00
12:09:39	0.00	87.4	324.4	0.6	0.00
12:14:41	0.00	134.8	11.8	0.4	0.00
12:19:28	0.00	157.9	34.9	0.6	0.00
12:24:21		162.5	39.5	0.9	0.00
12:29:16	0.03	157.6	34.6	1.2	0.28
12:34:08	0.02	179.6	56.6	1.0	0.26
12:38:56	0.01	195.0	72.0	0.8	0.26
12:43:51	0.02	178.2	55.2	0.9	0.69
12:48:43	0.02	186.0	63.0	1.0	0.67
12:53:39	0.01	182.4	59.4	0.9	0.99
12:58:32	0.09	161.9	38.9	1.1	0.42
13:03:27	0.08	161.1	38.1	1.0	0.42
13:08:27	0.07	157.4	34.4	0.9	0.18
13:13:26	0.00	149.3	26.3	0.7	0.00
13:18:24	0.00	154.6	31.6	0.8	0.00
13:23:21		165.8	42.8	1.0	0.00
13:28:15		171.8	48.8	1.1	0.00
13:33:12		173.7	50.7	1.2	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:38:14		176.8	53.8	1.4	0.00
13:43:14		191.9	68.9	1.4	0.00
13:48:20		197.0	74.0	1.5	0.00
13:53:21		193.5	70.5	1.1	0.00
13:58:22		194.4	71.4	1.1	0.00
14:03:25		190.2	67.2	1.1	0.00
14:08:26	0.29	148.6	25.6	1.1	0.61
14:13:35	1.06	127.5	4.5	1.6	0.50
14:18:44	2.79	120.7	357.7	2.5	0.67
14:23:51	3.08	107.0	344.0	2.6	0.63
14:28:54	4.00	103.4	340.4	2.7	0.82
14:33:54	2.44	97.0	334.0	2.2	0.94
14:39:00	1.03	76.1	313.1	1.5	0.99
14:44:01	0.19	45.9	282.9	1.2	0.92
14:49:00	-0.21	0.8	237.8	1.7	0.96
14:54:00	-0.02	0.8	237.8	1.7	0.86
14:58:56		345.3	222.3	2.1	0.00
15:03:56	-0.05	356.7	233.7	1.3	0.03
15:08:50	-0.01	16.8	253.8	1.1	0.04
15:13:50	0.00	20.1	257.1	1.1	0.04
15:18:51	0.00	19.4	256.4	1.2	0.04
15:23:47	-0.02	13.1	250.1	1.2	0.03
15:28:43		357.2	234.2	1.2	0.00
15:33:41		345.0	222.0	1.2	0.00
15:38:39		349.9	226.9	1.2	0.00
15:43:38	-0.05	1.5	238.5	1.1	0.02
15:48:33	0.08	37.9	274.9	1.2	0.04
15:53:30	0.53	65.2	302.2	1.8	0.93
15:58:23	0.62	69.1	306.1	2.1	1.00
16:03:19	0.73	71.5	308.5	2.4	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:08:13	0.19	57.8	294.8	2.0	0.96
16:13:08	0.01	36.8	273.8	1.8	1.00
16:18:03	0.00	26.7	263.7	1.9	0.60
16:22:58	0.03	31.9	268.9	1.9	0.10
16:27:52	0.15	45.5	282.5	2.1	0.02
16:32:48	0.43	59.4	296.4	2.4	0.03
16:37:45	0.89	65.2	302.2	2.5	0.30
16:42:38	0.68	64.9	301.9	2.5	0.07
16:47:34	0.57	63.6	300.6	2.2	0.11
16:52:27	0.42	58.4	295.4	2.3	0.73
16:57:24	0.21	55.9	292.9	2.2	0.93
17:02:21	0.07	55.9	292.9	2.0	0.89
17:07:14	0.01	50.6	287.6	1.5	0.86
17:12:10	0.01	36.8	273.8	1.2	0.69
17:17:04	-0.02	16.7	253.7	1.0	0.20
17:22:03	0.00	33.6	270.6	0.8	0.00
17:27:01	0.20	46.6	283.6	0.9	0.96
17:31:56	1.10	83.4	320.4	1.5	0.98

Table A-8. Summary Data Table of VRPM Plane E123 for August 7, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:32:12	-0.03	79.9	117.9	1.7	0.94
10:36:37	-0.02	70.4	108.4	1.4	0.74
10:41:02	-0.01	68.1	106.1	0.9	0.85
10:45:26	0.00	94.4	132.4	0.6	0.00
10:49:51	0.00	46.1	84.1	0.3	0.00
10:54:19	0.00	24.3	62.3	0.6	0.00
10:58:45	0.00	34.1	72.1	0.5	0.00
11:03:12	0.00	56.1	94.1	0.5	0.00
11:07:37	0.00	45.4	83.4	0.6	0.00
11:12:04	0.00	74.7	112.7	0.3	0.00
11:16:31	0.00	101.7	139.7	0.5	0.00
11:20:58	0.00	96.9	134.9	0.8	0.00
11:25:27	0.00	103.8	141.8	0.7	0.00
11:29:54	-0.01	106.3	144.3	1.2	1.00
11:34:20		103.2	141.2	1.0	0.00
11:38:48		101.7	139.7	1.1	0.00
11:43:19		98.4	136.4	1.3	0.00
11:47:47		89.6	127.6	1.0	0.00
11:52:15		90.1	128.1	1.2	0.00
11:56:42		92.6	130.6	1.3	0.00
12:01:14	-0.01	88.2	126.2	1.0	0.99
12:05:40	0.00	82.4	120.4	0.7	0.00
12:10:09	0.00	84.9	122.9	0.6	0.00
12:14:35	0.00	127.9	165.9	0.4	0.00
12:19:02	0.00	156.9	194.9	0.6	0.00
12:23:30	-0.02	164.0	202.0	0.9	0.74
12:27:56		160.5	198.5	1.2	0.00
12:32:22		163.6	201.6	1.1	0.00
12:36:51		187.1	225.1	0.9	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:41:17		188.7	226.7	0.7	0.00
12:45:46		180.1	218.1	1.0	0.00
12:50:12		191.5	229.5	1.1	0.00
12:54:43		172.7	210.7	1.0	0.00
12:59:10		159.8	197.8	1.1	0.00
13:03:38		161.6	199.6	1.0	0.00
13:08:08		154.0	192.0	0.9	0.00
13:12:37	0.00	147.1	185.1	0.8	0.00
13:17:08	0.00	156.2	194.2	0.7	0.00
14:07:51		153.3	191.3	1.0	0.00
14:13:18		135.0	173.0	1.6	0.00
14:17:48		123.7	161.7	2.5	0.00
14:22:17		110.9	148.9	3.0	0.00
14:26:48		103.3	141.3	2.8	0.00
14:31:17		103.3	141.3	2.6	0.00
14:35:47	-0.04	92.4	130.4	1.9	0.02
14:40:16	-0.20	72.5	110.5	1.4	0.02
14:44:48	0.47	4.8	42.8	1.6	0.05
14:49:20	0.88	0.8	38.8	1.7	0.13
14:53:53	1.13	357.9	35.9	1.8	0.10
14:58:24	2.16	345.4	23.4	2.4	0.07
15:02:56	0.88	347.8	25.8	1.4	0.41
15:07:27	0.22	18.9	56.9	0.9	0.06
15:12:12	0.18	17.9	55.9	1.2	0.04
15:16:32	0.12	19.6	57.6	1.1	0.03
15:21:05	0.06	22.1	60.1	1.2	0.66
15:25:36	0.16	10.8	48.8	1.2	1.00
15:30:06	0.26	354.6	32.6	1.1	0.92
15:34:36	0.30	341.4	19.4	1.2	0.86
15:39:11	0.35	346.8	24.8	1.2	0.97

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
15:43:42	0.28	355.3	33.3	1.1	1.00
15:48:11	0.05	36.7	74.7	1.3	0.99
15:52:41	-0.07	63.2	101.2	1.7	0.99
15:57:10	-0.11	70.5	108.5	2.1	0.19
16:01:42	-0.12	72.7	110.7	2.5	0.97
16:06:13	-0.06	64.8	102.8	2.1	0.24
16:10:42	0.00	44.6	82.6	1.9	0.94
16:15:12	0.09	28.0	66.0	1.9	0.99
16:19:45	0.09	25.3	63.3	1.9	0.99
16:24:15	0.06	31.7	69.7	2.0	1.00
16:28:48	0.01	47.9	85.9	2.2	1.00
16:33:12	-0.02	61.0	99.0	2.4	1.00
16:37:43	-0.01	67.0	105.0	2.6	0.58
16:42:13	-0.01	64.7	102.7	2.5	0.87
16:46:44	-0.02	62.9	100.9	2.3	0.06
16:51:09	-0.01	58.9	96.9	2.3	0.02
16:55:38	-0.01	59.9	97.9	2.2	0.02
17:00:09	-0.01	56.4	94.4	2.1	0.75
17:04:41	-0.03	55.2	93.2	1.8	0.25
17:09:11	0.02	42.4	80.4	1.4	1.00
17:13:42	0.06	31.6	69.6	1.1	0.99
17:18:13	0.00	14.6	52.6	0.8	0.00
17:22:47	0.00	36.6	74.6	0.8	0.00
17:27:16	-0.01	51.7	89.7	1.0	0.89
17:31:45	-0.05	83.5	121.5	1.4	0.98

Table A-9. Summary Data Table of VRPM Plane E456 for August 7, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:34:25	-0.11	78.3	200.3	1.6	0.84
10:38:50	-0.50	69.1	191.1	1.2	0.56
10:43:15	-0.32	69.5	191.5	0.9	0.02
10:47:38	0.00	129.7	251.7	0.4	0.00
10:52:06	0.00	25.2	147.2	0.6	0.00
10:56:31	0.00	33.2	155.2	0.5	0.00
11:00:59	0.00	49.1	171.1	0.4	0.00
11:05:25	0.00	49.2	171.2	0.5	0.00
11:09:52	0.00	45.3	167.3	0.5	0.00
11:14:17	0.00	100.1	222.1	0.4	0.00
11:18:46	0.00	98.7	220.7	0.8	0.00
11:23:14	0.00	101.0	223.0	0.6	0.00
11:27:41	0.00	99.8	221.8	0.9	0.00
11:32:08	-0.18	107.1	229.1	1.2	0.89
11:36:36	-0.19	100.0	222.0	1.1	0.89
11:41:04	-0.19	99.1	221.1	1.2	0.96
11:45:33	-0.27	90.7	212.7	1.3	0.96
11:50:03	-0.20	89.7	211.7	1.0	0.88
11:54:29	-0.28	92.9	214.9	1.3	0.97
11:59:00	-0.47	88.2	210.2	1.1	1.00
12:03:28	-0.44	78.9	200.9	0.8	0.97
12:07:55	0.00	78.6	200.6	0.6	0.00
12:12:23	0.00	108.0	230.0	0.5	0.00
12:16:49	0.00	153.3	275.3	0.5	0.00
12:21:18	0.00	163.6	285.6	0.7	0.00
12:25:42	0.04	160.8	282.8	1.0	0.99
12:30:11	0.29	161.2	283.2	1.3	0.08
12:34:40	0.27	178.6	300.6	1.0	0.14
12:39:05	0.31	196.3	318.3	0.8	0.10

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:43:33	0.34	180.7	302.7	0.9	0.88
12:48:48	0.40	186.2	308.2	1.0	1.00
12:52:27	0.16	188.8	310.8	1.0	0.97
12:56:56	1.11	167.6	289.6	1.0	0.24
13:01:23	1.51	161.6	283.6	1.2	0.41
13:05:55	1.45	163.1	285.1	0.9	0.32
13:10:24	0.00	145.1	267.1	0.9	0.00
13:14:53	0.00	158.9	280.9	0.7	0.00
14:11:05	-0.07	136.9	258.9	1.1	0.99
14:15:33	-0.33	126.7	248.7	2.1	1.00
14:20:02	-0.66	116.3	238.3	2.6	1.00
14:24:34	-1.62	104.4	226.4	2.9	0.99
14:29:04	-2.02	102.4	224.4	2.7	1.00
14:33:34	-1.77	100.0	222.0	2.4	1.00
14:38:03	-1.61	80.2	202.2	1.5	1.00
14:42:34	-1.92	62.8	184.8	1.3	1.00
14:47:05	-1.48	0.8	122.8	1.7	0.99
14:51:38	-1.43	0.8	122.8	1.7	0.98
14:56:09	-1.65	351.3	113.3	2.1	0.98
15:00:41	-1.00	337.8	99.8	2.2	1.00
15:05:12	-1.25	18.0	140.0	0.9	1.00
15:09:45	-1.14	16.8	138.8	1.1	1.00
15:14:14	-1.11	20.1	142.1	1.1	1.00
15:18:50	-0.94	19.2	141.2	1.2	0.99
15:23:22	-0.80	16.8	138.8	1.3	1.00
15:27:52	-0.62	4.3	126.3	1.2	1.00
15:32:22	-1.02	347.6	109.6	1.2	0.99
15:36:56	-1.14	345.9	107.9	1.2	0.87
15:41:27	-1.32	343.7	105.7	1.2	0.55
15:46:01	-1.38	20.8	142.8	1.2	0.69

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
15:50:27	-1.72	53.9	175.9	1.5	0.95
15:54:57	-0.58	68.5	190.5	2.0	1.00
15:59:27	-0.52	71.8	193.8	2.3	1.00
16:04:01	-0.23	71.4	193.4	2.3	1.00
16:08:29	-0.23	55.5	177.5	2.0	1.00
16:13:01	-0.24	37.8	159.8	1.8	1.00
16:17:30	-0.24	23.2	145.2	1.9	1.00
16:22:01	-0.20	29.8	151.8	1.9	1.00
16:26:33	-0.20	41.1	163.1	2.1	1.00
16:31:01	-0.34	55.0	177.0	2.2	0.90
16:35:28	-0.32	66.4	188.4	2.6	0.85
16:40:01	-0.30	66.2	188.2	2.6	0.94
16:44:30	-0.30	65.4	187.4	2.5	0.93
16:48:55	-0.35	61.8	183.8	2.2	0.97
16:53:24	-0.32	57.0	179.0	2.3	1.00
16:57:54	-0.48	57.9	179.9	2.2	0.99
17:02:26	-0.95	57.1	179.1	2.1	0.95
17:06:57	-2.18	52.5	174.5	1.6	0.03
17:11:29	-2.54	37.1	159.1	1.2	0.01
17:16:01	-1.92	14.6	136.6	1.0	0.01
17:20:30	0.00	26.4	148.4	0.7	0.00
17:25:03	0.00	39.8	161.8	0.8	0.00
17:29:31	-1.65	74.3	196.3	1.1	0.96
17:34:02	-1.17	89.5	211.5	1.8	1.00

