City of Fort Collins

Data Summary Report

H_2S and VOC

Air Monitoring Project

November 15, 2013 - February 15, 2014

Prepared for:

City of Fort Collins
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1.0 INTRODUCTION

Between November 15, 2013 and February 15, 2014, the City of Fort Collins performed a short term air quality monitoring assessment which was designed to help characterize ambient air quality in and around existing oil and gas operations within City limits. This project was funded jointly by the City of Fort Collins and Memorial Resource Development, LLC (MRD). Air Resource Specialists, Inc. (ARS) was the primary contractor for this effort, and laboratory analysis was performed by the Eastern Research Group, Inc. (ERG).

This 90-day study included continuous monitoring for hydrogen sulfide (H_2S) and meteorology, along with several 24-hour air samples which were analyzed for a number of speciated volatile organic compounds (VOCs). To ensure scientifically defensible data, monitoring systems adhered to operational protocols established and accepted by the U.S. Environmental Protection Agency (EPA). Additional background information on the project and methodology is included in the Air Monitoring Plan, which is provided as Appendix A. Any questions regarding this report should be addressed to:

The City of Fort Collins
Environmental Services Department
215 N. Mason Street
Fort Collins, CO 80524
(970) 221-6600

2.0 SITE SPECIFICATIONS

Monitoring for this effort was performed between November 15, 2013 and February 15, 2014 at a total of five (5) locations. Monitoring was conducted at three (3) sites in NE Fort Collins near existing oil and gas operations, and two (2) sites in downtown Fort Collins.

Figure 2-1 presents a map of the monitoring sites, and Table 2-1 presents site coordinates. Parameters monitored at each site are listed in Table 2-2. Figure 2-2 presents photos of monitoring systems at the NE sites, and Figure 2-3 presents photos of the canister samplers at the downtown sites. Site characteristics are described below.

NE Fort Collins Sites

- **Well Pad (WPFC) site:** The Well Pad site was located just north of the Richard's Lake subdivision, in an open field with an active well pad in a secure fenced location.
- **Hearth Fire (HFFC) site:** The Hearth Fire site was located within the Hearth Fire subdivision, in a fenced area with an active well.
- **Tank Battery (TBFC) site:** The Tank Battery site was located on Memorial Resource Development property near the north entrance to the Hearthfire development and co-located with the oil and gas production infrastructure, including storage tanks.

Downtown Fort Collins Sites

- **City Park (CPFC) site:** The City Park site was located within the fenced perimeter of the City Park pool off of City Park Drive and near Mulberry Street.
- **Mason Street (MSFC) site:** The Mason Street location was located on the roof of a Colorado State University maintenance building near the intersection of Mason and Pitkin streets. This site was chosen to represent downtown because it is collocated with existing particulate monitoring run by the Colorado Department of Health and Environment (CDPHE), and offered secure access.

The three (3) stations in NE Fort Collins continuously monitored hydrogen sulfide (H_2S) and meteorological parameters using a system of stations owned by Denbury Resources, Inc., and leased per a separate agreement between Denbury and the City for the duration of this effort. The Denbury systems were designed with Environmental Protection Agency (EPA) Prevention of Significant Deterioration (PSD) grade meteorological sensors and H_2S sensors which were originally designed to trigger H_2S exposure alarms at high concentrations.

Monitoring for speciated non-methane organic carbon compounds (SNMOCs) and methane (CH_4) (subsets of VOCs), was conducted at the Tank Battery and Well Pad sites in NE Fort Collins, and at both downtown sites (City Park and Mason Street). Siltek® evacuated stainless steel canisters were manually deployed at each monitoring site every 12 days in accordance with EPA's prescribed 12-day monitoring schedule. During this period, five (5)

canister samples were collected at each site and analyzed at ERG laboratories following EPA's Compendium Methods TO-12, augmented with CH_4 analysis.

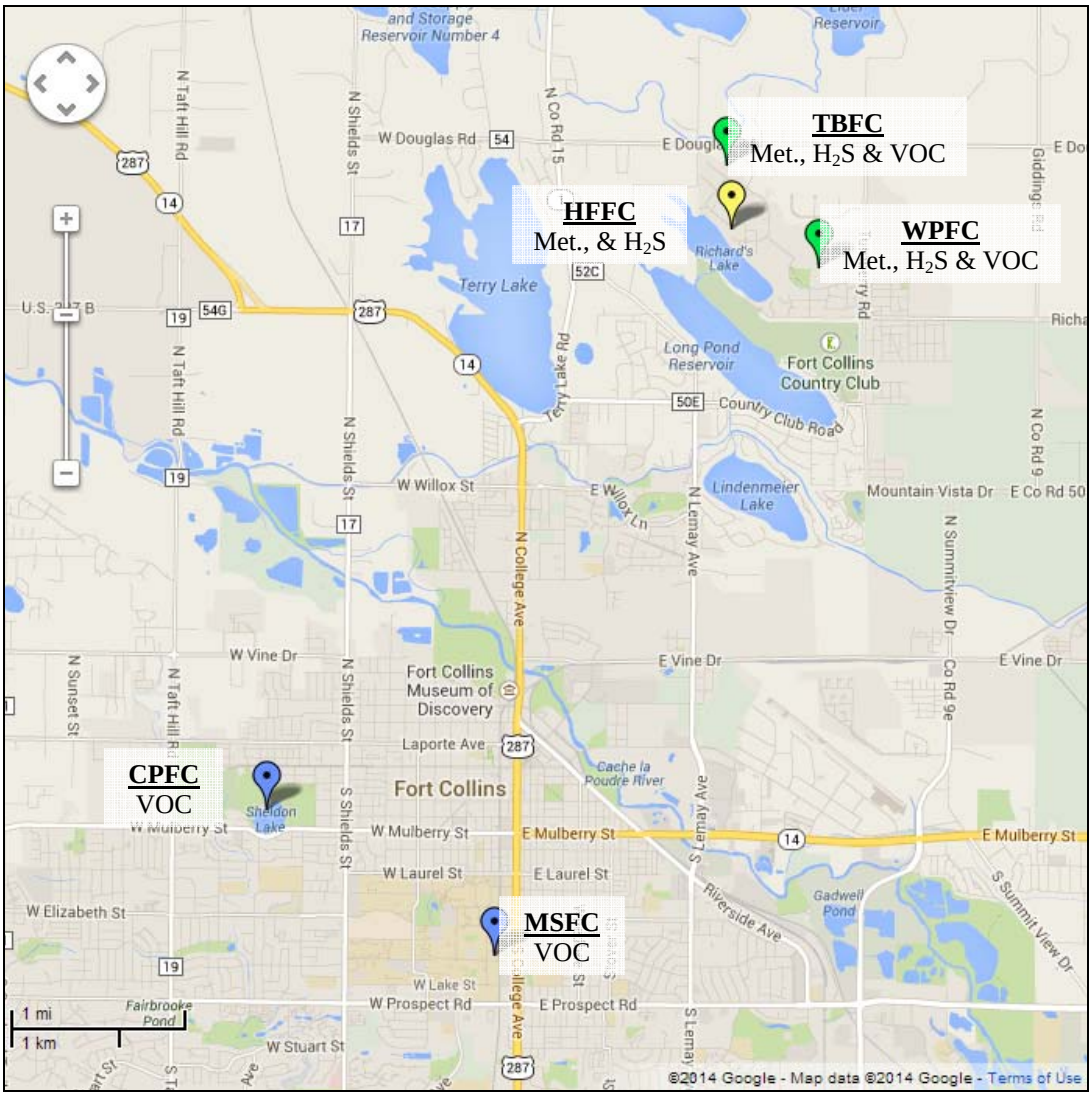

Figure 2-1. Map depicting City of Fort Collins monitoring sites.