Table A-10. Summary Data Table of VRPM Plane A123 for August 8, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:17:11	0.01	123.8	64.8	1.2	0.96
10:23:21	0.00	137.3	78.3	1.4	-0.01
10:28:32		146.4	87.4	1.4	0.00
10:33:39		150.1	91.1	1.2	0.00
10:38:48	0.00	131.0	72.0	1.1	0.32
10:43:56	0.01	104.7	45.7	1.1	0.04
10:49:05	0.02	91.4	32.4	1.1	0.00
10:54:12	0.02	81.4	22.4	1.1	0.00
10:59:20	0.03	78.2	19.2	1.0	0.41
11:04:28	0.00	93.0	34.0	0.7	0.00
11:09:37	0.00	118.8	59.8	0.8	0.00
11:14:46	0.00	139.6	80.6	1.4	0.89
11:19:54	0.00	150.3	91.3	1.5	0.97
11:25:03	-0.01	163.9	104.9	1.6	0.44
11:30:12		190.3	131.3	1.5	0.00
11:35:24		203.6	144.6	1.9	0.00
11:40:32		226.2	167.2	2.1	0.00
11:45:38		240.6	181.6	2.6	0.00
11:50:48		241.6	182.6	2.5	0.00
11:55:59		242.8	183.8	2.6	0.00
12:01:08		249.0	190.0	2.4	0.00
12:06:16		246.7	187.7	2.6	0.00
12:11:24		247.0	188.0	2.9	0.00
12:16:30		248.3	189.3	3.1	0.00
12:21:39		247.3	188.3	3.4	0.00
12:26:48		244.3	185.3	3.6	0.00
12:31:55		245.4	186.4	3.6	0.00
12:37:04		243.5	184.5	3.4	0.00
12:42:11		233.4	174.4	3.2	0.00
12:47:09		236.5	177.5	3.1	0.00
12:52:18		233.3	174.3	3.4	0.00
12:57:28		235.2	176.2	3.3	0.00
13:02:38		232.4	173.4	3.2	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:07:37		229.2	170.2	3.4	0.00
13:12:46		227.3	168.3	3.3	0.00
13:17:54		225.1	166.1	3.1	0.00
13:23:03		232.1	173.1	3.5	0.00
13:28:14		232.1	173.1	3.5	0.00
13:33:24		232.7	173.7	3.3	0.00
13:38:35		231.6	172.6	3.3	0.00
13:43:44		234.1	175.1	3.3	0.00
13:48:54		234.1	175.1	3.2	0.00
13:54:03		236.2	177.2	3.2	0.00
13:59:16		236.2	177.2	3.0	0.00
14:04:26		237.4	178.4	3.1	0.00
14:09:36		226.4	167.4	2.2	0.00
14:14:45		223.0	164.0	1.7	0.00
14:19:56		232.5	173.5	1.9	0.00
14:25:05		206.8	147.8	1.8	0.00
14:30:16		201.2	142.2	1.8	0.00
14:35:27		188.0	129.0	1.9	0.00
14:40:37		154.0	95.0	2.4	0.00
14:45:46		143.6	84.6	2.7	0.00
14:50:57		149.1	90.1	2.0	0.00
14:56:06		153.8	94.8	1.9	0.00
15:01:14		161.9	102.9	1.9	0.00
15:06:25		174.2	115.2	1.6	0.00
15:11:36		180.4	121.4	1.4	0.00
15:16:48		196.8	137.8	1.5	0.00
15:21:56		214.9	155.9	1.3	0.00
15:27:06		208.7	149.7	1.5	0.00
15:32:17		150.1	91.1	2.2	0.00
16:18:48	0.00	126.4	67.4	3.2	0.88
16:23:54	0.04	107.8	48.8	3.7	0.63
16:29:03	0.13	107.8	48.8	3.7	0.99
16:34:14	0.54	107.8	48.8	3.7	-0.01

Table A-11. Summary Data Table of VRPM Plane A456 for August 8, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:20:44	0.05	134.6	11.6	1.3	0.82
10:25:54	0.05	143.7	20.7	1.3	0.77
10:31:04	0.05	149.2	26.2	1.4	0.48
10:36:12	0.04	147.2	24.2	1.1	0.79
10:41:20	0.06	111.3	348.3	1.1	0.13
10:46:29	0.09	98.1	335.1	1.2	0.08
10:51:38	0.10	81.4	318.4	1.1	0.05
10:56:44	0.12	87.1	324.1	1.2	0.05
11:01:52	0.00	75.3	312.3	0.9	0.00
11:07:01	0.00	108.3	345.3	0.8	0.00
11:12:11	0.00	120.1	357.1	0.9	0.00
11:17:19		146.7	23.7	1.5	0.00
11:22:27		150.2	27.2	1.7	0.00
11:27:36		176.4	53.4	1.6	0.00
11:32:45		194.1	71.1	1.7	0.00
11:37:55		217.1	94.1	2.0	0.00
11:43:05		232.3	109.3	2.4	0.00
11:48:12		242.2	119.2	2.6	0.00
11:53:21		239.9	116.9	2.4	0.00
11:58:32		243.9	120.9	2.6	0.00
12:03:42		247.8	124.8	2.5	0.00
12:08:48		248.0	125.0	2.5	0.00
12:13:55		250.2	127.2	3.0	0.00
12:19:04		249.9	126.9	3.2	0.00
12:24:12		245.2	122.2	3.6	0.00
12:29:21		245.5	122.5	3.5	0.00
12:34:28		245.3	122.3	3.5	0.00
12:39:36		237.3	114.3	3.2	0.00
12:44:35		234.2	111.2	3.1	0.00
12:49:42		236.7	113.7	3.1	0.00
12:54:51		233.5	110.5	3.3	0.00
13:00:01		230.4	107.4	3.3	0.00
13:05:09		231.7	108.7	3.3	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:10:11		227.4	104.4	3.3	0.00
13:15:19		228.2	105.2	3.2	0.00
13:20:27		220.0	97.0	3.2	0.00
13:25:37		232.4	109.4	3.7	0.00
13:30:47		233.5	110.5	3.4	0.00
13:35:58		232.6	109.6	3.4	0.00
13:41:08		232.5	109.5	3.4	0.00
13:46:17		231.7	108.7	3.2	0.00
13:51:27		236.9	113.9	3.3	0.00
13:56:38		235.4	112.4	3.1	0.00
14:01:49		237.7	114.7	3.0	0.00
14:06:59		236.1	113.1	2.9	0.00
14:12:10		225.7	102.7	2.0	0.00
14:17:18		225.5	102.5	1.8	0.00
14:22:30		226.3	103.3	1.8	0.00
14:27:39		206.4	83.4	1.7	0.00
14:32:50		198.9	75.9	2.0	0.00
14:38:00		169.4	46.4	2.0	0.00
14:43:10		146.0	23.0	2.6	0.00
14:48:19		150.9	27.9	2.1	0.00
14:53:30		148.9	25.9	2.0	0.00
14:58:39		157.3	34.3	2.0	0.00
15:03:50		170.0	47.0	1.6	0.00
15:08:58		191.4	68.4	1.4	0.00
15:14:10		187.1	64.1	1.5	0.00
15:19:20		198.3	75.3	1.5	0.00
15:24:29		215.2	92.2	1.3	0.00
15:29:40		196.1	73.1	1.4	0.00
16:21:20	0.36	126.4	3.4	3.2	1.00
16:26:27	1.32	107.8	344.8	3.7	0.91
16:31:37	3.59	107.8	344.8	3.7	0.13

Table A-12. Summary Data Table of VRPM Plane E123 for August 8, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:35:02		154.6	192.6	1.0	0.00
10:39:29		128.4	166.4	1.1	0.00
10:43:55		106.1	144.1	1.2	0.00
10:48:21		91.3	129.3	1.1	0.00
10:52:45		81.5	119.5	1.2	0.00
10:57:10		73.0	111.0	1.3	0.00
11:01:37	0.00	73.9	111.9	0.8	0.00
11:06:02	0.00	99.9	137.9	0.7	0.00
11:10:28	0.00	126.1	164.1	0.9	0.00
11:14:55	-0.01	137.0	175.0	1.4	1.00
11:19:22	-0.01	143.9	181.9	1.6	1.00
11:23:48	-0.01	153.3	191.3	1.7	0.99
11:28:14	-0.01	179.7	217.7	1.5	0.98
12:04:50	0.03	248.8	286.8	2.6	0.84
12:10:11	0.03	248.2	286.2	2.6	0.83
12:14:39	0.03	247.2	285.2	3.0	0.92
12:19:04	0.02	247.0	285.0	3.2	0.74
12:23:24	0.02	247.9	285.9	3.5	0.04
12:27:50		245.5	283.5	3.7	0.00
12:32:13		245.1	283.1	3.6	0.00
12:36:36		243.5	281.5	3.4	0.00
12:41:03		233.3	271.3	3.1	0.00
12:45:28		231.6	269.6	2.8	0.00
12:49:53	0.01	234.9	272.9	3.2	0.99
12:54:14	0.00	230.5	268.5	3.5	0.94
12:58:36	0.00	234.2	272.2	3.5	1.00
13:03:02	0.00	233.0	271.0	3.2	1.00
13:07:27	0.00	228.7	266.7	3.2	1.00
13:11:49	0.00	225.5	263.5	3.3	1.00
13:16:14	0.00	227.4	265.4	3.3	1.00
13:20:38		219.9	257.9	3.3	0.00
13:25:05	0.01	235.4	273.4	3.6	0.04
13:29:30	0.01	233.7	271.7	3.3	0.10

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:33:59	0.01	231.3	269.3	3.3	0.12
13:38:23	0.01	233.0	271.0	3.5	0.91
13:42:48	0.01	234.3	272.3	3.3	0.98
13:47:13	0.01	232.7	270.7	3.1	1.00
13:51:36	0.01	238.1	276.1	3.2	1.00
13:56:02	0.01	233.8	271.8	3.1	1.00
14:00:28	0.01	237.5	275.5	3.0	0.99
14:04:51	0.02	240.2	278.2	3.3	0.99
14:09:11	0.00	229.1	267.1	2.6	1.00
14:13:37	0.00	213.6	251.6	1.4	1.00
14:18:04	0.00	228.0	266.0	1.5	0.95
14:22:28	0.00	227.5	265.5	1.9	0.96
14:26:48	-0.01	206.9	244.9	1.8	0.02
14:31:14	-0.01	209.9	247.9	2.1	0.02
14:40:00		165.5	203.5	2.1	0.00
14:44:30		150.5	188.5	2.4	0.00
14:48:51		149.3	187.3	2.2	0.00
14:53:15		151.8	189.8	2.0	0.00
14:57:42		152.9	190.9	2.0	0.00
15:06:33	-0.01	180.8	218.8	1.6	1.00
15:10:58	-0.01	187.6	225.6	1.4	0.48
15:15:24	-0.01	196.8	234.8	1.5	0.46
15:19:49	-0.01	216.0	254.0	1.4	0.41
15:24:15	-0.01	210.6	248.6	1.4	0.41
15:28:39	-0.01	191.0	229.0	1.4	0.18
16:21:30		126.4	164.4	3.2	0.00
16:25:54		107.8	145.8	3.7	0.00
16:30:20		107.8	145.8	3.7	0.00

Table A-13. Summary Data Table of VRPM Plane E456 for August 8, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:37:16	0.02	145.1	267.1	1.0	0.96
10:41:42	-0.10	111.1	233.1	1.2	0.96
10:46:09	-0.16	100.5	222.5	1.2	0.98
10:50:34	-0.21	86.5	208.5	1.1	0.98
10:54:59	-0.38	79.8	201.8	1.3	0.98
10:59:25	-0.34	73.6	195.6	1.1	0.97
11:03:50	0.00	81.1	203.1	0.7	0.00
11:08:17	0.00	120.4	242.4	0.8	0.00
11:12:44	-0.02	134.1	256.1	1.0	0.70
11:17:08	0.02	144.9	266.9	1.5	0.92
11:21:40	0.03	149.4	271.4	1.6	1.00
11:26:02	0.05	163.7	285.7	1.6	0.97
11:30:28	0.06	186.5	308.5	1.6	1.00
12:08:02	0.03	250.7	12.7	2.5	0.87
12:12:27	0.04	250.0	12.0	2.8	0.84
12:16:52	0.05	249.4	11.4	3.1	0.60
12:21:15	0.07	248.2	10.2	3.4	0.83
12:25:37	0.10	244.9	6.9	3.7	0.94
12:30:03	0.09	244.5	6.5	3.7	0.85
12:34:26	0.08	246.3	8.3	3.6	0.91
12:38:52	0.05	243.6	5.6	3.3	1.00
12:43:15	0.02	232.3	354.3	2.9	0.99
12:47:43	0.02	235.0	357.0	3.0	0.98
12:52:04	0.03	234.4	356.4	3.2	0.96
12:56:26	0.03	233.5	355.5	3.4	0.86
13:00:51	0.13	239.0	1.0	3.5	0.35
13:05:16	0.14	233.0	355.0	3.3	1.00
13:09:39	0.14	225.1	347.1	3.3	1.00
13:14:04	0.12	227.1	349.1	3.1	0.97

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:18:26	0.15	222.5	344.5	3.4	0.99
13:22:54	0.06	228.7	350.7	3.6	0.93
13:27:19	0.04	233.1	355.1	3.4	0.83
13:31:45	0.05	233.1	355.1	3.4	0.95
13:36:14	0.06	233.4	355.4	3.4	0.97
13:40:36	0.06	237.3	359.3	3.6	0.99
13:45:03	0.06	224.3	346.3	3.0	0.97
13:49:27	0.10	236.1	358.1	3.1	0.89
13:53:53	0.12	237.5	359.5	3.4	0.93
13:58:15	0.20	234.9	356.9	2.9	0.97
14:02:41	0.21	237.6	359.6	3.1	0.98
14:07:03	0.22	234.4	356.4	2.9	0.82
14:11:27	0.14	220.6	342.6	1.8	0.67
14:15:52	0.14	221.7	343.7	1.5	0.79
14:20:18	0.11	230.0	352.0	1.8	0.87
14:24:38	0.09	219.5	341.5	1.8	0.95
14:29:01	0.07	209.5	331.5	1.9	0.98
15:04:21	0.10	167.2	289.2	1.8	0.81
15:08:47	0.09	179.0	301.0	1.5	0.66
15:13:09	0.09	187.1	309.1	1.6	0.94
15:17:38	0.09	198.3	320.3	1.5	0.90
15:22:03	0.22	215.2	337.2	1.3	0.90
15:26:27	0.20	211.7	333.7	1.2	0.98
15:30:52	0.42	182.4	304.4	1.5	0.98
16:19:18	-0.43	124.8	246.8	2.9	0.80
16:23:44	-0.74	126.4	248.4	3.2	0.97
16:28:09	-2.41	107.8	229.8	3.7	1.00
16:32:34	-2.41	107.8	229.8	3.7	0.98

Table A-14. Summary Data Table of VRPM Plane A123 for August 9, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:45:33	0.27	65.9	6.9	2.3	1.00
11:50:33	0.23	69.8	10.8	2.0	0.98
11:55:23	0.16	79.4	20.4	2.0	0.89
12:00:21	0.14	84.4	25.4	2.1	1.00
12:05:21	0.09	93.2	34.2	2.1	0.79
12:10:20	0.06	97.1	38.1	2.2	1.00
12:15:19	0.06	89.4	30.4	2.0	0.93
12:20:17	0.07	81.3	22.3	1.8	0.91
12:25:15	0.04	85.8	26.8	1.5	0.93
12:30:15	0.03	71.8	12.8	1.0	0.96
12:35:15	0.04	79.9	20.9	1.1	0.99
12:40:15	0.02	94.2	35.2	1.0	0.98
12:45:14	0.01	108.8	49.8	0.9	0.99
12:50:12	0.01	119.0	60.0	1.3	0.97
12:55:11	0.02	106.9	47.9	1.3	0.97
13:00:11	0.01	103.0	44.0	1.4	0.99
13:05:13	0.01	95.5	36.5	1.3	0.99
13:10:14	0.01	79.0	20.0	1.0	0.99
13:15:08	0.00	108.3	49.3	0.8	0.00
13:20:08	0.01	135.1	76.1	1.0	0.96
13:25:12	0.00	153.1	94.1	0.5	0.00
13:30:11	0.00	188.7	129.7	0.6	0.00
13:35:12	0.00	174.2	115.2	0.4	0.00
13:40:07	0.00	229.5	170.5	0.4	0.00
13:45:06	0.00	197.4	138.4	0.4	0.00
13:50:09		160.3	101.3	1.1	0.00
13:55:10	0.00	171.9	112.9	0.9	0.00
14:00:10	0.00	180.8	121.8	1.4	1.00
14:05:12		156.1	97.1	1.7	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:10:13	0.00	172.9	113.9	1.9	0.99
14:15:14		169.6	110.6	2.2	0.00
14:20:15		158.9	99.9	2.8	0.00
14:25:16		159.9	100.9	2.9	0.00
14:30:18		155.4	96.4	2.9	0.00
14:35:17		149.0	90.0	3.0	0.00
14:40:19	0.00	146.7	87.7	3.1	0.98
14:45:14	0.00	144.3	85.3	3.0	1.00
14:50:13	0.00	143.5	84.5	2.8	1.00