Table 2-1
Monitoring Site Coordinates

Site Name	Latitude (°N)	Longitude (°W)
Well Pad (WPFC)	40° 37' 45"	105° 02' 39"
Hearth Fire (HFFC)	40° 37' 56"	105° 03' 12"
Tank Battery (TBFC)	40° 38' 16"	105° 03' 60"
City Park (CPFC)	40° 35' 00"	105° 06' 17"
Mason Street (MSFC)	40° 34' 17"	105° 04' 46"

Table 2-2
Parameters Monitored by Site

Parameter	Method	Sampling Frequency
Tank Battery Site, Fort Collins		
SNMOC	TO-12	24-hour (1/12 day)
Methane	ASTM D1946	24-hour (1/12 day)
H_2S	Electrochemical Sensor	Hourly
Meteorology	Various	Hourly
Well Pad Site, Fort Collins		
SNMOC	TO-12	24-hour (1/12 day)
Methane	ASTM D1946	24-hour (1/12 day)
H_2S	Electrochemical Sensor	Hourly
Meteorology	Various	Hourly
Hearth Fire Site, Fort Collins		
H_2S	Electrochemical Sensor	Hourly
Meteorology	Various	Hourly
City Park Site, Fort Collins		
SNMOC	TO-12	24-hour (1/12 day)
Methane	ASTM D1946	24-hour (1/12 day)
Mason Street Site, Fort Collins		
SNMOC	TO-12	24-hour (1/12 day)
Methane	ASTM D1946	24-hour (1/12 day)

Figure 2-2. NE Fort Collins monitoring sites including the Well Pad (WPFC) site (top left), the Tank Battery (TBFC) site (top right) and the Hearth Fire (HFFC) site (bottom).

Figure 2-3. VOC sample canisters located at the City Park (CPFC) site (left) and the Mason Street (MSFC) site (right).

3.0 DATA SUMMARIES

3.1 Meteorological Summaries

Meteorological data, including wind speed and wind direction, were collected along with H_2S and VOC measurements at the NE Fort Collins sites to better understand the local conditions and transport of air pollutants. Time series plots including hourly averages of H_2S and all monitored meteorological parameters are provided in Appendix B.

Figure 3-1 presents a map overlaid with wind roses, which depict wind direction and wind speed measured at each of the NE Fort Collins monitoring sites between November 15, 2013 and February 15, 2014. The direction of the bar signifies the direction the wind is coming from, the length of the bars indicate the cumulative frequency from each direction, and the colors indicate wind speed. The wind roses show that winds at the NE Fort Collins sites were influenced mostly by flow from the north and northwest. Wind pattern at the Tank Battery and Hearth Fire sites were nearly identical, while winds at the Well Pad site were from similar directions, but at higher speeds.

For this study, meteorological measurements were collected at the NE Fort Collins sites, but not at the downtown Fort Collins sites. For reference in comparison to VOC sample data at the downtown sites, meteorological conditions are presented here using data from a CSU weather station (http://ccc.atmos.colostate.edu/~autowx/), which is located between the CPFC and MSFC sites as depicted in Figure 3-2. A total of five (5) 24-hour VOC samples were collected between November 24, 2013 and January 23, 2014. For reference, Figures 3-3 through 3-5 present wind rose plots representing wind direction and wind speed for both the downtown and NE sites on the VOC sample dates.

Wind Rose Map
November 15, 2013 – February 15, 2014

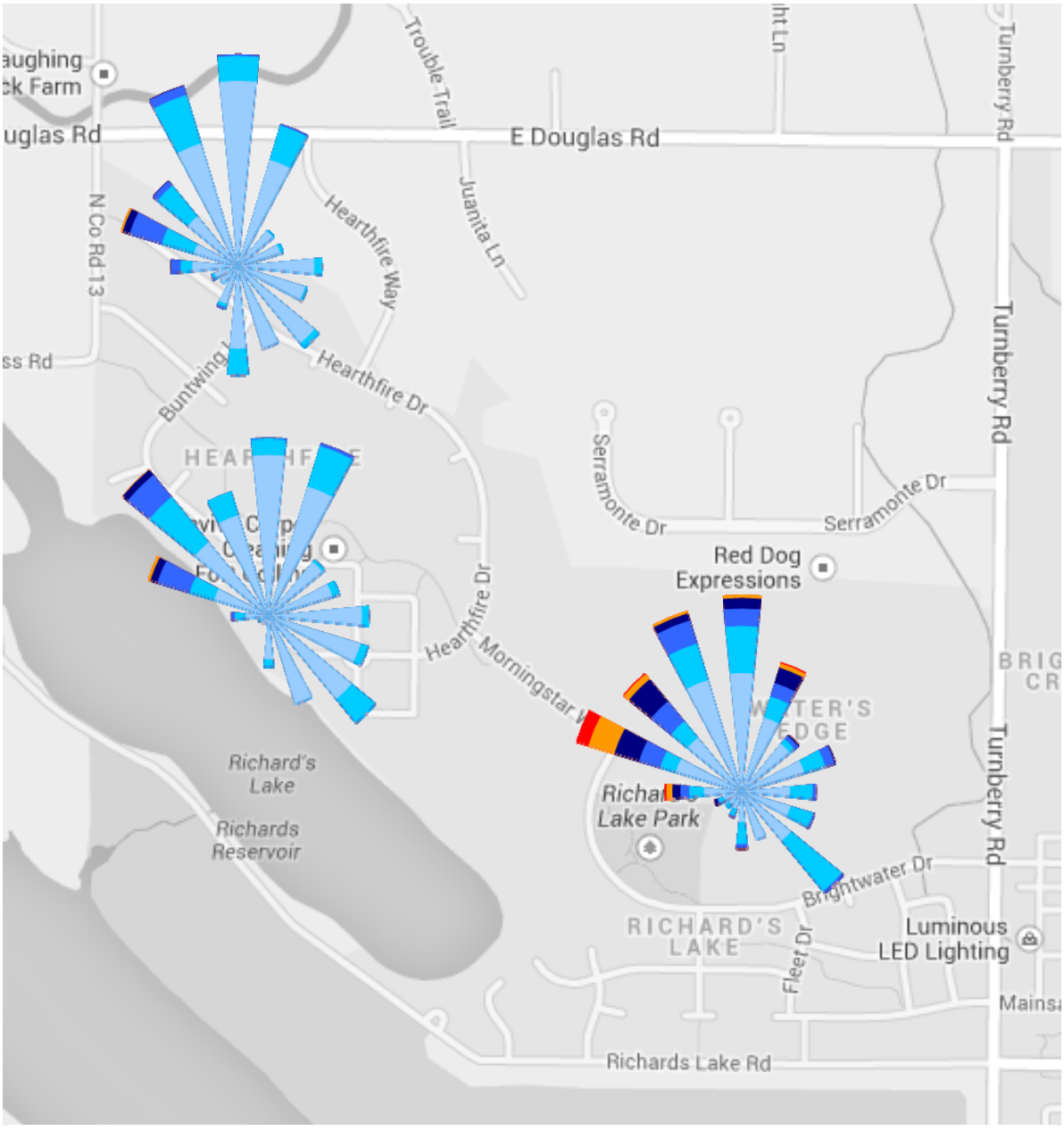

Figure 3-1. Map overlaid with wind roses depicting wind speed and direction measured at the NE Fort Collins Monitoring sites between November 15, 2013 and February 15, 2014.

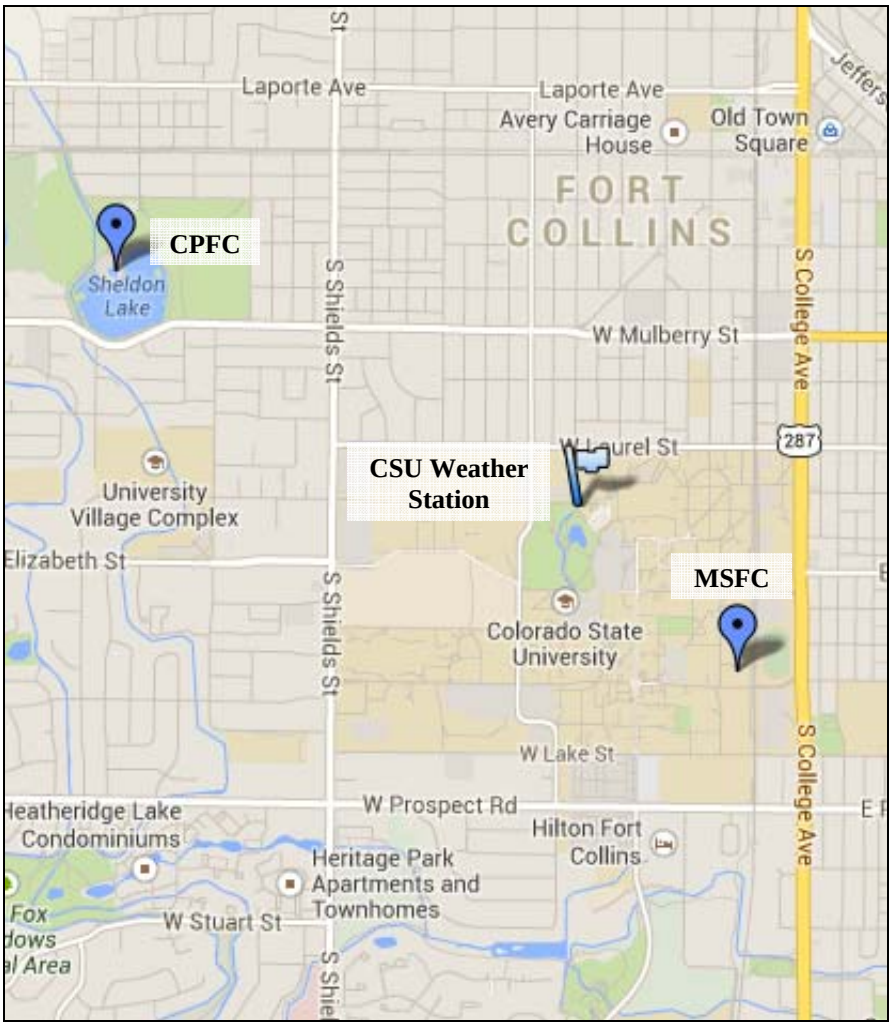

Figure 3-2. Location of CSU Weather Station relative to downtown City Park and Mason Street sites.

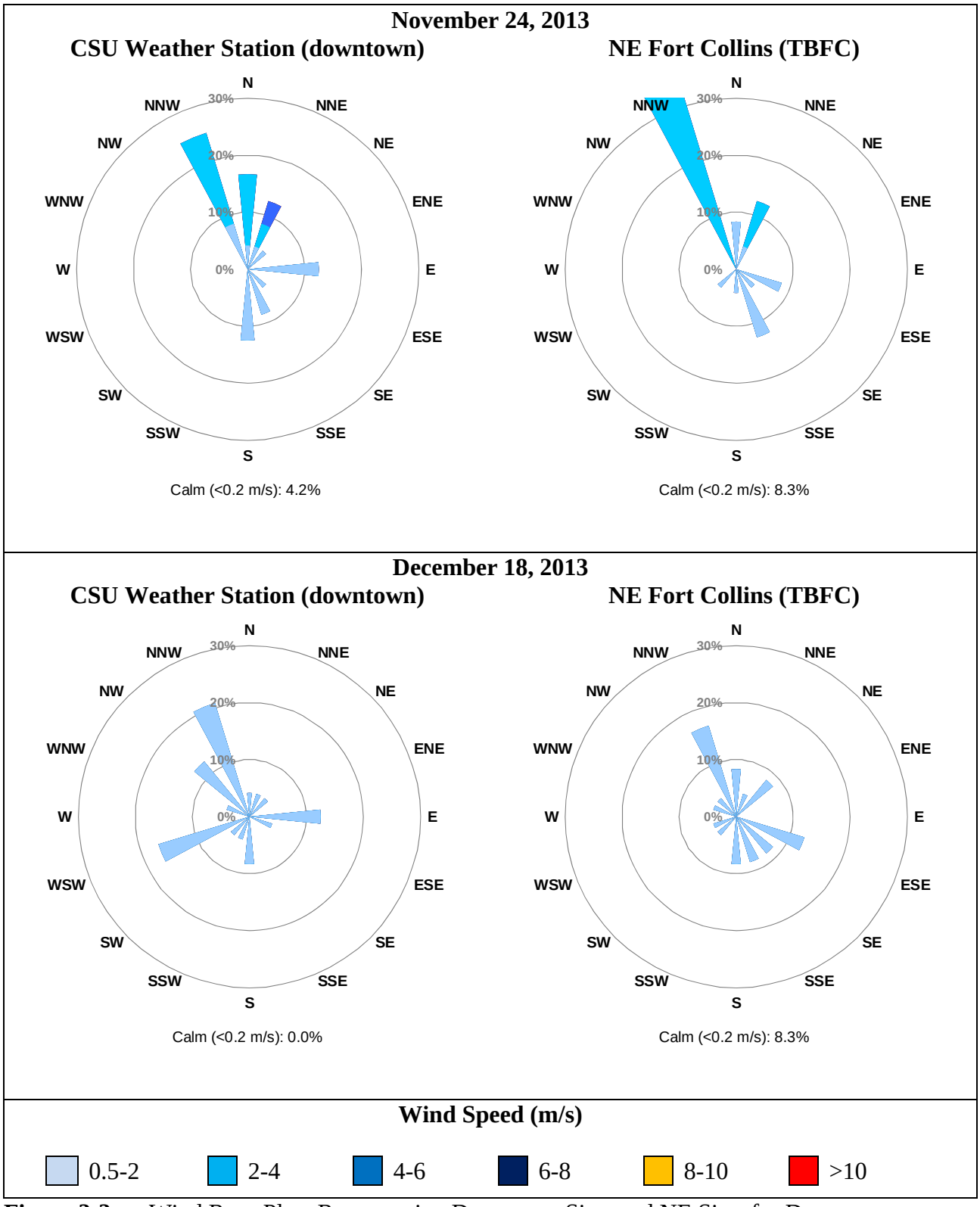

Figure 3-3. Wind Rose Plots Representing Downtown Sites and NE Sites for Dates Corresponding to VOC Samples (11/24/13 and 12/18/13).