Table A-15. Summary Data Table of VRPM Plane A456 for August 9, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:48:03	0.25	65.8	302.8	2.1	0.69
11:52:54	0.23	73.7	310.7	2.0	0.60
11:57:52	0.44	81.0	318.0	2.0	0.25
12:02:52	0.38	89.5	326.5	2.2	0.10
12:07:49	0.42	95.9	332.9	2.3	0.03
12:12:50	0.42	95.3	332.3	2.1	0.06
12:17:48	0.31	82.7	319.7	1.9	0.06
12:22:46	0.34	85.3	322.3	1.7	0.39
12:27:46	0.19	79.3	316.3	1.4	0.36
12:32:44	0.06	73.5	310.5	0.9	0.71
12:37:43	0.04	89.4	326.4	1.0	0.95
12:42:43	0.04	93.5	330.5	0.8	0.96
12:47:43	0.08	116.8	353.8	1.2	0.73
12:52:42	0.16	114.6	351.6	1.4	0.58
12:57:41	0.18	104.2	341.2	1.3	0.67
13:02:42	0.13	99.3	336.3	1.3	0.97
13:07:44	0.11	86.7	323.7	1.2	0.82
13:12:43	0.00	81.7	318.7	0.9	0.00
13:17:36	0.04	122.8	359.8	1.0	0.70
13:22:38	0.00	144.8	21.8	0.8	0.00
13:27:41	0.00	168.0	45.0	0.5	0.00
13:32:42	0.00	180.4	57.4	0.6	0.00
13:37:37	0.00	110.2	347.2	0.2	0.00
13:42:38	0.00	254.3	131.3	0.3	0.00
13:47:37	0.00	167.4	44.4	0.8	0.00
13:52:40	0.03	155.6	32.6	1.0	0.02
13:57:41	0.02	175.6	52.6	1.0	0.02
14:02:42	0.02	162.2	39.2	1.5	0.39
14:07:42	0.03	167.0	44.0	1.7	0.56

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:12:43		175.9	52.9	2.0	0.00
14:17:44	0.02	161.2	38.2	2.5	0.96
14:22:44	0.03	158.5	35.5	2.8	0.99
14:27:46	0.07	161.9	38.9	3.0	0.65
14:32:48	0.05	151.1	28.1	2.8	0.94
14:37:48	0.28	147.0	24.0	3.1	0.97
14:42:50	0.25	146.5	23.5	3.0	0.75
14:47:44	0.30	143.1	20.1	2.9	0.07
14:52:42	0.27	148.5	25.5	3.2	0.35

Table A-16. Summary Data Table of VRPM Plane E123 for August 9, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:14:24	-0.03	85.1	123.1	2.9	0.82
10:19:53	-0.04	85.2	123.2	2.9	0.67
10:24:20	-0.03	84.2	122.2	2.7	0.19
10:28:49	-0.03	84.3	122.3	2.5	0.05
10:33:16	-0.03	86.4	124.4	2.4	0.05
10:37:44	-0.03	86.7	124.7	2.3	0.03
10:42:11		93.1	131.1	2.3	0.00
10:46:41		96.2	134.2	2.2	0.00
10:51:10		99.9	137.9	2.1	0.00
10:55:36		96.2	134.2	2.0	0.00
11:00:05		95.3	133.3	1.9	0.00
11:04:32	-0.02	90.3	128.3	1.7	0.90
11:09:02	-0.01	82.6	120.6	1.8	0.72
11:13:32		86.3	124.3	1.6	0.00
11:18:01		89.6	127.6	1.7	0.00
11:22:29		94.4	132.4	1.7	0.00
11:26:58		90.4	128.4	1.8	0.00
11:31:27		85.7	123.7	2.1	0.00
11:35:56	-0.01	79.9	117.9	2.1	0.36
11:40:24	-0.02	68.7	106.7	2.2	0.32
11:44:52	-0.02	67.9	105.9	2.3	0.19
11:49:19	-0.02	66.6	104.6	2.1	0.46
11:53:47		76.5	114.5	2.1	0.00
11:58:14		83.4	121.4	2.0	0.00
12:02:43		87.2	125.2	2.2	0.00
12:07:10		100.1	138.1	2.3	0.00
12:11:39		96.8	134.8	2.3	0.00
12:16:07		88.8	126.8	2.0	0.00
12:20:38		80.4	118.4	1.7	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:25:09		79.6	117.6	1.6	0.00
12:29:38	-0.05	79.4	117.4	1.1	0.78
12:34:06	-0.04	77.6	115.6	1.0	0.87
12:38:33	-0.06	96.7	134.7	1.1	0.87
12:43:01	-0.04	88.2	126.2	0.7	0.88
12:47:31	-0.05	112.6	150.6	1.0	0.89
12:52:01	-0.01	121.6	159.6	1.5	0.99
12:56:25		108.5	146.5	1.3	0.00
13:00:54		104.0	142.0	1.4	0.00
13:05:21	-0.04	93.6	131.6	1.3	0.98
13:09:46		67.8	105.8	1.2	0.00
13:40:36	0.00	269.7	307.7	0.3	0.00
13:44:58	0.00	209.4	247.4	0.4	0.00
13:49:23	-0.12	153.7	191.7	1.1	1.00
13:53:44	-0.11	157.9	195.9	1.0	0.42
13:58:06	-0.07	186.0	224.0	1.2	0.77
14:02:32	-0.10	166.9	204.9	1.4	0.79
14:06:57	-0.02	158.9	196.9	1.7	0.95
14:11:20	-0.02	173.7	211.7	2.0	0.96
14:15:42	-0.01	169.6	207.6	2.2	1.00
14:20:08		158.4	196.4	2.6	0.00
14:24:33		161.2	199.2	2.8	0.00
14:28:55		157.0	195.0	3.2	0.00
14:33:18		149.5	187.5	3.0	0.00
14:37:41		147.3	185.3	3.0	0.00
14:42:07		145.2	183.2	2.9	0.00
14:46:27		141.6	179.6	2.9	0.00
14:50:51		144.4	182.4	2.9	0.00

Table A-17. Summary Data Table of VRPM Plane E456 for August 9, 2008 at the Williams Rulison Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:17:39	-0.24	87.0	209.0	2.9	1.00
10:22:07	-0.26	82.7	204.7	2.8	1.00
10:26:35	-0.21	83.6	205.6	2.6	1.00
10:31:04	-0.16	84.9	206.9	2.4	1.00
10:35:30	-0.22	88.6	210.6	2.4	0.99
10:40:01	-0.21	88.2	210.2	2.2	0.99
10:44:27	-0.22	93.2	215.2	2.3	0.99
10:48:56	-0.24	97.3	219.3	2.1	1.00
10:53:24	-0.26	99.0	221.0	2.1	0.99
10:57:52	-0.18	97.4	219.4	1.9	0.97
11:02:18	-0.19	94.8	216.8	1.7	0.97
11:06:50	-0.18	88.3	210.3	1.8	0.97
11:11:19	-0.24	82.9	204.9	1.6	0.99
11:15:47	-0.24	89.5	211.5	1.7	0.93
11:20:16	-0.35	97.1	219.1	1.7	0.97
11:24:45	-0.40	95.8	217.8	1.8	0.98
11:29:13	-0.45	88.7	210.7	1.9	0.98
11:33:43	-0.46	78.2	200.2	2.0	1.00
11:38:11	-0.46	76.1	198.1	2.1	1.00
11:42:39	-0.38	69.8	191.8	2.3	0.99
11:47:07	-0.33	66.8	188.8	2.1	0.99
11:51:34	-0.30	67.2	189.2	2.0	1.00
11:56:02	-0.29	75.9	197.9	2.0	1.00
12:00:30	-0.22	86.6	208.6	2.2	0.98
12:04:59	-0.29	95.1	217.1	2.1	0.98
12:09:27	-0.51	98.2	220.2	2.4	1.00
12:13:55	-0.37	93.7	215.7	2.0	0.96
12:18:24	-0.51	79.3	201.3	1.8	0.96
12:22:54	-0.80	81.6	203.6	1.7	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:27:25	-0.71	81.8	203.8	1.4	1.00
12:31:53	-0.79	70.9	192.9	1.0	0.99
12:36:19	-0.89	85.5	207.5	1.0	0.94
12:40:49	-0.79	95.5	217.5	1.0	0.98
12:45:19	-0.74	95.2	217.2	0.7	0.94
12:49:45	-0.71	119.8	241.8	1.3	0.90
12:54:12	-0.56	114.5	236.5	1.4	0.69
12:58:41	-0.64	104.6	226.6	1.3	0.64
13:03:09	-0.59	101.1	223.1	1.5	0.96
13:07:32	-0.46	77.2	199.2	1.2	0.95
13:42:50	0.00	234.8	356.8	0.4	0.00
13:47:12	0.00	170.6	292.6	0.9	0.00
13:51:34	0.02	152.2	274.2	1.0	0.91
13:55:57	0.06	166.7	288.7	1.0	1.00
14:00:21	0.10	175.8	297.8	1.2	0.99
14:04:47	0.07	160.6	282.6	1.8	1.00
14:09:11	0.11	171.7	293.7	1.9	1.00
14:13:33	0.10	174.4	296.4	2.0	0.98
14:17:55	0.09	162.4	284.4	2.6	0.99
14:22:21	0.06	158.9	280.9	2.8	1.00
14:26:42	0.10	162.4	284.4	3.1	1.00
14:31:09	0.05	152.8	274.8	3.1	1.00
14:35:30	0.01	148.8	270.8	3.0	0.99
14:39:56	0.00	147.9	269.9	3.0	0.98
14:44:17	-0.06	144.8	266.8	2.9	0.98
14:48:41	-0.13	141.9	263.9	3.0	0.94
14:53:04	-0.02	147.2	269.2	3.3	0.94

Calculated Flux Values for the EnCana Benzel Facility

Tables A-18 through A-33 present the summary tables of calculated flux values for each VRPM plane during each day of sampling at the EnCana Benzel facility. These values were calculated as described in Sections 2.3 and 3.1. Each table presents the time, flux value, wind direction, rotated wind direction, wind speed, and CCF (used to represent the level of fit for the reconstruction in the path-integrated domain, i.e., predicted versus measured path-averaged concentration). As described in Section 3.1.1, flux values were calculated for data which met a series of quality control criteria pertaining to horizontal and vertical plume capture and instrument DQIs. That section also described the flags that were added to flux values that did not meet the optimal data criteria, but that could still prove useful in understanding the source and magnitude of hydrocarbon emissions being generated from these sites. The input files used to calculate the AM (total alkanes) concentration values can be found in Appendix A.

Table A-18. Summary Data Table of VRPM Plane A123 for August 12, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:11:21	0.07	49.8	345.8	1.8	0.93
12:16:44	0.06	51.8	347.8	2.0	0.94
12:21:10	0.06	49.1	345.1	1.9	0.78
12:25:31	0.05	39.5	335.5	2.0	0.14
12:29:52	0.04	36.8	332.8	2.0	1.00
12:34:15	0.01	19.7	315.7	2.1	0.99
12:38:38	0.01	14.0	310.0	2.3	1.00
12:42:57	0.01	11.2	307.2	2.4	0.98
12:47:21		5.8	301.8	2.2	0.00
12:51:43		337.0	273.0	2.3	0.00
12:56:06		336.8	272.8	2.1	0.00
13:00:28		339.6	275.6	2.1	0.00
13:04:52		333.0	269.0	2.1	0.00
13:09:15		303.1	239.1	2.0	0.00
13:13:41		289.0	225.0	2.1	0.00
13:18:05		316.9	252.9	2.1	0.00
13:22:29		328.1	264.1	2.7	0.00
13:26:54		327.6	263.6	2.9	0.00
13:31:36		346.2	282.2	3.8	0.00
13:36:11		354.1	290.1	3.8	0.00
13:40:54		356.7	292.7	3.1	0.00
13:45:23		344.2	280.2	2.6	0.00
13:50:04		337.0	273.0	2.4	0.00
13:54:43		322.6	258.6	2.0	0.00
14:00:00		311.6	247.6	1.7	0.00
15:23:59	0.01	1.4	297.4	1.5	0.95
15:29:21	0.01	349.7	285.7	1.8	0.96
15:33:42	0.03	5.1	301.1	2.5	0.59
15:46:48	0.03	78.6	14.6	0.5	1.00
15:51:10	0.04	26.4	322.4	2.1	0.13
15:55:32	0.02	26.0	322.0	1.4	0.77
15:59:52	0.07	17.4	313.4	1.8	0.72
16:04:17	0.06	333.7	269.7	1.1	0.95

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:08:38	-0.01	283.6	219.6	1.3	0.57
16:12:59	-0.01	282.8	218.8	1.6	0.64
16:17:19	-0.01	288.8	224.8	1.5	0.58
16:21:41	0.00	309.2	245.2	1.4	0.64
16:26:00	0.07	352.2	288.2	2.0	0.99
16:30:20	0.14	13.4	309.4	2.4	0.99
16:34:40	0.12	17.6	313.6	2.4	1.00
16:39:01	0.15	20.0	316.0	2.6	0.98
16:43:22	0.13	24.8	320.8	2.1	0.99
16:47:41	0.11	28.2	324.2	1.9	0.92
16:52:01	0.11	22.6	318.6	1.8	0.03
16:56:21	0.17	15.3	311.3	1.5	0.02
17:00:43	0.11	11.3	307.3	1.3	0.02
17:05:06	0.06	350.4	286.4	1.5	0.02
17:09:29	0.03	342.4	278.4	1.7	0.01
17:13:50	0.05	346.5	282.5	2.0	0.03
17:18:11	0.03	350.9	286.9	2.1	0.47
17:22:35	0.02	5.7	301.7	2.1	0.56
17:26:59	0.06	10.9	306.9	2.6	0.84
17:31:23	0.13	14.1	310.1	2.7	0.96
17:35:43	0.08	16.2	312.2	2.7	0.94
17:40:06	0.20	17.1	313.1	2.8	0.99
17:44:29	0.21	18.0	314.0	2.8	0.99
17:48:52	0.17	21.6	317.6	2.6	0.99
17:53:13	0.11	22.9	318.9	2.4	0.95
17:57:35	0.10	11.5	307.5	2.5	0.97
18:01:56	0.08	6.5	302.5	2.1	0.99
18:06:19	0.04	358.8	294.8	1.4	0.98
18:10:40	0.07	9.8	305.8	1.4	0.98

Table A-19. Summary Data Table of VRPM Plane A456 for August 12, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:14:31	0.01	50.9	85.9	2.1	1.00
12:18:57	0.02	50.0	85.0	1.9	1.00
12:23:20	0.03	47.4	82.4	1.9	0.94
12:27:41	0.06	39.2	74.2	2.1	0.79
12:32:03	0.07	25.5	60.5	2.0	0.88
12:36:25	0.08	15.3	50.3	2.3	0.96
12:40:49	0.07	13.2	48.2	2.3	1.00
12:45:10	0.06	5.8	40.8	2.3	1.00
12:49:31	0.08	348.6	23.6	2.5	1.00
12:53:55	0.08	335.5	10.5	2.1	1.00
12:58:17	0.08	339.8	14.8	2.1	1.00
13:02:41	0.07	339.1	14.1	2.1	1.00
13:07:04	0.06	300.0	335.0	2.1	1.00
13:11:29		285.1	320.1	2.1	0.00
13:15:52		302.1	337.1	2.0	0.00
13:20:17		320.4	355.4	2.6	0.00
13:24:41		328.8	3.8	3.0	0.00
13:29:23		332.0	7.0	3.0	0.00
13:33:54		351.0	26.0	3.9	0.00
13:38:42		354.1	29.1	3.7	0.00
13:43:12		351.7	26.7	2.9	0.00
13:47:36		338.8	13.8	2.5	0.00
13:52:27		327.3	2.3	2.2	0.00
13:57:44		316.1	351.1	1.9	0.00
14:02:17		308.1	343.1	1.6	0.00
15:27:10	0.06	349.9	24.9	1.8	0.94
15:31:31	0.07	10.5	45.5	2.4	0.99
15:35:52	0.08	5.1	40.1	2.5	0.94
15:49:01	0.07	30.6	65.6	1.4	0.94
15:53:21	0.06	26.0	61.0	1.7	0.94
15:57:42	0.04	15.9	50.9	1.7	1.00
16:02:03	0.04	359.2	34.2	1.4	1.00
16:06:28	0.03	302.8	337.8	1.1	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:10:49	0.04	277.4	312.4	1.6	0.99
16:15:09	0.04	292.5	327.5	1.6	0.99
16:19:30	0.06	291.2	326.2	1.5	1.00
16:23:49	0.08	333.2	8.2	1.6	1.00
16:28:10	0.11	2.5	37.5	2.3	0.99
16:32:29	0.08	15.7	50.7	2.4	0.99
16:36:49	0.07	18.3	53.3	2.6	1.00
16:41:12	0.06	20.5	55.5	2.4	1.00
16:45:30	0.07	27.6	62.6	2.0	0.85
16:49:50	0.10	21.2	56.2	1.9	1.00
16:54:11	0.17	21.5	56.5	1.8	0.40
16:58:32	0.25	13.0	48.0	1.4	0.92
17:02:53	0.16	359.3	34.3	1.4	0.88
17:07:16	0.22	347.6	22.6	1.6	0.99
17:11:39	0.33	344.0	19.0	1.9	1.00
17:16:00	0.31	350.1	25.1	2.1	1.00
17:20:22	0.31	354.3	29.3	2.1	0.94
17:24:46	0.32	10.1	45.1	2.3	0.99
17:29:11	0.23	15.7	50.7	2.8	0.98
17:33:32	0.13	11.8	46.8	2.6	0.98
17:37:54	0.06	18.6	53.6	2.7	1.00
17:42:16	0.08	15.9	50.9	2.9	1.00
17:46:40	0.06	21.7	56.7	2.7	1.00
17:51:02	0.04	21.9	56.9	2.4	0.89
17:55:24	0.07	16.7	51.7	2.4	0.97
17:59:45	0.09	8.5	43.5	2.3	1.00
18:04:07	0.10	4.5	39.5	1.7	1.00
18:08:29	0.07	2.1	37.1	1.2	1.00

Table A-20. Summary Data Table of VRPM Plane E123 for August 12, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:16:41	-0.02	50.4	232.4	1.6	0.14
11:22:10	-0.02	47.9	229.9	1.8	0.04
11:26:39	-0.02	44.7	226.7	1.9	0.80
11:31:12	-0.02	43.4	225.4	2.1	0.12
11:35:51	-0.02	24.0	206.0	2.0	0.85
11:40:19	-0.02	12.7	194.7	2.2	0.36
11:44:46	-0.03	13.4	195.4	2.9	0.24
11:49:23	-0.02	14.4	196.4	2.8	0.03
11:54:02	-0.02	25.5	207.5	2.1	0.00
11:58:28	-0.02	25.2	207.2	2.1	0.00
12:02:53	-0.02	29.7	211.7	2.1	0.00
12:07:22	-0.02	35.9	217.9	2.0	0.00
12:11:48	-0.02	47.0	229.0	1.8	0.05
12:16:14	-0.02	51.0	233.0	2.0	0.08
12:20:39	-0.02	49.1	231.1	1.9	0.45
12:25:05	-0.02	41.3	223.3	2.0	0.60
12:29:29	-0.02	36.6	218.6	2.0	0.98
12:33:54	-0.02	19.7	201.7	2.1	1.00
12:38:20	-0.02	14.0	196.0	2.3	1.00
12:42:47	-0.03	11.4	193.4	2.4	0.94
12:47:12	-0.02	5.8	187.8	2.2	0.92
12:51:36	-0.02	339.9	161.9	2.3	0.99
12:55:59	-0.03	336.8	158.8	2.1	0.82
13:00:29	-0.02	339.6	161.6	2.1	0.91
13:04:57	-0.02	333.0	155.0	2.1	1.00
13:09:17	0.00	304.1	126.1	2.1	0.95
13:13:45	0.01	292.6	114.6	2.1	0.77
13:18:09	0.00	316.9	138.9	2.1	0.90
13:22:36	-0.01	328.5	150.5	2.8	1.00
13:27:01	-0.01	327.6	149.6	2.9	0.94
13:31:24	-0.03	344.7	166.7	3.7	0.95
13:35:48	-0.03	353.8	175.8	3.8	1.00
13:40:12	-0.03	356.2	178.2	3.4	0.98

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:44:37	-0.03	348.0	170.0	2.9	0.99
13:49:03	-0.03	338.1	160.1	2.5	0.58
13:53:26	-0.02	322.8	144.8	2.1	0.00
13:57:52	-0.01	309.6	131.6	1.9	0.06
14:02:18	-0.01	304.7	126.7	1.6	0.98
14:06:46	-0.02	315.0	137.0	1.5	0.77
14:11:09	-0.02	325.6	147.6	1.9	0.68
14:15:37	-0.01	335.1	157.1	2.2	0.82
14:20:03	-0.04	336.8	158.8	2.7	0.25
14:24:28	-0.06	342.4	164.4	2.9	0.17
14:28:56	-0.11	350.5	172.5	2.1	0.44
14:33:22	-0.09	68.2	250.2	0.9	0.43
14:37:50	-0.07	117.2	299.2	0.8	0.31
14:42:16	-0.05	23.0	205.0	1.4	0.84
14:46:41	-0.07	25.8	207.8	2.3	0.97
14:51:10	-0.02	25.1	207.1	2.0	0.99
14:55:37	-0.02	22.2	204.2	2.4	0.98
15:00:03	-0.02	18.8	200.8	2.5	0.99
15:04:28	-0.02	22.8	204.8	2.2	1.00
15:08:54	-0.01	10.6	192.6	2.6	0.83
15:13:20	-0.02	357.4	179.4	2.1	0.44
15:17:45	-0.01	0.2	182.2	2.0	0.55
15:22:15	-0.01	1.4	183.4	1.5	0.65
15:26:42	-0.01	350.7	172.7	1.7	0.69
15:31:12		359.2	181.2	1.9	0.00
15:35:39	-0.01	5.1	187.1	2.5	0.97
15:49:05	-0.02	26.0	208.0	1.6	0.99
15:53:32	-0.01	27.0	209.0	1.7	0.96
15:57:54	-0.01	16.1	198.1	1.8	0.99
16:02:20	-0.02	353.8	175.8	1.4	0.10
16:06:47	-0.04	299.6	121.6	1.1	0.16
16:11:13	-0.03	277.6	99.6	1.6	0.06
16:15:39	-0.06	293.7	115.7	1.6	0.11
16:20:02	-0.07	293.2	115.2	1.5	0.08
16:24:28	-0.09	340.1	162.1	1.7	0.21

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:28:55	-0.03	5.5	187.5	2.3	0.00
16:33:21		16.7	198.7	2.4	0.00
16:37:48		19.7	201.7	2.6	0.00
16:42:14		21.5	203.5	2.3	0.00
16:46:41		26.4	208.4	1.9	0.00
16:51:09		21.8	203.8	1.9	0.00
16:55:35		17.6	199.6	1.7	0.00
17:00:01		14.8	196.8	1.3	0.00
17:04:27		352.9	174.9	1.5	0.00
17:08:54		344.5	166.5	1.6	0.00
17:13:20		346.4	168.4	2.0	0.00
17:17:46		351.3	173.3	2.1	0.00
17:22:13		1.8	183.8	2.1	0.00
17:26:39		10.4	192.4	2.5	0.00
17:31:05		14.5	196.5	2.8	0.00
17:35:31		16.1	198.1	2.6	0.00
17:39:59		17.4	199.4	2.8	0.00
17:44:25		17.7	199.7	2.8	0.00
17:48:51		21.3	203.3	2.6	0.00
17:53:20		22.8	204.8	2.4	0.00
17:57:47		11.4	193.4	2.5	0.00
18:02:13		6.4	188.4	2.0	0.00
18:06:39		358.9	180.9	1.4	0.00

Table A-21. Summary Data Table of VRPM Plane E456 for August 12, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:19:57		48.6	163.6	1.7	0.00
11:24:24		44.0	159.0	1.9	0.00
11:28:59		45.9	160.9	2.1	0.00
11:33:37		39.6	154.6	2.2	0.00
11:38:06	-0.01	17.3	132.3	2.0	0.85
11:42:30	-0.02	13.4	128.4	2.9	0.91
11:47:08	-0.02	10.8	125.8	2.8	0.37
11:51:48	-0.02	19.7	134.7	2.6	0.29
11:56:13	-0.02	25.6	140.6	2.1	0.57
12:00:39	-0.01	27.8	142.8	2.1	0.88
12:05:07	-0.01	33.3	148.3	2.0	1.00
12:09:35	-0.01	42.3	157.3	1.9	0.93
12:14:00	-0.01	50.9	165.9	2.1	0.75
12:18:25	-0.01	47.9	162.9	1.9	0.94
12:22:51	-0.01	46.1	161.1	1.9	0.72
12:27:16	-0.02	35.5	150.5	2.1	0.72
12:31:40	-0.02	31.0	146.0	2.0	0.70
12:36:07	-0.01	18.0	133.0	2.2	0.89
12:40:32	-0.01	13.9	128.9	2.3	0.95
12:45:45	-0.01	4.1	119.1	2.3	0.92
12:49:23	-0.01	350.7	105.7	2.4	0.96
12:53:49	0.00	335.5	90.5	2.1	0.96
12:58:12	-0.01	339.8	94.8	2.1	1.00
13:02:44	-0.01	339.1	94.1	2.1	1.00
13:07:08	0.01	290.6	45.6	2.1	0.46
13:11:30	0.03	285.1	40.1	2.1	1.00
13:15:52	0.02	302.1	57.1	2.0	0.98
13:20:20	0.02	320.4	75.4	2.6	1.00
13:24:47	0.01	328.8	83.8	3.0	0.92
13:29:08	0.00	331.9	86.9	3.0	0.89
13:33:34	-0.01	350.9	105.9	3.9	0.94
13:37:59	-0.01	353.8	108.8	4.0	0.96
13:42:24	-0.01	355.9	110.9	3.1	0.99

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:46:50	0.00	344.1	99.1	2.5	0.86
13:51:15	0.02	334.1	89.1	2.3	0.79
13:55:40	0.03	319.2	74.2	2.0	0.74
14:00:05	0.04	312.9	67.9	1.7	0.93
14:04:30	0.04	307.9	62.9	1.4	0.98
14:08:56	0.02	319.9	74.9	1.6	0.98
14:13:23	0.01	335.4	90.4	2.0	0.97
14:17:49	0.01	342.5	97.5	2.2	0.65
14:22:15	0.00	343.1	98.1	3.1	0.95
14:26:42	0.00	342.3	97.3	2.5	0.97
14:31:09	-0.01	13.0	128.0	1.3	0.97
14:35:35	-0.01	100.8	215.8	0.7	0.94
14:40:03	-0.01	105.1	220.1	0.8	0.91
14:44:28	-0.02	19.8	134.8	2.0	0.95
14:48:56	-0.01	25.6	140.6	2.0	0.91
14:53:22	0.00	23.2	138.2	2.1	0.77
14:57:50	-0.01	21.9	136.9	2.5	0.95
15:02:15	-0.01	22.2	137.2	2.5	0.93
15:06:41	0.00	12.7	127.7	2.0	0.82
15:11:07	0.00	0.9	115.9	2.4	0.77
15:15:33	0.00	0.1	115.1	2.1	0.82
15:20:02	0.00	3.8	118.8	1.8	0.69
15:24:28	0.00	1.4	116.4	1.5	0.61
15:28:59	0.00	349.7	104.7	1.8	0.46
15:33:24	-0.01	23.2	138.2	2.3	0.72
15:46:46	0.00	78.6	193.6	0.5	0.85
15:51:18	-0.01	26.0	141.0	2.1	0.91
15:55:45	-0.01	22.9	137.9	1.3	0.87
16:00:06	-0.01	15.0	130.0	1.8	0.85
16:04:32	0.00	326.3	81.3	1.1	0.85
16:08:59	0.01	282.0	37.0	1.3	0.91
16:13:25	0.01	284.5	39.5	1.7	0.85
16:17:48	0.01	291.2	46.2	1.5	0.72
16:22:14	0.00	314.5	69.5	1.4	0.74
16:26:40	-0.01	356.0	111.0	2.0	0.68

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:31:07	-0.01	14.5	129.5	2.5	0.92
16:35:34		17.8	132.8	2.5	0.00
16:40:01	-0.01	19.2	134.2	2.6	0.89
16:44:26	-0.01	26.5	141.5	2.0	0.85
16:48:55	-0.01	24.4	139.4	1.9	0.86
16:53:21	-0.01	23.1	138.1	1.8	0.86
16:57:47	-0.01	12.4	127.4	1.5	0.89
17:02:13	-0.01	3.0	118.0	1.4	0.17
17:06:41	-0.02	347.9	102.9	1.5	0.51
17:11:07	-0.02	343.6	98.6	1.8	0.57
17:15:33	-0.02	349.1	104.1	2.1	0.58
17:19:59	0.01	352.5	107.5	2.1	0.45
17:24:25	0.00	9.8	124.8	2.3	0.93
17:28:51		14.5	129.5	2.7	0.00
17:33:18		12.2	127.2	2.6	0.00
17:37:45		18.5	133.5	2.7	0.00
17:42:12		16.0	131.0	2.9	0.00
17:46:37		21.6	136.6	2.7	0.00
17:51:03		21.6	136.6	2.4	0.00
17:55:32		17.1	132.1	2.4	0.00
17:59:58		8.5	123.5	2.2	0.00
18:04:25		4.0	119.0	1.6	0.00

Table A-22. Summary Data Table of VRPM Plane A123 for August 13, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:33:15	0.01	14.0	310.0	1.3	0.16
09:38:38	0.00	17.7	313.7	1.2	0.32
09:42:59	0.02	23.8	319.8	1.2	0.29
09:47:22	0.03	18.4	314.4	1.3	0.28
09:51:46	0.03	19.2	315.2	1.3	0.25
09:56:08	0.04	19.3	315.3	1.4	0.51
10:00:32	0.03	19.6	315.6	1.5	0.48
10:04:54	0.01	13.5	309.5	1.4	0.70
10:09:16	0.01	14.2	310.2	1.4	0.97
10:13:37	0.01	10.2	306.2	1.2	0.91
10:18:18	0.01	2.1	298.1	0.9	0.99
10:22:22	0.01	356.5	292.5	0.9	1.00
10:26:46		341.3	277.3	0.9	0.00
10:31:09	0.00	336.6	272.6	0.8	0.03
10:35:30	0.01	354.6	290.6	1.0	0.01
10:39:53	0.01	350.1	286.1	1.1	0.01
10:44:17	0.01	356.9	292.9	1.0	0.02
10:48:41	0.01	357.7	293.7	1.2	0.01
10:53:06	0.00	346.4	282.4	1.2	0.03
10:57:29		343.8	279.8	1.2	0.00
11:01:53	0.00	347.6	283.6	1.3	0.11
11:06:15	0.00	346.2	282.2	1.3	0.02
11:10:41	0.00	345.3	281.3	1.1	0.03
11:15:06	0.00	356.7	292.7	1.3	0.64
11:19:31	0.00	358.9	294.9	1.2	0.59
11:23:52	0.00	344.3	280.3	0.9	0.73
11:28:15	0.00	340.4	276.4	0.9	0.75
11:32:41	0.00	338.9	274.9	0.9	0.00
11:37:05	0.00	332.1	268.1	1.0	0.91
11:41:29		334.6	270.6	1.2	0.00
11:45:50		343.4	279.4	1.4	0.00
11:50:13		345.8	281.8	1.5	0.00
11:54:38		331.7	267.7	1.0	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:58:58		334.8	270.8	0.9	0.00
12:03:20	0.00	330.2	266.2	0.4	0.00
12:07:42	0.00	132.0	68.0	0.2	0.00
12:12:05	0.00	73.8	9.8	0.4	0.00
12:16:24	0.00	93.5	29.5	0.5	0.00
12:20:48	0.00	68.7	4.7	0.5	0.00
12:25:09	0.00	23.4	319.4	0.7	0.00
12:29:33	0.00	32.8	328.8	0.8	1.00
12:33:56	0.03	33.2	329.2	1.3	0.97
12:38:21	0.03	29.0	325.0	1.5	0.97
12:42:42	0.02	19.9	315.9	1.4	0.86
12:47:07	0.02	14.5	310.5	1.5	0.90
12:51:31	0.01	26.8	322.8	0.9	0.93
12:55:55	0.01	31.6	327.6	1.0	0.93
13:00:17	0.00	14.2	310.2	0.9	0.88
13:04:39	-0.01	345.6	281.6	0.9	0.99
13:09:02	-0.01	334.7	270.7	0.9	0.74
13:13:23	-0.04	320.9	256.9	1.1	0.96
13:17:47	-0.04	345.1	281.1	1.1	0.84
13:22:09	0.04	29.3	325.3	1.6	0.97
13:26:30	0.11	45.8	341.8	1.9	0.99
13:30:53	0.12	47.3	343.3	2.4	0.95
13:35:15	0.11	46.0	342.0	2.4	0.98
13:39:37	0.11	45.8	341.8	2.0	0.99
13:43:59	0.14	37.3	333.3	1.8	0.98
13:48:20	0.13	35.4	331.4	2.0	1.00
13:52:42	0.11	40.2	336.2	1.7	0.99
13:57:03	0.09	54.7	350.7	1.8	1.00
14:01:27	0.10	56.4	352.4	2.3	1.00
14:05:50	0.07	49.2	345.2	2.5	0.98
14:10:14	0.07	41.3	337.3	2.9	0.98
14:14:38	0.07	31.4	327.4	3.1	0.95
14:19:01	0.08	21.4	317.4	3.2	0.97
14:23:23	0.08	12.2	308.2	3.3	0.96
14:27:46	0.03	359.4	295.4	3.1	0.70