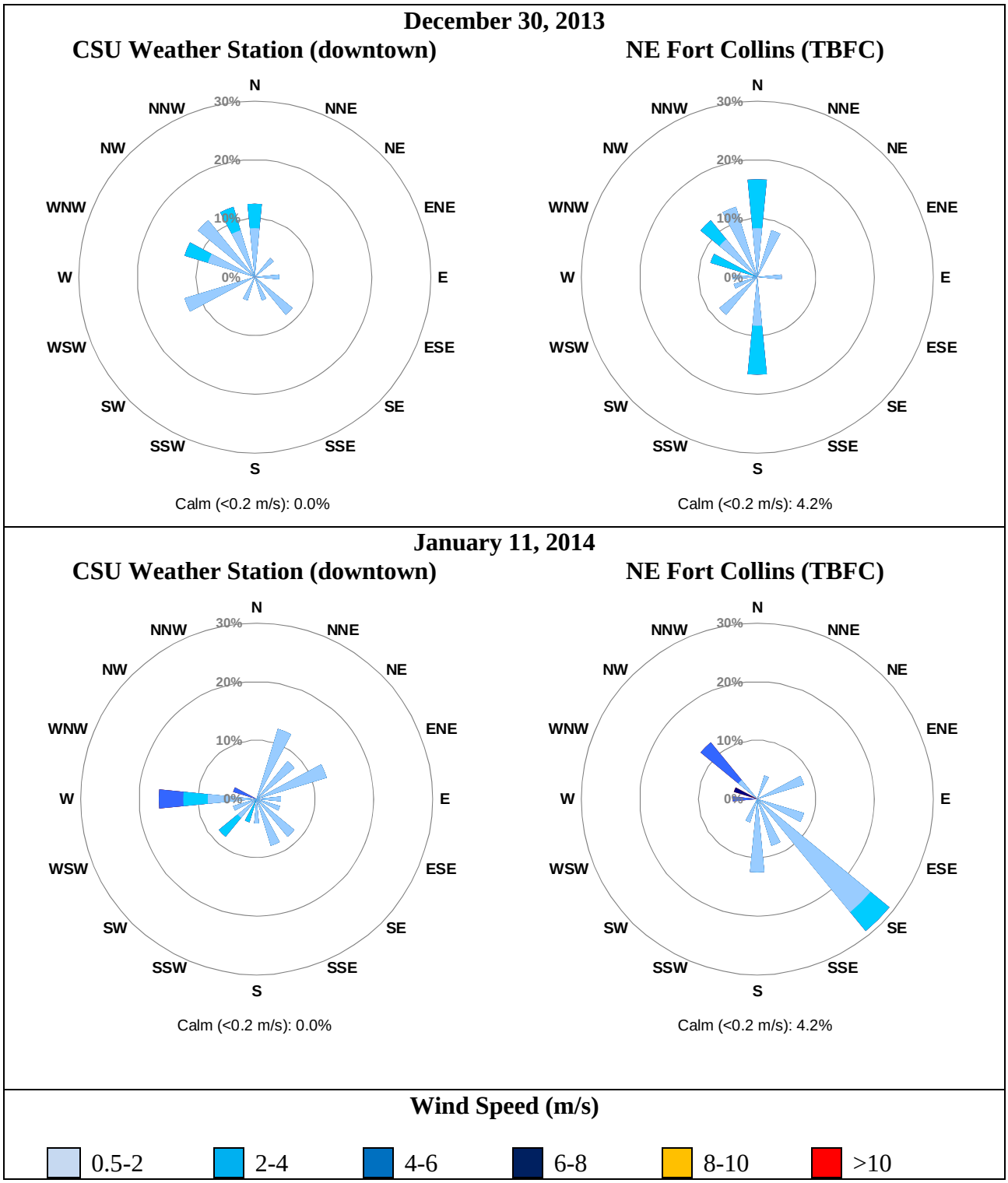

Figure 3-4. Wind Rose Plots Representing Downtown Sites and NE Sites for Dates Corresponding to VOC Samples (12/30/13 and 01/11/14).

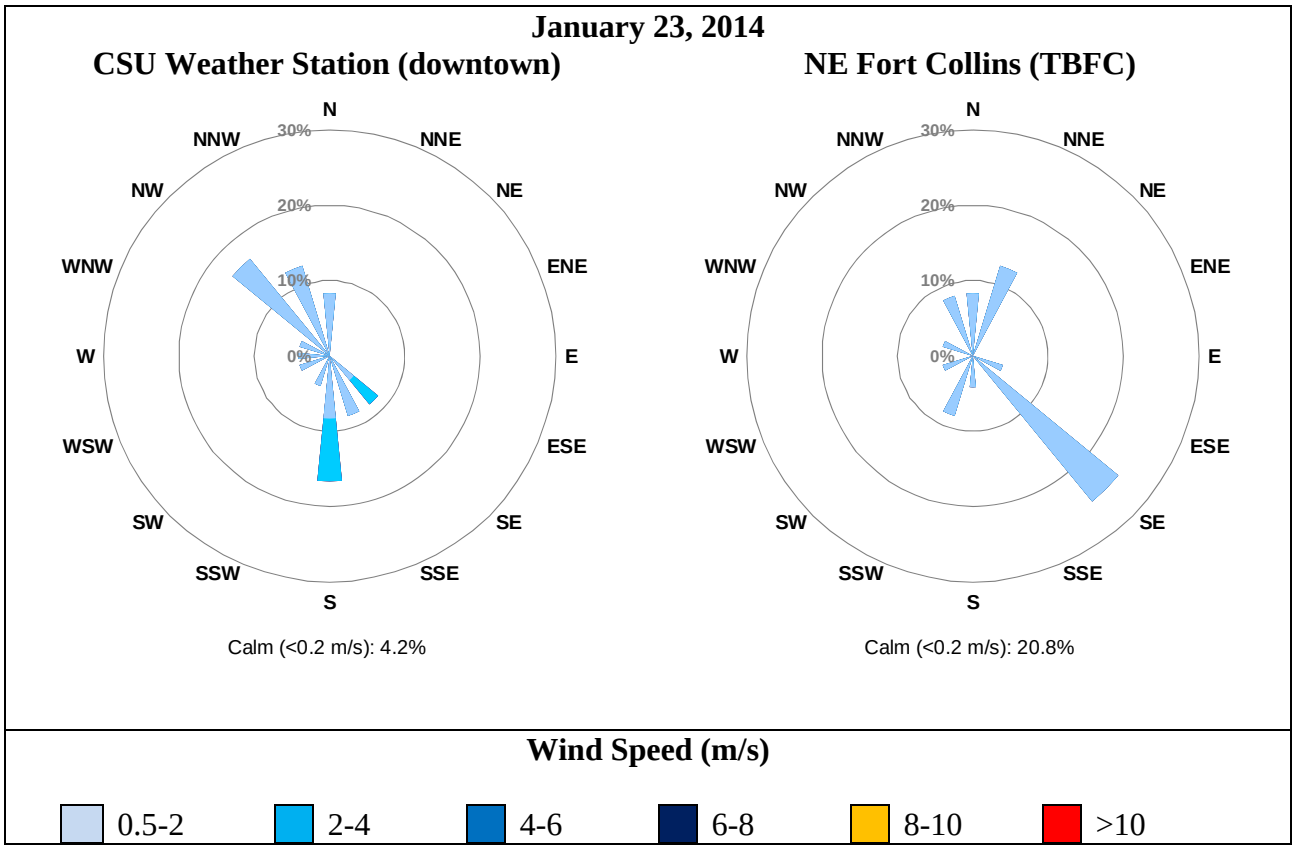

Figure 3-5. Wind Rose Plots Representing Downtown Sites and NE Sites for Dates Corresponding to VOC Samples (01/23/14).

3.2 Hydrogen Sulfide

Hydrogen sulfide (H_2S) was monitored at the three (3) NE Fort Collins sites (TBFC, HFFC, and WPFC) during this study. The monitoring system was leased by the City from Denbury Resources, Inc. With a monitor resolution of 1 part per million (ppm), the H_2S monitors used in these systems are capable of reporting H_2S levels greater than 0.5 ppm. H_2S is an odorous and toxic compound that has been detected near oil and gas operations in the Hearthfire neighborhood and the site operator has received odor complaints from some neighbors. Hydrogen sulfide odors can be detected at levels as low as 0.01 ppm and toxic effects can be exhibited at concentrations from 10 ppm and higher.