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:32:09	0.01	358.1	294.1	3.0	0.01
14:36:31	0.01	355.1	291.1	2.5	0.10
14:40:52	0.01	326.6	262.6	1.9	0.13
14:45:15	0.00	310.9	246.9	2.1	0.12
14:49:38	0.00	296.4	232.4	2.1	0.09
14:54:01	0.01	279.1	215.1	2.2	0.30
14:58:22		293.3	229.3	2.5	0.00
15:02:46		306.1	242.1	1.5	0.00
15:07:09	0.01	320.0	256.0	1.1	0.79
15:11:31	0.01	354.4	290.4	1.3	0.93
15:15:52	0.01	351.8	287.8	1.5	0.88
15:42:56	-0.02	182.0	118.0	1.0	0.89
15:46:19	-0.02	173.3	109.3	2.6	0.89
15:48:41	-0.02	176.7	112.7	2.4	0.90
15:51:04	-0.01	167.9	103.9	2.5	0.93
15:53:26	-0.01	156.1	92.1	2.0	0.97
15:55:48	0.00	122.9	58.9	1.1	0.98
15:58:11	0.01	77.5	13.5	0.9	0.98
16:00:33	0.01	61.6	357.6	1.0	0.98
16:02:53	0.00	10.9	306.9	1.2	0.98
16:05:15	0.00	342.0	278.0	1.9	0.93
16:07:37		341.5	277.5	3.2	0.00
16:09:59		335.4	271.4	4.1	0.00
16:12:20		324.1	260.1	3.7	0.00
16:14:42		326.8	262.8	3.5	0.00
16:17:03		323.4	259.4	3.4	0.00
16:19:24		318.2	254.2	2.7	0.00
16:21:46	-0.02	336.3	272.3	1.8	0.01
16:24:06	-0.02	353.8	289.8	1.4	0.17
16:26:26	-0.02	18.7	314.7	1.1	0.91
16:28:49	-0.04	49.1	345.1	1.1	0.93
16:31:09	-0.02	26.7	322.7	1.1	0.99
16:33:29	0.00	13.4	309.4	0.7	1.00
16:35:51	0.01	8.8	304.8	0.7	0.95
16:38:12	0.01	333.0	269.0	0.7	0.47

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:40:32		308.2	244.2	0.5	0.00
16:42:53		292.6	228.6	0.6	0.00
16:45:15		290.1	226.1	1.1	0.00
16:47:35		286.9	222.9	1.5	0.00
16:49:58		295.7	231.7	1.7	0.00
16:52:18		307.6	243.6	2.2	0.00
16:54:39		314.8	250.8	2.3	0.00
16:57:01		334.4	270.4	2.5	0.00
16:59:24	0.00	348.5	284.5	2.8	0.32
17:01:44	0.01	358.6	294.6	2.6	0.32
17:04:05	0.01	5.1	301.1	2.4	0.24
17:06:30	0.00	359.4	295.4	1.9	0.36
17:08:52	0.00	320.0	256.0	1.6	0.41
17:11:13		294.8	230.8	2.0	0.00
17:13:36		280.6	216.6	2.3	0.00
17:16:00		264.6	200.6	2.4	0.00
17:18:23		264.4	200.4	2.4	0.00
17:20:45		267.9	203.9	1.8	0.00
17:23:07		282.3	218.3	1.2	0.00
17:25:27		300.8	236.8	1.5	0.00
17:27:52		306.2	242.2	2.2	0.00
17:30:15		313.0	249.0	2.1	0.00
17:32:37		308.8	244.8	2.5	0.00
17:34:59		307.6	243.6	2.7	0.00
17:37:22		312.9	248.9	3.0	0.00
17:39:42		316.3	252.3	2.9	0.00
17:42:03		313.6	249.6	3.1	0.00
17:44:25		317.6	253.6	3.7	0.00
17:46:47		317.4	253.4	4.5	0.00

Table A-23. Summary Data Table of VRPM Plane A456 for August 13, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:36:27	0.04	13.7	48.7	1.3	1.00
09:40:49	0.03	18.4	53.4	1.1	1.00
09:45:10	0.02	22.0	57.0	1.2	0.99
09:49:33	0.03	18.6	53.6	1.2	0.95
09:53:57	0.02	18.7	53.7	1.3	0.95
09:58:21	0.03	19.4	54.4	1.4	0.87
10:02:42	0.03	15.7	50.7	1.4	0.81
10:07:05	0.03	14.0	49.0	1.4	0.91
10:11:26	0.03	11.7	46.7	1.3	0.85
10:15:49	0.02	1.6	36.6	0.9	0.90
10:20:12	0.02	358.5	33.5	0.8	0.98
10:24:34		349.8	24.8	0.9	0.00
10:28:58		338.6	13.6	0.8	0.00
10:33:20		341.1	16.1	0.8	0.00
10:37:42		345.9	20.9	1.0	0.00
10:42:06		354.5	29.5	1.1	0.00
10:46:29	0.05	357.3	32.3	1.1	0.99
10:50:54	0.05	353.2	28.2	1.2	0.96
10:55:18	0.05	345.7	20.7	1.1	0.92
10:59:42	0.04	344.6	19.6	1.2	0.97
11:04:03	0.04	349.7	24.7	1.4	0.94
11:08:29	0.04	342.4	17.4	1.1	0.99
11:12:55	0.05	354.0	29.0	1.3	1.00
11:17:17	0.04	1.5	36.5	1.3	1.00
11:21:41	0.04	352.7	27.7	1.1	1.00
11:26:04	0.04	343.1	18.1	0.8	0.99
11:30:29	0.04	337.6	12.6	0.8	1.00
11:34:54	0.04	335.2	10.2	1.0	1.00
11:39:16	0.04	329.5	4.5	1.1	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:43:40	0.06	340.7	15.7	1.4	1.00
11:48:02	0.07	346.2	21.2	1.5	0.98
11:52:26	0.05	337.9	12.9	1.2	1.00
11:56:48	0.04	332.0	7.0	1.0	0.96
12:01:09	0.03	325.8	0.8	0.7	0.95
12:05:31	0.00	4.3	39.3	0.1	0.00
12:09:55	0.00	110.1	145.1	0.3	0.00
12:14:15	0.00	74.4	109.4	0.4	0.00
12:18:36	0.00	94.8	129.8	0.4	0.00
12:22:58	0.00	39.4	74.4	0.6	0.00
12:27:21	0.02	32.4	67.4	0.8	0.80
12:31:45	0.02	31.6	66.6	1.0	0.81
12:36:09	0.02	26.7	61.7	1.4	0.90
12:40:31	0.04	19.4	54.4	1.5	0.98
12:44:55	0.05	18.2	53.2	1.5	0.95
12:49:19	0.03	17.2	52.2	1.3	0.98
12:53:43	0.02	25.4	60.4	0.9	0.96
12:58:06	0.04	11.4	46.4	1.0	0.98
13:02:29	0.03	353.3	28.3	0.9	0.87
13:06:51	0.02	341.6	16.6	0.8	1.00
13:11:13	0.06	326.3	1.3	1.0	1.00
13:15:36	0.08	330.1	5.1	1.2	0.91
13:19:58	0.09	0.9	35.9	1.2	0.79
13:24:20	0.07	44.6	79.6	1.6	0.98
13:28:41	0.07	48.5	83.5	2.0	0.51
13:33:04	0.04	44.4	79.4	2.4	0.99
13:37:25	0.03	43.1	78.1	2.2	1.00
13:41:47	0.01	48.8	83.8	1.7	1.00
13:46:09	0.03	37.2	72.2	1.9	1.00
13:50:32	0.03	36.0	71.0	1.7	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:54:53	0.03	46.9	81.9	1.7	1.00
13:59:16	0.02	59.3	94.3	2.1	0.99
14:03:38	0.01	55.5	90.5	2.5	0.99
14:08:03	0.02	42.9	77.9	2.6	1.00
14:12:27	0.02	36.4	71.4	2.9	0.99
14:16:49	0.03	29.4	64.4	3.2	0.99
14:21:11	0.04	17.1	52.1	3.3	0.98
14:25:34	0.06	3.0	38.0	3.0	0.99
14:29:57	0.09	358.3	33.3	3.1	0.97
14:34:19	0.08	358.7	33.7	2.8	0.99
14:38:42	0.06	348.8	23.8	2.0	1.00
14:43:04	0.07	313.8	348.8	2.2	0.99
14:47:26	0.07	310.7	345.7	2.1	0.98
14:51:50	0.04	290.7	325.7	2.0	0.97
14:56:12	0.03	284.9	319.9	2.3	0.95
15:00:33	0.03	297.4	332.4	2.1	0.97
15:04:58	0.02	319.3	354.3	1.4	0.97
15:09:21	0.04	347.0	22.0	1.0	0.96
15:13:42	0.05	346.7	21.7	1.5	0.95
15:45:08		170.1	205.1	2.1	0.00
15:47:30		176.1	211.1	2.7	0.00
15:49:53		172.1	207.1	2.4	0.00
15:52:15		161.6	196.6	2.3	0.00
15:54:36	0.03	149.2	184.2	1.6	0.91
15:56:59	0.04	91.2	126.2	0.9	0.74
15:59:22	0.03	90.2	125.2	1.1	0.76
16:01:43	0.08	29.8	64.8	1.1	0.89
16:04:04	0.10	351.0	26.0	1.5	0.83
16:06:25	0.12	342.6	17.6	2.4	0.87
16:08:48	0.15	340.7	15.7	3.8	0.94

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
16:11:10	0.15	325.3	0.3	3.9	0.95
16:13:30	0.14	327.2	2.2	3.6	0.98
16:15:50	0.12	325.0	360.0	3.5	0.99
16:18:14	0.08	320.1	355.1	3.2	1.00
16:20:35	0.07	319.9	354.9	2.2	0.97
16:22:56	0.06	351.9	26.9	1.6	0.99
16:25:17	0.06	359.9	34.9	1.2	0.97
16:27:38	0.05	33.0	68.0	1.1	0.97
16:29:58	0.05	37.0	72.0	1.0	0.97
16:32:19	0.03	22.4	57.4	0.8	0.98
16:34:40	0.05	10.9	45.9	0.7	0.84
16:37:00	0.03	354.0	29.0	0.6	0.97
16:39:21	0.03	317.6	352.6	0.6	1.00
16:41:43	0.02	279.7	314.7	0.4	0.86
16:44:05	0.03	292.8	327.8	0.8	0.77
16:46:25	0.05	287.5	322.5	1.3	0.82
16:48:48	0.06	287.0	322.0	1.6	0.77
16:51:08	0.06	300.9	335.9	2.0	0.87
16:53:28	0.07	310.7	345.7	2.3	0.90
16:55:50	0.06	326.1	1.1	2.3	0.92
16:58:13	0.06	342.9	17.9	2.6	0.96
17:00:34	0.05	351.2	26.2	2.7	0.96
17:02:54	0.05	0.1	35.1	2.4	0.96
17:05:17	0.04	5.2	40.2	2.3	0.98
17:07:41	0.03	338.6	13.6	1.6	0.99
17:10:04	0.03	303.3	338.3	1.8	0.99
17:12:24	0.03	287.5	322.5	2.2	0.99
17:14:47		270.2	305.2	2.3	0.00
17:17:11		262.8	297.8	2.4	0.00
17:19:35		264.5	299.5	2.2	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
17:21:56		274.7	309.7	1.4	0.00
17:24:18		294.2	329.2	1.2	0.00
17:26:42		301.8	336.8	1.8	0.00
17:29:04		311.2	346.2	2.2	0.00
17:31:27		309.7	344.7	2.3	0.00
17:33:47		307.2	342.2	2.6	0.00
17:36:10		308.6	343.6	2.8	0.00
17:38:31		315.3	350.3	2.9	0.00
17:40:53		314.5	349.5	3.1	0.00
17:43:14		313.9	348.9	3.2	0.00
17:45:37		318.5	353.5	4.2	0.00

Table A-24. Summary Data Table of VRPM Plane E123 for August 13, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:30:58	-0.01	336.6	158.6	0.8	0.74
10:35:22	-0.02	354.4	176.4	1.0	0.89
10:39:50	-0.02	349.9	171.9	1.1	0.04
10:44:14	-0.02	356.1	178.1	1.0	0.03
10:48:38	-0.02	357.4	179.4	1.2	0.98
10:53:01	-0.02	346.4	168.4	1.2	0.76
10:57:24	-0.01	343.7	165.7	1.2	0.92
11:01:49	-0.02	347.5	169.5	1.3	0.93
11:06:11	-0.01	346.3	168.3	1.3	0.86
11:10:35	-0.02	344.9	166.9	1.1	1.00
11:14:58	-0.02	356.6	178.6	1.3	0.99
11:19:21	-0.02	359.0	181.0	1.2	0.99
11:23:44	-0.01	344.7	166.7	0.9	0.93
11:28:09	-0.01	340.6	162.6	0.9	0.78
11:32:31	0.00	339.6	161.6	0.9	0.00
11:36:54	-0.01	331.9	153.9	1.0	1.00
11:41:17	-0.01	333.9	155.9	1.2	0.98
11:45:41	-0.02	343.5	165.5	1.4	0.88
11:50:03	-0.02	345.7	167.7	1.5	0.71
11:54:27	-0.02	331.3	153.3	1.0	0.93
11:58:50	-0.01	334.7	156.7	0.9	0.81
12:03:14	0.00	329.9	151.9	0.4	0.00
12:07:37	0.00	130.8	312.8	0.2	0.00
12:12:01	0.00	73.8	255.8	0.4	0.00
12:16:25	0.00	94.1	276.1	0.5	0.00
12:20:48	0.00	67.9	249.9	0.5	0.00
12:25:12	0.00	25.8	207.8	0.7	0.00
12:29:36	-0.01	32.8	214.8	0.8	0.94
12:34:00	-0.01	33.4	215.4	1.3	0.96
12:38:25	-0.01	28.7	210.7	1.5	0.99
12:42:47		20.0	202.0	1.4	0.00
12:47:12	-0.01	14.4	196.4	1.5	0.53
12:51:35	-0.01	27.1	209.1	0.9	0.64

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:55:59	-0.01	31.6	213.6	1.0	0.56
13:00:21	-0.01	13.6	195.6	0.9	0.38
13:04:45	-0.01	345.3	167.3	0.9	0.00
13:09:10	-0.01	334.2	156.2	0.9	0.99
13:13:32	-0.01	321.5	143.5	1.1	0.67
13:17:56	-0.01	345.6	167.6	1.1	0.69
13:22:18	-0.01	30.1	212.1	1.6	0.79
13:26:43	-0.01	46.9	228.9	1.9	0.98
13:31:06	-0.02	46.9	228.9	2.4	0.94
13:35:29	-0.01	46.3	228.3	2.4	0.99
13:39:51	-0.02	46.2	228.2	2.0	0.76
13:44:16	-0.02	37.2	219.2	1.8	0.52
13:48:39	-0.02	35.4	217.4	1.9	0.44
13:53:03	-0.01	39.6	221.6	1.7	0.01
13:57:26	-0.01	54.7	236.7	1.9	0.03
14:01:50	-0.01	56.4	238.4	2.4	0.01
14:06:13	-0.01	48.5	230.5	2.5	0.58
14:10:36	-0.02	41.2	223.2	2.9	0.96
14:15:15	-0.02	31.2	213.2	3.2	0.83
14:19:23	-0.03	20.2	202.2	3.3	0.97
14:23:47	-0.02	11.0	193.0	3.2	0.96
14:28:10	-0.02	359.1	181.1	3.1	1.00
14:32:33	-0.02	358.2	180.2	3.0	0.97
14:36:57	-0.05	356.9	178.9	2.3	0.10
14:41:21	-0.04	321.3	143.3	1.9	0.01
14:45:45	-0.05	310.9	132.9	2.1	0.00
14:50:08	-0.06	294.0	116.0	2.1	0.00
14:54:31	-0.12	278.8	100.8	2.2	0.62
14:58:55	-0.07	295.1	117.1	2.4	0.97
15:03:20	-0.04	309.5	131.5	1.5	1.00
15:07:44	-0.05	328.5	150.5	1.0	0.94
15:12:07	-0.01	352.4	174.4	1.4	0.94
15:16:33		352.4	174.4	1.6	0.00
15:21:21		352.6	174.6	1.5	0.00
15:25:23	-0.04	330.2	152.2	1.0	0.96

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
15:29:48	-0.03	300.9	122.9	1.9	1.00
15:34:14	-0.07	295.6	117.6	1.1	0.50
15:38:40	-0.16	225.1	47.1	0.8	0.65
15:43:05	-0.08	190.7	12.7	1.6	0.98
15:47:30	-0.04	166.3	348.3	1.4	1.00
15:51:56	-0.02	157.9	339.9	1.7	1.00
15:56:21	-0.02	148.3	330.3	1.1	0.99
16:00:47	-0.01	5.2	187.2	0.8	1.00
16:05:11	-0.02	350.8	172.8	2.2	1.00
16:09:36		331.0	153.0	2.9	0.00
16:13:59		328.3	150.3	3.2	0.00
16:18:25		332.6	154.6	2.6	0.00
16:22:49		334.1	156.1	1.9	0.00
16:27:12		357.2	179.2	1.3	0.00
16:35:14	0.00	352.2	174.2	0.6	0.82
16:39:38	0.00	320.5	142.5	0.7	0.68
16:44:03	-0.01	312.9	134.9	1.2	0.59
16:48:28	0.00	321.7	143.7	1.5	0.96
16:52:51		329.2	151.2	1.6	0.00
17:00:53		343.1	165.1	2.1	0.00
17:05:18		331.4	153.4	2.1	0.00
17:09:43	-0.01	315.7	137.7	1.7	1.00
17:14:07	0.00	283.3	105.3	1.7	0.99
17:18:30	0.00	281.4	103.4	1.9	0.97
17:22:55	0.00	283.4	105.4	2.1	0.85
17:27:20	0.00	296.1	118.1	1.9	0.68

Table A-25. Summary Data Table of VRPM Plane E456 for August 13, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
10:33:10	0.00	340.7	95.7	0.8	0.82
10:37:33	-0.01	347.0	102.0	1.0	0.82
10:42:01	0.00	354.4	109.4	1.1	0.57
10:46:24	0.00	357.4	112.4	1.1	0.97
10:50:48	0.00	353.6	108.6	1.2	0.82
10:55:12	0.00	345.7	100.7	1.1	0.92
10:59:36	0.00	344.5	99.5	1.2	-0.04
11:04:01	0.00	349.8	104.8	1.4	0.97
11:08:23	0.00	342.5	97.5	1.1	0.78
11:12:46	0.00	353.5	108.5	1.3	0.99
11:17:08	0.00	1.7	116.7	1.3	0.97
11:21:32	0.00	353.0	108.0	1.1	0.95
11:25:55	0.00	343.1	98.1	0.8	0.90
11:30:19	0.00	338.9	93.9	0.8	0.52
11:34:42	0.01	336.0	91.0	1.0	0.72
11:39:04	0.00	329.5	84.5	1.1	0.75
11:43:29	0.00	340.5	95.5	1.3	0.88
11:47:51	0.00	346.1	101.1	1.5	0.95
11:52:15	0.00	339.1	94.1	1.3	1.00
11:56:38	0.00	332.2	87.2	1.0	0.85
12:01:00	0.00	327.9	82.9	0.7	0.88
12:05:25	0.00	355.9	110.9	0.1	0.00
12:09:48	0.00	110.0	225.0	0.3	0.00
12:14:12	0.00	74.2	189.2	0.4	0.00
12:18:37	0.00	94.8	209.8	0.4	0.00
12:22:59	0.00	39.6	154.6	0.6	0.00
12:27:24	0.00	32.4	147.4	0.8	0.52
12:31:47	0.00	31.8	146.8	1.0	0.41
12:36:11	0.00	26.6	141.6	1.4	0.99

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:40:35		19.5	134.5	1.5	0.00
12:44:58		18.2	133.2	1.5	0.00
12:49:23		17.6	132.6	1.3	0.00
12:53:46		25.4	140.4	0.9	0.00
12:58:09	0.00	11.2	126.2	1.0	0.75
13:02:32	0.00	352.9	107.9	0.9	0.74
13:06:57	0.00	341.6	96.6	0.8	0.80
13:11:20	0.00	325.8	80.8	1.0	0.96
13:15:43	0.00	332.0	87.0	1.2	-0.06
13:20:06	0.00	2.6	117.6	1.2	0.77
13:24:29	-0.01	45.0	160.0	1.6	0.82
13:28:54	-0.01	48.5	163.5	2.0	0.88
13:33:16		44.3	159.3	2.4	0.00
13:37:39		43.1	158.1	2.2	0.00
13:42:03		48.9	163.9	1.7	0.00
13:46:27		36.7	151.7	2.0	0.00
13:50:50		36.6	151.6	1.7	0.00
13:55:14		46.7	161.7	1.6	0.00
13:59:38		59.8	174.8	2.2	0.00
14:04:01		54.9	169.9	2.5	0.00
14:08:24		43.0	158.0	2.6	0.00
14:12:46		36.1	151.1	2.9	0.00
14:17:10		28.0	143.0	3.2	0.00
14:21:34		16.3	131.3	3.3	0.00
14:25:58	-0.01	2.2	117.2	3.1	0.20
14:30:21	-0.01	358.2	113.2	3.1	0.33
14:34:45	-0.01	357.8	112.8	2.7	0.43
14:39:08	-0.01	343.3	98.3	1.9	0.44
14:43:32	0.00	312.4	67.4	2.1	0.87
14:47:55	-0.01	309.8	64.8	2.1	0.70

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:52:18	-0.01	287.6	42.6	2.0	0.83
14:56:42	0.00	287.3	42.3	2.5	0.99
15:01:08	-0.01	299.9	54.9	2.0	0.88
15:05:31	-0.01	318.7	73.7	1.3	0.89
15:09:56	-0.01	351.5	106.5	1.1	0.93
15:14:20	0.00	346.5	101.5	1.6	1.00
15:18:46	-0.01	348.6	103.6	1.4	1.00
15:23:11	-0.01	349.1	104.1	1.3	0.98
15:27:34	0.01	308.9	63.9	1.5	0.97
15:32:00	0.01	308.3	63.3	1.6	0.98
15:36:26	0.02	271.9	26.9	0.9	0.59
15:40:52	0.02	191.3	306.3	1.5	0.46
15:45:17	0.02	184.3	299.3	1.3	0.68
15:49:42	0.01	158.1	273.1	1.5	0.43
15:54:09	0.01	154.7	269.7	1.5	0.30
15:58:33	0.00	127.7	242.7	0.5	0.83
16:02:57	0.00	2.1	117.1	1.6	0.41
16:07:23	0.02	330.7	85.7	2.6	0.45
16:11:47	0.03	327.0	82.0	3.2	0.67
16:16:12	0.02	330.1	85.1	2.9	0.96
16:20:36	0.01	334.7	89.7	2.3	0.88
16:25:00	0.01	336.0	91.0	1.4	0.94
16:58:40	0.00	338.6	93.6	2.1	0.99
17:03:06	0.00	340.5	95.5	2.0	0.64
17:07:30	0.00	322.3	77.3	1.9	0.94
17:11:54	0.01	297.7	52.7	1.5	0.89
17:16:18	0.01	282.2	37.2	1.8	0.90
17:20:43	0.01	279.4	34.4	2.0	0.86
17:25:07	0.01	289.7	44.7	1.9	0.95
17:29:31	0.01	303.3	58.3	2.0	0.91

Table A-26. Summary Data Table of VRPM Plane A123 for August 14, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:18:50	0.03	48.8	344.8	1.0	0.97
09:24:10	0.03	32.3	328.3	1.2	0.98
09:28:31	0.02	14.3	310.3	1.4	0.84
09:32:54	0.01	15.3	311.3	1.2	0.91
09:37:16		11.9	307.9	1.3	0.00
09:41:38	0.03	11.4	307.4	1.4	0.45
09:45:58	0.02	6.9	302.9	1.3	0.94
09:50:21	0.03	12.6	308.6	1.4	0.90
09:54:42	0.04	13.0	309.0	1.5	0.91
09:59:04	0.04	3.8	299.8	1.4	0.94
10:03:28	0.03	5.5	301.5	1.5	0.44
10:07:51	0.02	357.8	293.8	1.7	0.77
10:12:14		349.9	285.9	1.9	0.00
10:16:35		345.7	281.7	1.8	0.00
10:20:58	0.01	351.6	287.6	1.9	0.89
10:25:22	0.01	353.6	289.6	1.7	0.64
10:29:44	0.02	0.5	296.5	1.6	0.94
10:34:05	0.02	1.7	297.7	1.5	0.97
10:38:27	0.01	358.4	294.4	1.4	0.91
10:42:48	0.01	0.3	296.3	1.2	0.92
10:47:09	0.00	350.0	286.0	1.2	0.82
10:51:30	0.00	347.3	283.3	1.1	0.94
10:55:51	0.01	349.8	285.8	1.3	0.92
11:00:15	0.01	355.4	291.4	1.5	0.92
11:04:36	0.01	356.8	292.8	1.5	0.79
11:08:59	0.01	2.6	298.6	1.4	0.15
11:13:20	0.01	10.6	306.6	1.7	0.13
11:17:43	0.02	11.1	307.1	1.6	0.03
11:22:04	0.02	7.0	303.0	1.6	0.05

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:26:26	0.02	6.8	302.8	1.7	0.03
11:30:47	0.02	3.9	299.9	1.6	0.15
11:35:08	0.01	354.8	290.8	1.3	0.06
11:39:32	0.00	345.7	281.7	1.1	0.98
11:43:54	0.01	13.9	309.9	0.8	0.97
11:48:15	0.01	34.3	330.3	0.5	0.98
11:52:36	0.01	110.5	46.5	0.3	0.94
11:57:00	0.01	142.3	78.3	0.8	0.96
12:01:21	0.01	146.5	82.5	1.3	1.00
12:05:44	-0.01	165.1	101.1	1.4	0.99
12:10:05	0.02	155.1	91.1	1.1	0.98
12:14:30	0.03	134.5	70.5	0.9	0.98
12:18:54	0.04	112.3	48.3	0.9	1.00
12:23:17	0.07	76.0	12.0	1.0	1.00
12:27:39	0.08	53.9	349.9	1.2	0.99
12:32:03	0.07	65.8	1.8	0.9	1.00
12:36:26	0.04	61.3	357.3	0.5	1.00
12:40:49	-0.01	200.8	136.8	0.4	1.00
12:45:11	0.00	205.4	141.4	0.6	0.00
12:49:33	0.00	205.7	141.7	0.6	0.00
12:53:56	0.00	182.3	118.3	0.5	0.00
12:58:17	0.00	142.0	78.0	0.6	1.00
13:02:39	0.05	96.5	32.5	1.0	0.99
13:07:00	0.08	81.8	17.8	1.2	0.99
13:11:24	0.12	67.7	3.7	1.3	0.98
13:15:47	0.11	50.4	346.4	1.3	0.97
13:20:09	0.00	6.0	302.0	0.3	0.00
13:24:30	0.00	229.2	165.2	0.4	0.00
13:28:53	-0.01	225.9	161.9	0.4	1.00
13:33:15	0.00	254.6	190.6	0.3	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:37:38	0.03	24.2	320.2	1.0	0.81
13:42:01	0.06	18.7	314.7	2.6	0.91
13:46:23	0.06	10.8	306.8	2.7	0.97
13:50:46	0.01	346.7	282.7	2.1	0.85
13:55:08	0.01	336.3	272.3	1.6	0.74
13:59:30	0.00	277.3	213.3	1.0	1.00
14:03:51	0.00	228.1	164.1	1.2	0.95
14:08:14	0.02	200.9	136.9	0.8	0.97
14:12:36	0.05	138.1	74.1	0.9	0.50
14:16:58	0.05	128.9	64.9	0.7	0.62
14:21:20	0.03	178.8	114.8	0.8	0.63
14:25:41	0.02	220.8	156.8	1.4	0.62
14:30:02	-0.01	250.7	186.7	1.6	0.98
14:34:26		263.1	199.1	2.3	0.00
14:38:47		280.7	216.7	2.2	0.00
14:43:09	0.00	313.7	249.7	1.9	1.00
14:47:30	0.00	318.1	254.1	1.8	0.97
14:51:53	0.00	338.7	274.7	1.4	1.00
14:56:15	0.01	347.5	283.5	1.8	1.00
15:00:37	0.00	344.5	280.5	1.6	1.00
15:04:59	0.00	339.0	275.0	1.5	0.98
15:09:21	0.00	336.7	272.7	1.7	0.99
15:13:42	-0.02	330.0	266.0	1.4	0.02
15:18:03	-0.02	336.7	272.7	1.8	0.01
15:22:26	-0.01	341.9	277.9	1.8	0.02
15:26:49	-0.01	350.5	286.5	2.0	0.02
15:31:10	-0.01	354.5	290.5	2.2	0.01
15:35:31	0.00	3.2	299.2	2.5	0.01
15:39:55	0.00	352.7	288.7	2.1	0.01
15:44:19	0.00	345.9	281.9	2.4	0.01

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
15:48:41	0.01	343.1	279.1	2.5	0.20
15:53:02		333.4	269.4	2.7	0.00
15:57:25		340.2	276.2	2.8	0.00
16:01:49		340.4	276.4	2.7	0.00
16:06:12		344.3	280.3	2.8	0.00
16:10:35		346.3	282.3	2.7	0.00
16:14:57		337.2	273.2	2.5	0.00
16:19:22		323.2	259.2	2.3	0.00
16:23:44		297.6	233.6	2.1	0.00
16:28:08		285.9	221.9	2.4	0.00
16:32:30		269.0	205.0	2.8	0.00
16:36:54		273.4	209.4	2.8	0.00
16:41:15		264.4	200.4	2.0	0.00
16:45:37	0.00	313.5	249.5	1.9	1.00
16:50:00		315.8	251.8	2.2	0.00

Table A-27. Summary Data Table of VRPM Plane A456 for August 14, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:22:01	0.01	37.8	72.8	1.1	1.00
09:26:21	0.02	23.0	58.0	1.3	0.76
09:30:42	0.02	14.1	49.1	1.4	0.88
09:35:04	0.02	9.3	44.3	1.2	0.85
09:39:27	0.02	11.7	46.7	1.5	0.87
09:43:48	0.02	9.7	44.7	1.4	0.92
09:48:09	0.02	13.6	48.6	1.3	0.93
09:52:32	0.02	10.2	45.2	1.4	0.85
09:56:53	0.02	8.2	43.2	1.5	0.78
10:01:15	0.02	3.7	38.7	1.4	0.95
10:05:39	0.03	4.8	39.8	1.6	1.00
10:10:03	0.04	352.7	27.7	1.8	0.88
10:14:25	0.05	345.9	20.9	1.8	1.00
10:18:47	0.06	350.5	25.5	1.8	0.96
10:23:10	0.06	349.4	24.4	1.7	0.91
10:27:33	0.06	357.6	32.6	1.6	0.90
10:31:54	0.06	2.8	37.8	1.6	0.86
10:36:15	0.07	1.6	36.6	1.4	0.96
10:40:38	0.07	359.6	34.6	1.3	0.60
10:45:45	0.07	356.6	31.6	1.3	0.58
10:49:21	0.07	347.5	22.5	1.2	0.75
10:53:42	0.06	348.2	23.2	1.2	0.93
10:58:04	0.06	353.6	28.6	1.4	0.98
11:02:25	0.06	352.8	27.8	1.5	0.92
11:06:48	0.05	1.8	36.8	1.5	0.74
11:11:10	0.05	7.2	42.2	1.5	0.98
11:15:31	0.06	13.9	48.9	1.7	0.96
11:19:54	0.07	7.8	42.8	1.5	0.93
11:24:15	0.08	3.0	38.0	1.6	0.91