Table 3-1 lists data collection statistics and summary results. No H_2S levels were detected at high enough levels for an instrument response (>0.5 ppm) during this monitoring period. Note that odors from H_2S can be detected at levels much lower than 0.5 ppm, so it is possible that H_2S odors occurred without an instrument response.

Table 3-1
City of Fort Collins H_2S Monitoring Results
November 15, 2013 – February 15, 2014

Site	No. Possible (hours)	No. Collected	% Collected	Max Value Detected (ppm)
Tank Battery	2232	2228	99.8%	0
Well Pad	2232	2232	100%	0
Hearth Fire	2232	2232	100%	0

Table 3-2 lists calibration check results for the instruments. Instrument response was tested against a calibration standard before the monitoring period began (11/12/2013), during the monitoring period (01/29/14) and after the monitoring period ended (02/19/2014). Calibration check results indicated that instruments were responding to the reference standard between 8% low and 20% high. Because H_2S was not monitored at levels high enough for an instrument reading, these calibration biases did not affect reported results.

Table 3-2
City of Fort Collins H_2S Calibration Results

Date	Reference Standard (ppm H_2S)	Instrument Response (ppm H_2S) (% deviation)		
		Hearth Fire	Well Pad	Tank Battery
11/12/2013	25.1	24 (-4%)	25 (0%)	25 (0%)
1/29/2014	25.1	23 (-8%)	24 (-4%)	28 (+12%)
2/19/2014	25.1	23 (-8%)	24 (-4%)	30 (+20%)

3.3 Volatile Organic Compounds

Volatile organic compounds (VOCs) consist of a multitude of carbon- and hydrogen-based chemicals that exist in the gas phase or can evaporate from liquids. VOCs can react in the atmosphere to form ozone and particulate matter, and a subset of VOCs are also considered Hazardous Air Pollutants (HAPs); which are compounds that are known or believed to cause human health effects. For summary purposes here, select VOC compounds are grouped into classifications with similar characteristics, as described below:

- **BTEX Parameters:** These compounds consist of benzene, toluene, ethyl-benzene and xylenes. These are parameters of interest because they are part of a subset of VOC compounds designated by the EPA as hazardous air pollutants (HAPs). BTEX compounds are commonly associated with motor vehicles, but can also have sources associated with oil and gas production.

- **Light Alkanes:** Alkanes are the simplest hydrocarbons, consisting of only carbon and hydrogen with single bonds. Light alkanes, which include alkanes with up to five carbon atoms (ethane, propane, iso/n-butane and iso/n-pentane), along with methane, are primary components of natural gas and gasoline vapors. These compounds are not considered HAPs, but in large concentrations can contribute to odor issues and have potential to contribute to ozone formation.

- **Methane:** Methane is not considered a HAP, but is associated with oil and gas development and is of interest because of its potency as a greenhouse gas and to a lesser extent, its role in ozone formation. Methane is a pollutant that persists in the atmosphere for long periods of time (~12 years), so a background concentration of methane is present globally even in remote locations.

This section presents a summary of VOC measurements, including comparisons to regional measurements and HAP screening values. Methane and SNMOC Concentrations (Appendix B) lists minimum, maximum, and average concentrations of all detected methane and SNMOC compounds by site.

3.3.1 VOC Data Summary

Air samples were collected for VOC analysis at two (2) of the NE Fort Collins sites (TBFC and WPFC) and at the two (2) downtown sites (CPFC and MSFC). A total of five (5) samples were collected at each site per EPA's 1-12 day schedule (http://www.epa.gov/ttnamti1/calendar.html) for 24-hour periods, and analyzed off-site by ERG laboratories.

The first of five (5) samples was collected on November 24, 2013, and the last sample was collected on January 23, 2014. The sample scheduled for December 6, 2013 was not collected due to extreme cold weather. Two duplicate canister samples were collected, which included a duplicate at the CPFC site on December 18, 2013, and at the WPFC site on December

30, 2013. A subset of VOCs, referred to as Speciated Non-Methane Hydrocarbons (SNMOCs), along with methane, were analyzed according to EPA Compendium Method TO-12.

Table 3-3 lists average concentrations by site for several individual compounds measured. Note that concentrations of benzene, toluene, ethylbenzene, and xylene and select light alkanes detected in the samples, these results are presented in parts per billion by volume (ppbV), but because methane is prevalent in the atmosphere in much higher concentrations, these results are presented in parts per million by volume (ppmV).

Figures 3-6 through 3-10 depict daily average concentrations for select compounds of interest. Figures 3-6 and 3-7 present daily averages for benzene and toluene, two of the BTEX compounds which are commonly associated with urban sources such as vehicle exhaust, but can also be associated with oil and gas development activities. These parameters averaged highest at the downtown sites, with concentrations slightly higher at the Mason Street site than the City Park site. The highest daily concentration was recorded at all sites on December 18, 2013. Wind rose plots for this day (Figure 3-3) indicate low wind speeds, which is indicative of stagnant conditions which allow pollutants to build up rather than dispersing.

Figures 3-8 and 3-9 present propane and ethane, two of the light alkanes commonly associated with oil and gas development activities. These compounds were highest at the Tank Battery site, while concentrations at the Well Pad site were comparable with the downtown sites. The highest light alkane concentrations at all four (4) sites were measured on January 11, 2014. Wind rose plots for this day (Figure 3-9) indicate that winds were predominantly from the west at the downtown sites, and from both the northwest and southeast at the NE sites.

Figure 3-10 presents concentrations of methane measured at the site in units of ppmV. Methane concentrations at all sites were comparable in magnitude, averaging slightly lower at the NE well pad site than the tank battery and downtown sites.

Table 3-3
Select VOCs, Average Concentration
November 24, 2013 – January 23, 2014

Pollutant	Tank Battery (TBFC)	Well Pad (WPFC)	City Park (CPFC)	Mason Street (MSFC)
BTEX Parameters (ppbV)				
Benzene	0.27	0.23	0.41	0.43
Toluene	0.37	0.42	0.72	0.80
Ethylbenzene	0.05	0.05	0.10	0.12
Xylenes	0.13	0.13	0.32	0.38
Select Light Alkanes (ppbV)				
Ethane	21.30	16.20	16.68	18.61
Propane	28.67	14.43	11.81	14.25
n-Butane	13.34	6.24	5.70	7.26
n-Pentane	3.68	4.27	1.89	2.36
Methane (ppmV)				
Methane	2.43	2.13	2.35	2.39