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:28:37	0.07	9.6	44.6	1.7	1.00
11:32:58	0.07	2.1	37.1	1.4	0.46
11:37:20	0.08	351.4	26.4	1.3	0.29
11:41:42	0.07	356.5	31.5	1.0	0.88
11:46:04	0.04	25.2	60.2	0.7	0.86
11:50:26	0.03	72.1	107.1	0.4	0.87
11:54:47	0.01	140.1	175.1	0.5	0.91
11:59:10	-0.01	135.5	170.5	1.1	0.98
12:03:32	-0.01	155.5	190.5	1.4	0.95
12:07:55	-0.01	164.2	199.2	1.3	0.93
12:12:18	-0.01	139.9	174.9	0.9	0.95
12:16:41	-0.01	128.3	163.3	0.9	0.99
12:21:05	0.00	85.0	120.0	0.9	0.96
12:25:27	0.00	63.5	98.5	1.1	0.96
12:29:51	0.00	50.9	85.9	1.1	0.98
12:34:14	0.00	63.5	98.5	0.8	1.00
12:38:36	0.00	85.6	120.6	0.2	1.00
12:42:59	0.00	209.7	244.7	0.6	0.00
12:47:21	0.00	203.9	238.9	0.7	0.00
12:51:45	0.00	198.5	233.5	0.5	0.00
12:56:05	0.00	163.5	198.5	0.6	0.00
13:00:28	-0.02	109.9	144.9	0.8	0.69
13:04:50	-0.01	88.1	123.1	1.0	0.09
13:09:12	-0.04	77.4	112.4	1.3	0.89
13:13:35	-0.01	61.7	96.7	1.3	0.98
13:17:58	0.00	41.7	76.7	0.8	0.00
13:22:20	0.00	310.3	345.3	0.3	0.00
13:26:42	0.00	227.3	262.3	0.5	0.99
13:31:05	0.00	231.8	266.8	0.3	0.00
13:35:27	0.00	318.5	353.5	0.2	0.99

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
13:39:50	0.01	23.5	58.5	2.0	0.84
13:44:12	0.03	11.1	46.1	2.9	0.85
13:48:34	0.03	358.3	33.3	2.3	0.85
13:52:57	0.03	338.7	13.7	1.8	0.92
13:57:19	0.01	320.0	355.0	1.2	0.99
14:01:41	0.00	240.0	275.0	1.3	0.99
14:06:02	0.00	223.4	258.4	1.0	0.99
14:10:24	-0.01	163.1	198.1	0.8	0.98
14:14:47	-0.01	133.1	168.1	0.9	0.96
14:19:09	-0.01	156.4	191.4	0.8	0.97
14:23:30	-0.01	206.6	241.6	1.2	0.98
14:27:51	0.00	233.9	268.9	1.4	1.00
14:32:13	0.01	259.4	294.4	2.0	1.00
14:36:36	0.01	263.9	298.9	2.3	1.00
14:40:58	0.01	295.6	330.6	2.0	0.87
14:45:20	0.02	318.9	353.9	2.0	0.89
14:49:41	0.03	327.4	2.4	1.5	0.99
14:54:04	0.04	342.7	17.7	1.6	1.00
14:58:25	0.05	345.6	20.6	1.7	0.99
15:02:48	0.05	339.0	14.0	1.6	0.99
15:07:09	0.05	343.0	18.0	1.5	1.00
15:11:31	0.05	330.0	5.0	1.7	0.99
15:15:52	0.05	332.6	7.6	1.5	0.96
15:20:15	0.05	337.6	12.6	1.9	0.97
15:24:37	0.06	353.6	28.6	1.8	0.97
15:29:00	0.09	349.2	24.2	2.1	0.99
15:33:21	0.10	359.1	34.1	2.5	0.99
15:37:43	0.08	358.3	33.3	2.2	1.00
15:42:06	0.09	350.8	25.8	2.3	1.00
15:46:30	0.09	345.5	20.5	2.6	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
15:50:51	0.09	339.7	14.7	2.7	0.99
15:55:13	0.08	333.1	8.1	2.7	0.97
15:59:37	0.08	341.3	16.3	2.8	0.90
16:04:00	0.07	341.6	16.6	2.9	0.91
16:08:24	0.06	346.1	21.1	2.7	0.96
16:12:47	0.05	346.7	21.7	2.8	0.97
16:17:09	0.05	327.3	2.3	2.2	0.94
16:21:32	0.04	313.6	348.6	2.2	0.97
16:25:54	0.03	292.1	327.1	2.2	0.99
16:30:18	0.02	277.5	312.5	2.6	0.99
16:34:42	0.01	272.5	307.5	2.7	0.99
16:39:03	0.01	263.0	298.0	2.3	1.00
16:43:26	0.02	292.8	327.8	1.7	0.89
16:47:48	0.03	317.8	352.8	2.2	0.99
16:52:12	0.02	309.8	344.8	2.2	0.99

Table A-28. Summary Data Table of VRPM Plane E123 for August 14, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:22:29		34.7	216.7	1.2	0.00
09:27:55		17.4	199.4	1.4	0.00
09:32:18		15.2	197.2	1.2	0.00
09:36:43		12.2	194.2	1.3	0.00
09:41:07		11.1	193.1	1.4	0.00
09:45:32		6.6	188.6	1.3	0.00
09:49:55		12.8	194.8	1.3	0.00
09:54:20		13.8	195.8	1.5	0.00
09:58:44		3.1	185.1	1.4	0.00
10:03:09		5.4	187.4	1.5	0.00
10:07:32		358.5	180.5	1.7	0.00
10:11:57		350.4	172.4	1.9	0.00
10:16:24		345.7	167.7	1.8	0.00
10:20:48		351.5	173.5	1.9	0.00
10:25:12		353.6	175.6	1.7	0.00
10:29:38		0.5	182.5	1.6	0.00
10:34:05	-0.01	1.8	183.8	1.5	0.24
10:38:30		358.6	180.6	1.4	0.00
10:42:56		0.4	182.4	1.2	0.00
10:47:22		349.8	171.8	1.2	0.00
10:51:48		347.7	169.7	1.1	0.00
10:56:14		351.2	173.2	1.3	0.00
11:00:40		354.9	176.9	1.5	0.00
11:05:07		357.1	179.1	1.5	0.00
11:09:33		4.7	186.7	1.5	0.00
11:13:59		11.3	193.3	1.8	0.00
11:18:23		9.0	191.0	1.6	0.00
11:22:50	-0.01	6.1	188.1	1.6	0.57
11:27:15	-0.01	8.6	190.6	1.7	0.95
11:31:40		2.2	184.2	1.5	0.00
11:36:05		353.1	175.1	1.3	0.00
11:40:31		349.6	171.6	1.1	0.00
11:44:56		26.5	208.5	0.8	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:49:22	-0.01	52.2	234.2	0.4	0.04
11:53:47	-0.01	136.0	318.0	0.3	0.01
11:58:13	0.00	137.7	319.7	1.0	0.01
12:02:39	0.00	151.6	333.6	1.4	0.02
12:07:01	0.00	165.8	347.8	1.4	0.02
12:11:27	-0.01	146.4	328.4	0.9	0.96
12:15:54	-0.01	133.1	315.1	0.9	0.95
12:20:19	-0.01	90.1	272.1	0.8	1.00
12:24:45	-0.01	68.7	250.7	1.1	0.93
12:29:08	-0.01	52.3	234.3	1.2	0.01
12:33:34	-0.03	63.7	245.7	0.8	0.75
12:37:59	-0.03	66.3	248.3	0.3	0.19
12:42:25	0.00	209.4	31.4	0.6	0.00
12:46:51	0.00	203.1	25.1	0.7	0.00
12:51:13	0.00	197.9	19.9	0.6	0.00
12:55:39	0.00	167.5	349.5	0.6	0.00
13:00:05	0.01	116.2	298.2	0.8	0.97
13:04:32	0.00	88.2	270.2	1.0	0.87
13:08:57	0.00	78.0	260.0	1.2	0.79
13:13:18	-0.01	63.0	245.0	1.3	0.94
13:17:44	0.00	42.2	224.2	0.9	0.00
13:22:10	0.00	317.2	139.2	0.3	0.00
13:26:36	-0.02	228.6	50.6	0.5	0.03
13:31:01	0.00	229.9	51.9	0.3	0.00
13:35:26	-0.01	318.7	140.7	0.2	0.01
13:39:50	-0.01	23.3	205.3	1.9	0.01
13:44:15	-0.01	11.1	193.1	2.9	1.00
13:48:40	-0.01	357.7	179.7	2.3	0.90
13:53:04	-0.01	338.5	160.5	1.8	1.00
13:57:29	-0.01	318.3	140.3	1.1	0.75
14:01:53	-0.01	238.5	60.5	1.3	0.66
14:06:19	-0.02	222.1	44.1	0.9	0.81
14:10:44	-0.05	159.0	341.0	0.9	0.86
14:15:11	-0.01	133.6	315.6	0.9	0.22
14:19:36	-0.01	159.6	341.6	0.8	0.61

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:24:02	0.01	211.9	33.9	1.3	0.95
14:28:27	0.03	237.1	59.1	1.4	0.84
14:32:52	0.02	261.6	83.6	2.1	0.70
14:37:17	0.02	269.0	91.0	2.3	0.71
14:41:40	0.00	299.6	121.6	1.9	0.99
14:46:05	0.00	319.0	141.0	1.9	0.88
14:50:30		331.7	153.7	1.4	0.00
14:54:54		346.4	168.4	1.7	0.00
14:59:17		345.3	167.3	1.6	0.00
15:03:42		336.4	158.4	1.6	0.00
15:08:07		340.9	162.9	1.6	0.00
15:12:33		327.8	149.8	1.6	0.00
15:16:55		334.8	156.8	1.6	0.00
15:21:20		337.7	159.7	2.0	0.00
15:25:44		350.1	172.1	1.8	0.00
15:30:08		350.7	172.7	2.1	0.00
15:34:32		3.0	185.0	2.5	0.00
15:38:54		352.6	174.6	2.0	0.00
15:43:18		348.3	170.3	2.4	0.00
15:47:40		344.1	166.1	2.6	0.00
15:52:04		337.1	159.1	2.7	0.00
15:56:27		337.0	159.0	2.8	0.00
16:00:50		341.3	163.3	2.8	0.00
16:05:13		344.0	166.0	2.9	0.00
16:09:38		347.6	169.6	2.7	0.00
16:14:02		343.2	165.2	2.7	0.00

Table A-29. Summary Data Table of VRPM Plane E456 for August 14, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:25:41		25.3	140.3	1.3	0.00
09:30:05		14.5	129.5	1.4	0.00
09:34:31		9.1	124.1	1.2	0.00
09:38:54	-0.01	12.8	127.8	1.5	0.73
09:43:18		10.1	125.1	1.4	0.00
09:47:42		13.0	128.0	1.3	0.00
09:52:07		10.1	125.1	1.4	0.00
09:56:32		8.4	123.4	1.5	0.00
10:00:55		4.1	119.1	1.4	0.00
10:05:20	-0.01	5.1	120.1	1.6	0.91
10:09:45	-0.01	352.7	107.7	1.8	0.85
10:14:11	-0.01	345.8	100.8	1.8	0.77
10:18:35	-0.01	350.4	105.4	1.8	0.78
10:22:59	-0.01	349.3	104.3	1.7	0.80
10:27:24	-0.01	357.2	112.2	1.6	0.77
10:31:51	-0.01	2.3	117.3	1.6	0.87
10:36:17	0.00	1.3	116.3	1.4	0.88
10:40:44	0.00	359.8	114.8	1.3	0.87
10:45:09	0.00	356.3	111.3	1.3	0.83
10:49:35	0.00	347.3	102.3	1.2	0.67
10:54:01	0.00	347.9	102.9	1.2	1.00
10:58:27	0.00	354.9	109.9	1.4	0.81
11:02:53	0.00	353.0	108.0	1.5	0.57
11:07:19	0.00	1.7	116.7	1.4	0.30
11:11:44	0.00	8.5	123.5	1.6	0.80
11:16:09	-0.01	12.9	127.9	1.7	0.76
11:20:35	0.00	6.9	121.9	1.5	0.47
11:25:01	0.00	4.2	119.2	1.6	0.81
11:29:27	0.00	7.5	122.5	1.6	0.80
11:33:51	0.00	0.8	115.8	1.4	0.87
11:38:17	0.00	348.2	103.2	1.2	1.00
11:42:42	0.00	6.1	121.1	0.9	0.75
11:47:08	0.00	30.4	145.4	0.6	0.81

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:51:33	0.00	93.4	208.4	0.3	0.82
11:55:59	0.00	143.5	258.5	0.7	0.95
12:00:25	0.00	140.0	255.0	1.2	0.96
12:04:51	0.00	163.9	278.9	1.4	0.96
12:09:14	0.00	158.7	273.7	1.2	0.97
12:13:40	-0.01	134.2	249.2	0.9	0.89
12:18:05	0.00	117.6	232.6	0.9	0.91
12:22:32	-0.01	80.2	195.2	0.9	0.93
12:26:54	-0.01	54.4	169.4	1.2	0.96
12:31:20	-0.01	59.7	174.7	0.9	0.90
12:35:46	0.00	64.6	179.6	0.6	0.93
12:40:12	0.00	189.1	304.1	0.3	0.90
12:44:38	0.00	208.9	323.9	0.6	0.00
12:49:04	0.00	206.6	321.6	0.6	0.00
12:53:26	0.00	184.5	299.5	0.6	0.00
12:57:51	0.00	150.2	265.2	0.7	0.98
13:02:17	0.00	97.2	212.2	1.0	0.89
13:06:42	0.00	81.2	196.2	1.1	0.85
13:11:04	-0.01	68.6	183.6	1.3	0.99
13:15:31	-0.01	51.4	166.4	1.3	0.41
13:19:57	0.00	14.0	129.0	0.4	0.00
13:24:23	0.00	232.0	347.0	0.3	0.00
13:28:48	0.00	227.6	342.6	0.4	0.92
13:33:12	0.00	257.0	12.0	0.3	0.00
13:37:36	0.00	23.6	138.6	0.9	0.99
13:42:01	-0.01	18.7	133.7	2.6	0.98
13:46:27	-0.01	10.5	125.5	2.7	0.96
13:50:52	-0.02	346.3	101.3	2.1	0.40
13:55:17	-0.02	336.3	91.3	1.6	0.50
13:59:41	-0.02	275.6	30.6	1.0	0.63
14:04:05	-0.03	228.7	343.7	1.1	0.79
14:08:30	-0.02	200.8	315.8	0.7	0.88
14:12:57	-0.02	136.3	251.3	0.9	0.67
14:17:23	-0.03	137.0	252.0	0.7	0.93
14:21:47	-0.01	188.9	303.9	0.8	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
14:26:13	0.00	225.4	340.4	1.5	0.97
14:30:38	0.04	256.8	11.8	1.7	0.79
14:35:03	0.08	261.8	16.8	2.3	0.94
14:39:28	0.05	284.9	39.9	2.1	0.85
14:43:51	0.02	319.5	74.5	2.0	0.94
14:48:18	0.01	320.4	75.4	1.7	1.00
14:52:41	0.00	340.6	95.6	1.5	1.00
14:57:05	0.00	345.4	100.4	1.8	0.99
15:01:30	0.00	344.5	99.5	1.5	1.00
15:05:53	0.00	342.7	97.7	1.6	1.00
15:10:19	0.01	333.4	88.4	1.8	0.83
15:14:44	0.01	330.2	85.2	1.5	1.00
15:19:06	0.01	340.2	95.2	1.8	0.96
15:23:30	0.00	348.1	103.1	1.7	1.00
15:27:54	0.00	350.5	105.5	2.0	0.94
15:32:20	0.00	357.7	112.7	2.4	0.99
15:36:42	0.00	3.4	118.4	2.3	0.92
15:41:05	0.00	351.4	106.4	2.2	0.98
15:45:29	0.00	346.7	101.7	2.6	0.85
15:49:51	0.00	341.1	96.1	2.6	0.93
15:54:15	0.00	331.7	86.7	2.7	1.00
15:58:37	0.00	341.0	96.0	2.9	1.00
16:03:00	0.00	340.6	95.6	2.8	0.50
16:07:26	0.00	343.6	98.6	2.6	1.00
16:11:49	0.00	347.1	102.1	2.8	0.89
16:16:14	0.01	328.6	83.6	2.3	0.94