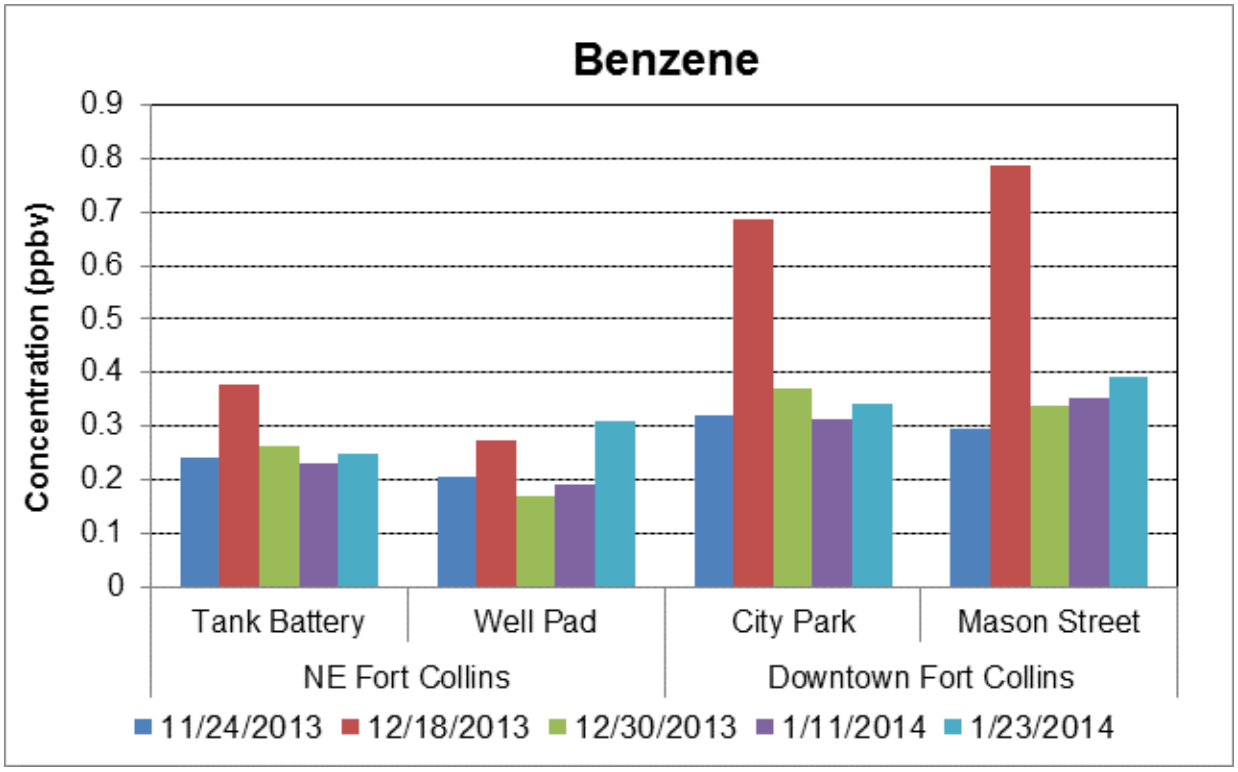

Figure 3-6. Average benzene concentrations measured at the City of Fort Collins monitoring sites between November 24, 2013 and January 23, 2014.

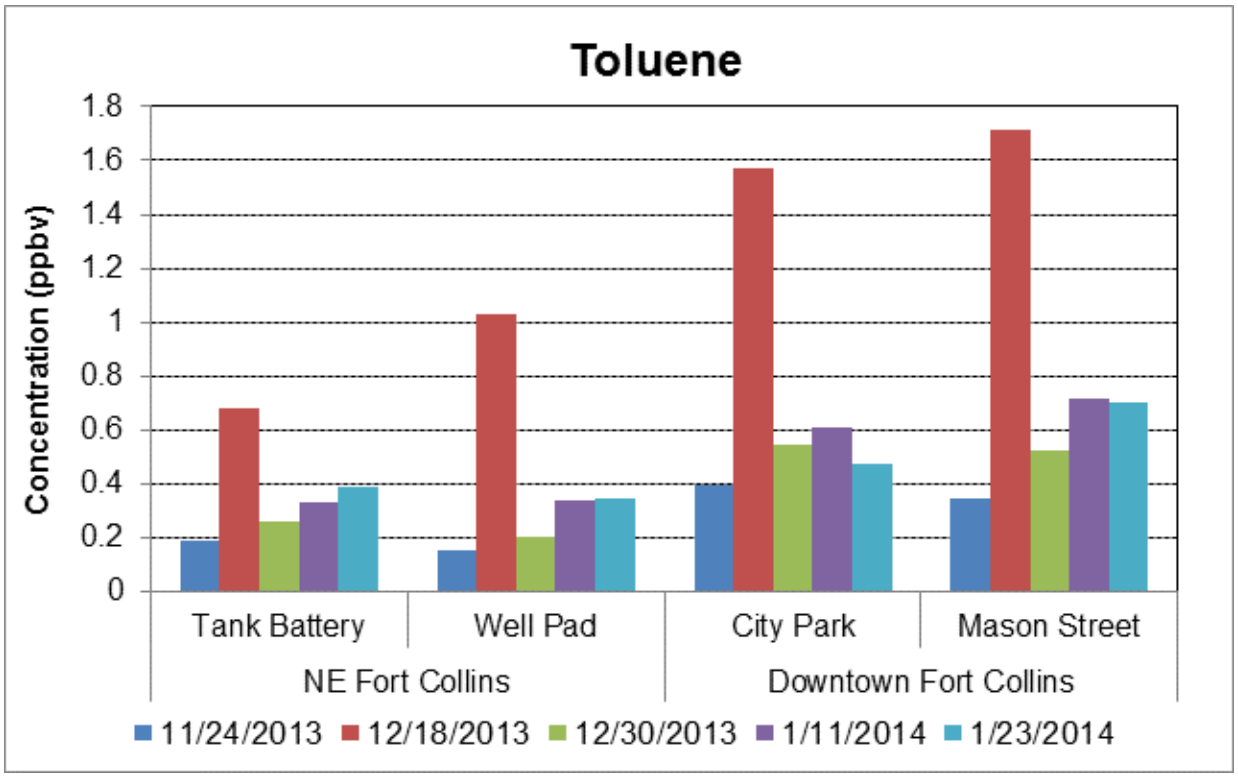

Figure 3-7. Average toluene concentrations measured at the City of Fort Collins monitoring sites between November 24, 2013 and January 23, 2014.

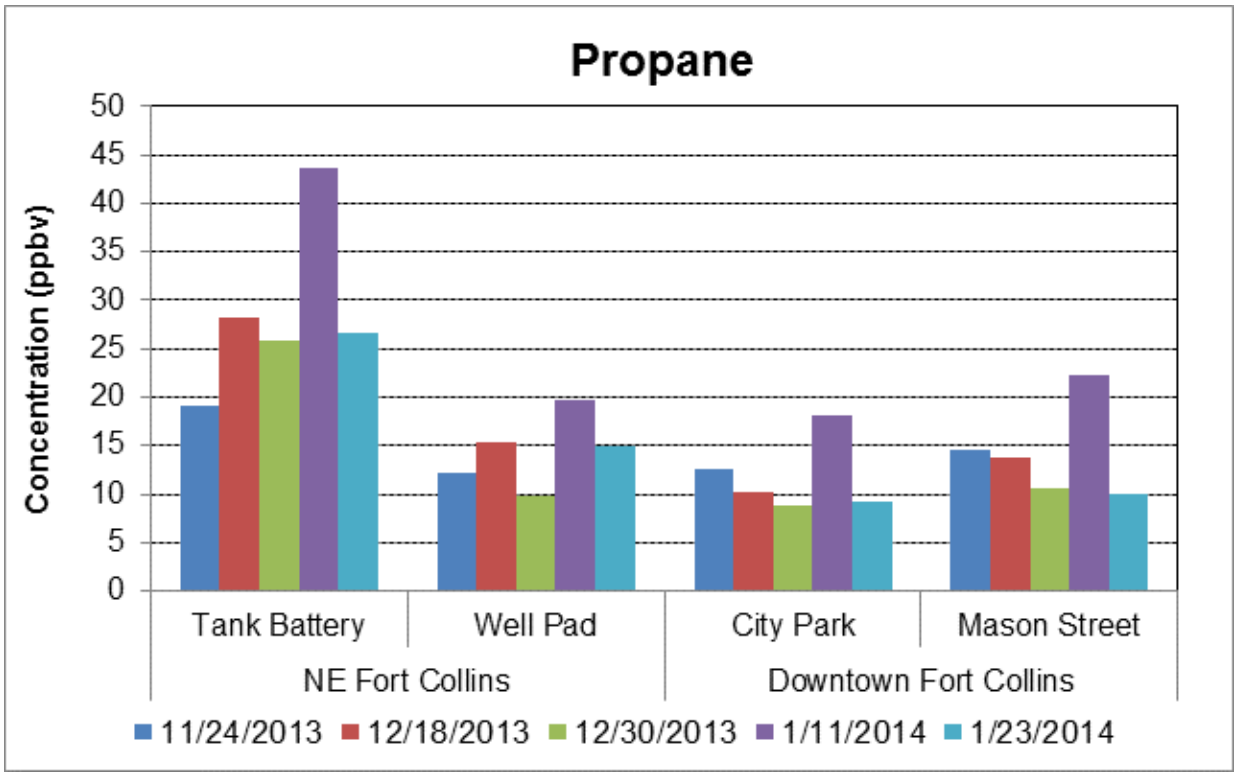

Figure 3-8. Average propane concentrations measured at the City of Fort Collins monitoring sites between November 24, 2013 and January 23, 2014.