Table A-30. Summary Data Table of VRPM Plane A123 for August 15, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:29:09	0.04	60.9	356.9	0.8	0.99
09:34:31	0.05	41.7	337.7	1.0	0.98
09:38:53	0.06	48.3	344.3	0.9	0.91
09:43:15	0.05	67.1	3.1	0.8	1.00
09:47:39	0.07	74.3	10.3	1.2	1.00
09:52:01	0.06	64.6	0.6	1.2	0.69
09:56:23	0.05	73.2	9.2	1.2	0.80
10:00:45	0.05	72.0	8.0	1.2	0.98
10:05:08	0.04	53.1	349.1	1.5	0.76
10:09:30	0.04	45.5	341.5	1.3	0.79
10:13:50	0.04	28.7	324.7	1.5	0.60
10:18:12	0.07	16.5	312.5	1.7	0.59
10:22:33	0.06	4.8	300.8	1.5	0.88
10:26:54	0.05	1.6	297.6	1.5	0.94
10:31:15	0.06	8.4	304.4	1.4	0.81
10:35:36	0.05	31.8	327.8	1.1	0.70
10:40:01	0.04	32.6	328.6	1.2	0.74
10:44:21	0.04	34.1	330.1	1.3	0.86
10:48:41	0.07	45.3	341.3	1.4	0.98
10:53:01	0.07	37.9	333.9	1.3	0.71
10:57:24	0.06	42.0	338.0	1.2	0.14
11:01:46	0.06	55.0	351.0	1.3	0.95
11:06:07	0.07	55.6	351.6	1.4	0.99
11:10:30	0.06	57.5	353.5	1.5	0.85
11:14:51	0.03	52.2	348.2	1.6	0.95
11:19:13	0.04	35.8	331.8	1.5	0.94
11:23:36	0.06	29.8	325.8	1.5	0.98
11:27:57	0.07	21.9	317.9	1.6	0.95
11:32:19	0.07	17.2	313.2	1.6	0.92
11:36:42	0.09	14.9	310.9	2.0	0.90
11:41:05	0.05	19.2	315.2	2.0	1.00
11:45:27	0.02	2.1	298.1	2.3	0.95
11:49:50	0.01	352.0	288.0	2.2	0.95

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:54:11	0.01	351.9	287.9	2.5	1.00
11:58:33	0.00	345.4	281.4	2.4	1.00
12:02:56	0.00	339.4	275.4	2.4	0.93
12:07:17	0.01	348.2	284.2	2.3	0.65
12:11:40	0.01	335.5	271.5	2.0	0.45
12:16:02	0.01	316.0	252.0	1.9	0.01
12:20:23	0.01	310.4	246.4	1.7	0.01
12:24:46	0.01	302.7	238.7	1.8	0.08
12:29:08		302.6	238.6	2.4	0.00
12:33:30		316.4	252.4	1.8	0.00
12:37:51		320.0	256.0	1.3	0.00
12:42:13		333.3	269.3	1.4	0.00
12:46:35		348.4	284.4	2.1	0.00
12:50:56		351.5	287.5	2.4	0.00
12:55:18		346.3	282.3	3.0	0.00
12:59:36		346.7	282.7	3.6	0.00
13:03:58		351.6	287.6	4.1	0.00
13:08:18		347.0	283.0	3.8	0.00
13:12:41		347.4	283.4	3.7	0.00
13:17:00		342.5	278.5	3.8	0.00
13:21:22		340.5	276.5	3.7	0.00
13:25:43		341.4	277.4	3.6	0.00
13:30:06		344.8	280.8	3.9	0.00
13:34:28		348.2	284.2	4.1	0.00
13:38:49		347.5	283.5	4.3	0.00
13:43:13		346.6	282.6	4.8	0.00
13:47:34		344.1	280.1	4.7	0.00
13:51:55		343.1	279.1	4.7	0.00
13:56:17		341.0	277.0	4.8	0.00
14:00:41		344.7	280.7	5.0	0.00

Table A-31. Summary Data Table of VRPM Plane A456 for August 15, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:32:20	-0.01	41.1	76.1	1.0	0.82
09:36:42	-0.01	38.1	73.1	0.9	1.00
09:41:04	-0.01	50.0	85.0	0.8	1.00
09:45:28	0.00	72.4	107.4	1.1	0.98
09:49:50	0.00	69.2	104.2	1.2	0.93
09:54:11	0.01	65.1	100.1	1.2	0.78
09:58:34	0.00	77.8	112.8	1.2	0.98
10:02:56	0.01	61.5	96.5	1.4	0.95
10:07:18	0.01	45.9	80.9	1.4	0.86
10:11:40	0.01	38.2	73.2	1.3	0.99
10:16:01	0.01	21.5	56.5	1.7	0.89
10:20:23	0.02	9.6	44.6	1.6	0.88
10:24:44	0.01	4.6	39.6	1.5	0.97
10:29:05	0.02	355.4	30.4	1.4	1.00
10:33:25	0.01	17.8	52.8	1.1	0.88
10:37:48	0.02	34.9	69.9	1.0	0.98
10:42:10	0.01	33.5	68.5	1.3	1.00
10:46:30	0.01	37.9	72.9	1.3	0.86
10:50:51	0.00	41.3	76.3	1.2	0.84
10:55:13	0.00	33.3	68.3	1.2	0.00
10:59:35	0.00	53.2	88.2	1.1	0.97
11:03:57	0.00	50.8	85.8	1.3	0.99
11:08:19	0.00	53.9	88.9	1.5	0.99
11:12:40	0.00	58.0	93.0	1.5	0.99
11:17:03	0.01	41.7	76.7	1.5	0.99
11:21:25	0.01	26.5	61.5	1.6	0.96
11:25:47	0.01	25.9	60.9	1.5	0.97
11:30:09	0.02	18.0	53.0	1.7	1.00
11:34:31	0.02	16.2	51.2	1.7	0.99
11:38:53	0.03	15.5	50.5	2.1	0.89
11:43:16	0.04	13.5	48.5	2.2	0.98
11:47:37	0.06	356.8	31.8	2.1	0.82
11:52:01	0.07	350.6	25.6	2.5	1.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
11:56:23	0.06	350.0	25.0	2.3	0.98
12:00:45	0.07	340.6	15.6	2.5	0.89
12:05:06	0.07	342.2	17.2	2.2	0.66
12:09:29	0.05	347.0	22.0	2.1	0.81
12:13:51	0.05	320.4	355.4	1.8	0.80
12:18:13	0.04	314.3	349.3	1.7	0.98
12:22:35	0.03	304.1	339.1	1.8	1.00
12:26:57	0.03	296.0	331.0	2.2	0.99
12:31:19	0.03	309.6	344.6	2.1	0.98
12:35:41	0.02	319.8	354.8	1.5	0.98
12:40:02	0.03	329.9	4.9	1.3	0.94
12:44:25	0.03	342.2	17.2	1.7	0.96
12:48:45	0.04	353.7	28.7	2.2	0.96
12:53:07	0.04	347.4	22.4	2.8	0.95
12:57:27	0.04	347.9	22.9	3.4	0.99
13:01:48	0.03	352.1	27.1	3.8	0.97
13:06:08	0.03	349.3	24.3	3.9	0.99
13:10:28	0.03	346.2	21.2	3.7	0.99
13:14:51	0.03	343.4	18.4	3.7	0.99
13:19:11	0.03	342.9	17.9	3.8	1.00
13:23:33	0.03	339.9	14.9	3.5	0.99
13:27:55	0.03	342.5	17.5	3.8	0.97
13:32:17	0.04	344.0	19.0	4.1	1.00
13:36:39	0.04	349.7	24.7	4.3	0.99
13:41:02	0.04	347.2	22.2	4.6	0.98
13:45:24	0.04	345.8	20.8	4.8	1.00
13:49:44		342.7	17.7	4.6	0.00
13:54:07		343.6	18.6	5.0	0.00
13:58:29		344.7	19.7	5.0	0.00
14:02:52		339.0	14.0	5.0	0.00

Table A-32. Summary Data Table of VRPM Plane E123 for August 15, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:46:14		72.6	254.6	1.2	0.00
09:51:26		66.1	248.1	1.2	0.00
09:55:38		71.3	253.3	1.2	0.00
09:59:51		77.1	259.1	1.2	0.00
10:04:03		56.4	238.4	1.5	0.00
10:08:16		45.8	227.8	1.4	0.00
10:12:28		35.8	217.8	1.3	0.00
10:16:41		20.0	202.0	1.7	0.00
10:20:53		7.6	189.6	1.6	0.00
10:25:06		3.5	185.5	1.4	0.00
10:29:18		354.6	176.6	1.4	0.00
10:33:31		18.9	200.9	1.1	0.00
10:37:44		36.4	218.4	1.0	0.00
10:41:56		33.3	215.3	1.3	0.00
10:46:09		38.2	220.2	1.3	0.00
10:50:21		42.7	224.7	1.2	0.00
10:54:34		35.2	217.2	1.3	0.00
10:58:47		49.0	231.0	1.2	0.00
11:03:03		51.7	233.7	1.3	0.00
11:07:12		53.7	235.7	1.5	0.00
11:11:26		56.6	238.6	1.5	0.00
11:15:38		49.5	231.5	1.5	0.00
11:19:51		31.3	213.3	1.5	0.00
11:24:03		27.8	209.8	1.5	0.00
11:28:16		20.8	202.8	1.6	0.00
11:32:29		16.8	198.8	1.7	0.00
11:36:41		15.4	197.4	2.0	0.00
11:40:54		19.3	201.3	1.9	0.00
11:45:06		2.7	184.7	2.3	0.00
11:49:19		352.9	174.9	2.1	0.00
11:53:31		351.4	173.4	2.3	0.00
11:57:44		347.4	169.4	2.4	0.00
12:01:57		340.5	162.5	2.4	0.00

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:06:09		344.6	166.6	2.3	0.00
12:10:22		343.3	165.3	2.1	0.00
12:14:35		316.1	138.1	1.8	0.00
12:18:47	-0.01	313.9	135.9	1.7	1.00
12:23:01	-0.01	304.1	126.1	1.9	1.00
12:27:13		293.8	115.8	2.3	0.00
12:31:26		311.3	133.3	2.1	0.00
12:35:38	-0.02	319.1	141.1	1.5	0.00
12:39:52	-0.02	330.6	152.6	1.2	0.10
12:44:04	-0.02	338.6	160.6	1.7	0.01
12:48:17	-0.02	353.7	175.7	2.2	0.00
12:52:30	-0.02	346.6	168.6	2.7	0.00
12:56:42		347.6	169.6	3.3	0.00
13:00:56		350.4	172.4	3.7	0.00
13:05:08		349.9	171.9	3.9	0.00
13:09:21		346.1	168.1	3.8	0.00
13:13:33		346.1	168.1	3.8	0.00
13:17:47		342.8	164.8	3.8	0.00
13:22:00		338.8	160.8	3.6	0.00
13:26:14		341.7	163.7	3.7	0.00
13:30:27		343.9	165.9	4.0	0.00
13:34:39		349.7	171.7	4.1	0.00
13:38:53		347.9	169.9	4.4	0.00
13:43:07		346.2	168.2	4.7	0.00
13:47:19		344.3	166.3	4.8	0.00
13:51:32		343.9	165.9	4.7	0.00
13:55:45		341.7	163.7	4.9	0.00
14:00:03		345.6	167.6	5.0	0.00
14:04:15		339.2	161.2	5.0	0.00

Table A-33. Summary Data Table of VRPM Plane E456 for August 15, 2008 at the EnCana Benzel Facility

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
09:49:18		70.3	185.3	1.2	0.00
09:53:31		63.0	178.0	1.2	0.00
09:57:43		77.1	192.1	1.1	0.00
10:01:57		64.6	179.6	1.4	0.00
10:06:09		49.0	164.0	1.5	0.00
10:10:22		44.3	159.3	1.3	0.00
10:14:34		26.3	141.3	1.6	0.00
10:18:47		13.7	128.7	1.7	0.00
10:22:59	-0.02	4.2	119.2	1.4	0.37
10:27:11		359.9	114.9	1.5	0.00
10:31:24		8.4	123.4	1.4	0.00
10:35:36		32.9	147.9	1.1	0.00
10:39:49		33.9	148.9	1.2	0.00
10:44:02		34.7	149.7	1.2	0.00
10:48:14		44.2	159.2	1.3	0.00
10:52:27		41.7	156.7	1.2	0.00
10:56:40		37.1	152.1	1.3	0.00
11:00:52		59.0	174.0	1.2	0.00
11:05:05		55.2	170.2	1.3	0.00
11:09:18		54.1	169.1	1.5	0.00
11:13:31		56.5	171.5	1.5	0.00
11:17:44		40.8	155.8	1.5	0.00
11:21:56		27.3	142.3	1.6	0.00
11:26:09		24.0	139.0	1.5	0.00
11:30:21		17.2	132.2	1.7	0.00
11:34:34		17.3	132.3	1.7	0.00
11:38:47		15.4	130.4	2.1	0.00
11:42:59		14.2	129.2	2.3	0.00
11:47:12		357.1	112.1	2.1	0.00
11:51:24	0.00	350.2	105.2	2.5	0.99
11:55:37	0.00	352.6	107.6	2.3	0.97
11:59:49	0.00	343.0	98.0	2.6	0.96
12:04:02	0.00	343.2	98.2	2.3	0.97

Time	Flux [g/sec]	Wind Direction [degrees]	Rotated Wind Direction [degrees]	Wind Speed	CCF
12:08:15	0.00	349.0	104.0	2.3	0.87
12:12:27	0.00	330.1	85.1	2.0	0.88
12:16:40	0.00	314.5	69.5	1.8	0.99
12:20:53	0.00	308.5	63.5	1.8	0.89
12:25:06	0.00	299.5	54.5	1.9	1.00
12:29:18	0.01	300.7	55.7	2.3	1.00
12:33:31	0.00	316.7	71.7	1.7	1.00
12:37:45	0.01	319.9	74.9	1.3	0.99
12:41:57	0.00	335.4	90.4	1.4	0.93
12:46:10	0.00	346.2	101.2	1.9	1.00
12:50:23	-0.01	353.4	108.4	2.4	0.96
12:54:35	0.00	346.9	101.9	2.9	0.99
12:58:49	0.00	346.9	101.9	3.6	0.98
13:03:01	-0.01	353.2	108.2	4.0	0.99
13:07:14	0.00	346.6	101.6	3.8	1.00
13:11:26	0.00	349.5	104.5	3.8	1.00
13:15:40	0.00	340.6	95.6	3.7	0.87
13:19:53	0.00	340.6	95.6	3.8	0.97
13:24:06	0.00	340.4	95.4	3.5	1.00
13:28:19	0.00	343.1	98.1	3.8	0.99
13:32:31	0.00	345.4	100.4	4.1	0.84
13:36:46		349.3	104.3	4.2	0.00
13:40:59		347.3	102.3	4.6	0.00
13:45:12		345.1	100.1	4.7	0.00
13:49:24		342.5	97.5	4.6	0.00
13:53:38		343.0	98.0	4.9	0.00
13:57:56		344.8	99.8	4.9	0.00
14:02:08		342.4	97.4	5.1	0.00
14:06:21		340.8	95.8	4.9	0.00

This page intentionally left blank.