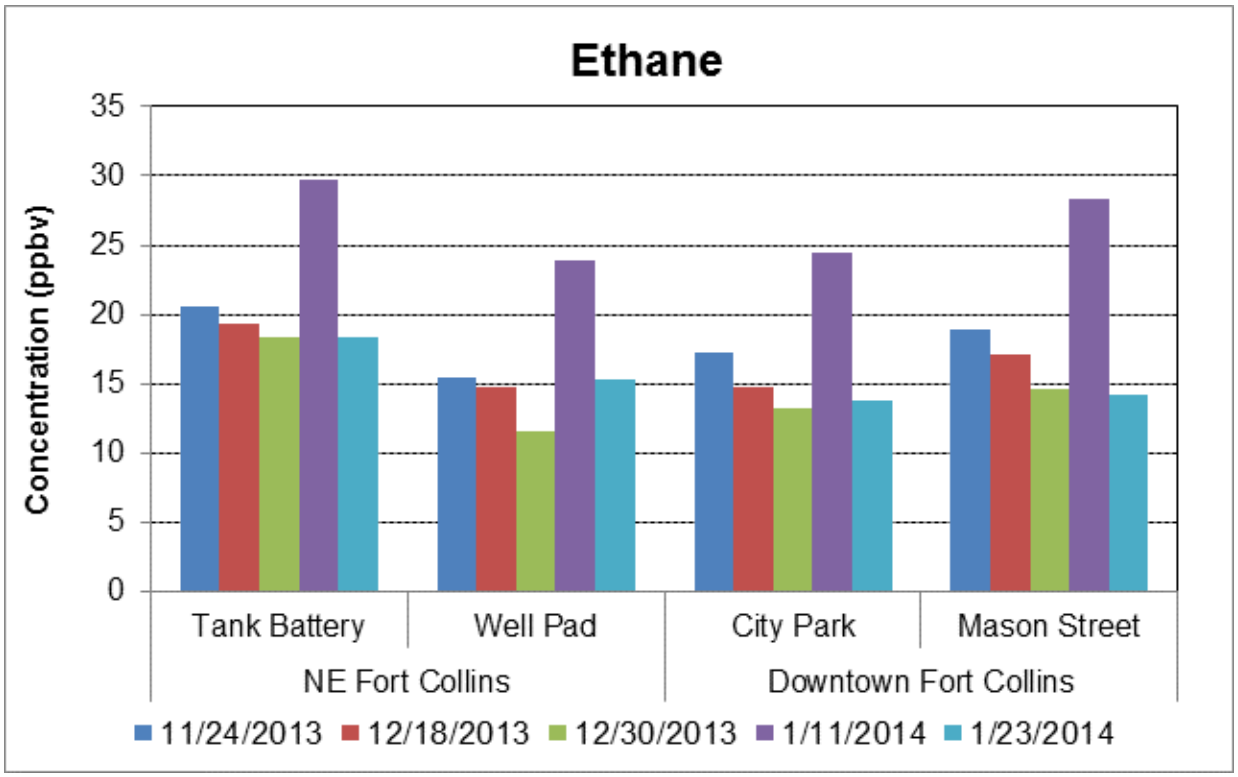

Figure 3-9. Average ethane concentrations measured at the City of Fort Collins monitoring sites between November 24, 2013 and January 23, 2014.

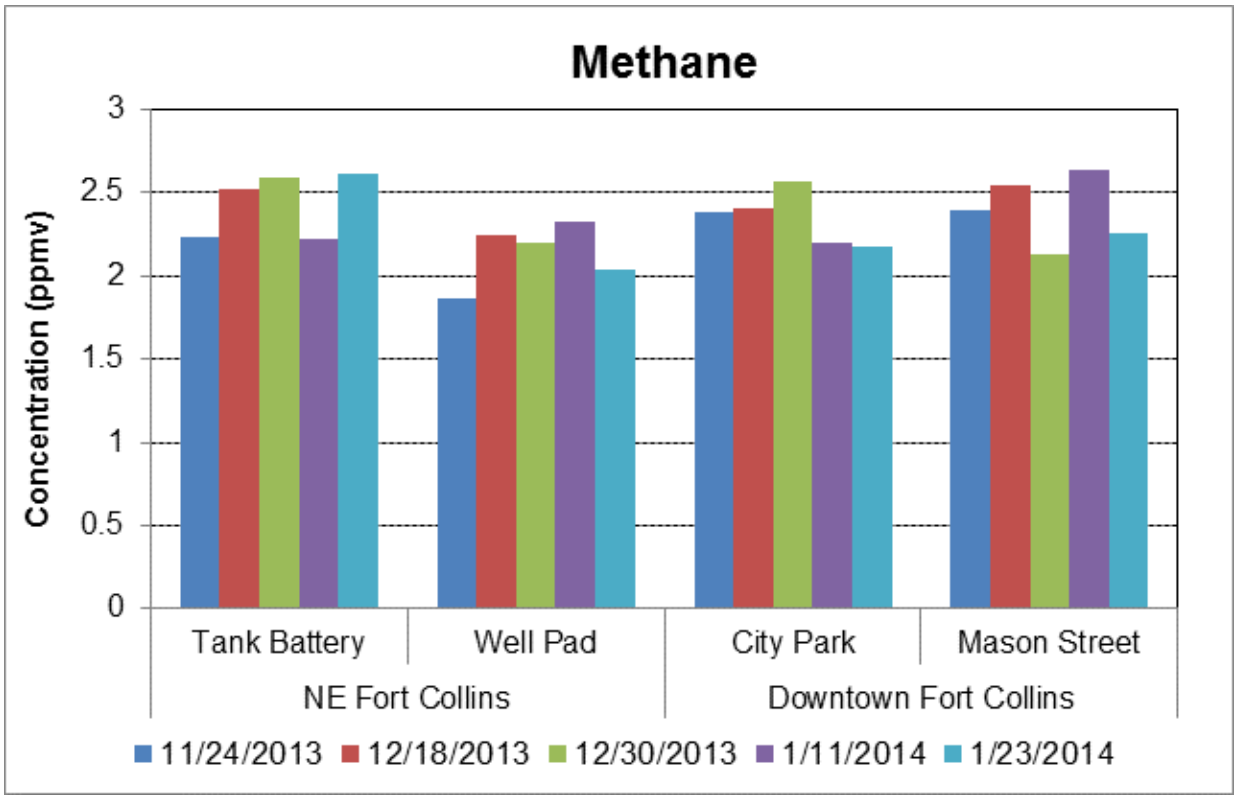

Figure 3-10. Average methane concentrations measured at the City of Fort Collins monitoring sites between November 24, 2013 and January 23, 2014.

3.3.2 Regional Comparisons

This section contains comparisons of data collected during this study to several similar VOC data subsets collected in Colorado. Regional studies summarized here include:

- **Current Study, Fort Collins (Winter 2013-14)**: Averages of VOC data collected for the current study during the 2013-14 winter period, including the two NE Fort Collins sites (Tank Battery and Well Pad) and the two downtown Fort Collins sites (City Park and Mason Street). These averages represent five (5) 24-hour samples collected between November 24, 2013 and January 23, 2014.

- **Fort Collins (Summer 2006)**: Data were collected in the summer of 2006 by the Colorado Department of Public Health and Environment (CDPHE) at a site in Fort Collins located at 3416 LaPorte Ave. Averages represent three (3) samples collected during daytime hours (1-4pm) between July 19 and July 28, 2006.

- **Platteville and Denver (Winter 2013-14)**: Data were collected by CDPHE at a site in Platteville, Colorado, near a number of oil and gas wells in Weld County, and a site in downtown Denver, Colorado. These samples are collected on a 1 in 6 day schedule, and for this comparison, only samples collected between November 2013 and January 2014 are included in these averages, representing fifteen (15) 24-hour samples.

- **Erie (Summer 2013):** These concentrations represent recently published data from a study which looked at the influence of oil and gas emissions on air quality near Erie, Colorado, published by Thompson et al.[1] Averages represent 30 samples collected at residences in and around Erie, Colorado between March and June of 2013.

Data provided by CDPHE (Fort Collins 2006, Platteville and Denver), were analyzed by the same analytical laboratory used for this study (ERG Laboratories). For the Erie study, VOC samples were analyzed using similar methods at the Institute of Arctic and Alpine Research (INSTAAR) laboratory at University of Colorado, Boulder.

Table 3-4 and Figures 3-11 and 3-12 depict a comparison of the BTEX parameters, and select light alkane compounds. For the Fort Collins data, comparisons show concentrations of BTEX parameters and light alkanes in summer of 2006 were lower that the concentrations collected during the current winter study. Although different sites and time periods are represented, s this is consistent with comparisons noted in the article published by Thompson et al., which notes that higher concentrations of VOC compounds generally occur during the wintertime in this region, due in part to the prevalence of stable boundary layer conditions and temperature inversions in the wintertime, and lower VOC compound depletion due to photoreactivity as compared to summertime.

For the Denver and Plattevelle data, only measurements collected between November 2013 and January 2014 are presented in averages here, in order to be consistent with the sampling period of the current study. For the BTEX parameters, data at the Denver and Platteville sites averaged about twice the concentrations of the Fort Collins sites. These parameters are generally associated with urban sources, but are also emitted from various industrial and oil and gas related activities.

For the light alkanes, the Tank Battery site in Fort Collins measured the highest of the Fort Collins sites, but had average concentrations about 10 times lower than averages reported for the Platteville site, which is located near gas development in the Greater Wattenberg Field in Weld County, Colorado. As noted previously, emissions of these light alkanes are primarily associated with natural gas development, though vehicles can emit small amounts of these compounds. Light alkane averages collected at the Tank Battery site were slightly higher than those collected in Erie, but the Erie measurements were made during the summer when concentrations of these compounds are generally lower due to photoreactivity.

[1] Chelsea R. Thompson, Jacques Heber and Detlev Helmig, "Influence of Oil And Gas Emissions on Ambient Atmospheric Non-Methane Hydrocarbons in Residential Areas of Northeastern Colorado," *Elementa: Science of the Anthropocene*, November 14, 2104

Table 3-4
Select VOCs, Average Concentration
Regional Comparisons

Pollutant	Tank Battery	Well Pad	City Park	Mason Street	Fort Collins	Denver	Platteville	Erie
	Winter 2013-14				Summer 2006	Winter 2013-14		Summer 2013
BTEX Parameters (ppbV)								
Benzene	0.27	0.23	0.41	0.43	0.08	0.42	0.68	0.57
Toluene	0.37	0.42	0.72	0.80	0.12	1.27	1.29	0.43
Ethylbenzene	0.05	0.05	0.10	0.12	0.03	0.17	0.12	0.05
m/p-Xylene	0.13	0.13	0.32	0.38	0.09	0.56	0.51	0.17
Select Light Alkanes (ppbV)								
Ethane	21.30	16.20	16.68	18.61	3.38	14.77	138.68	27.00
Propane	28.67	14.43	11.81	14.25	1.94	7.14	104.78	18.50
n-Butane	13.34	6.24	5.70	7.26	1.08	3.47	51.71	8.09
n-Pentane	3.68	4.27	1.89	2.36	0.36	1.64	17.31	2.55
Methane (ppmV)								
Methane	2.43	2.13	2.35	2.39	N/A	2.52	3.55	N/A

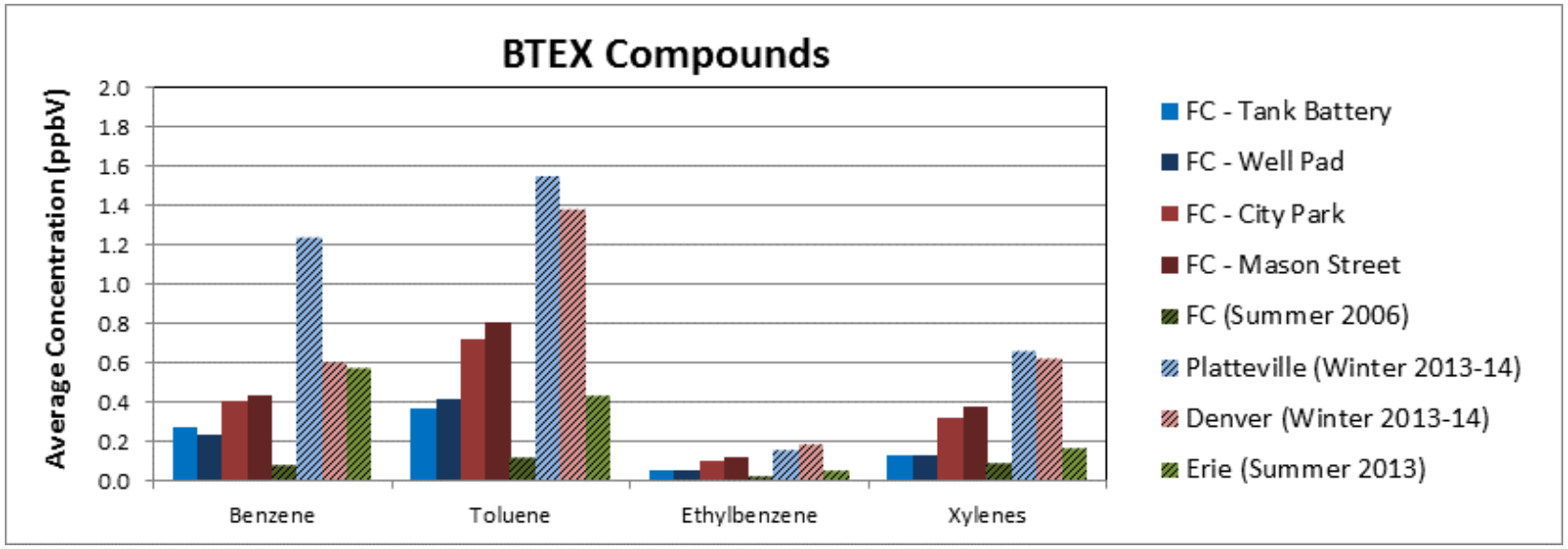

Figure 3-11. Regional comparison of average BTEX concentrations.

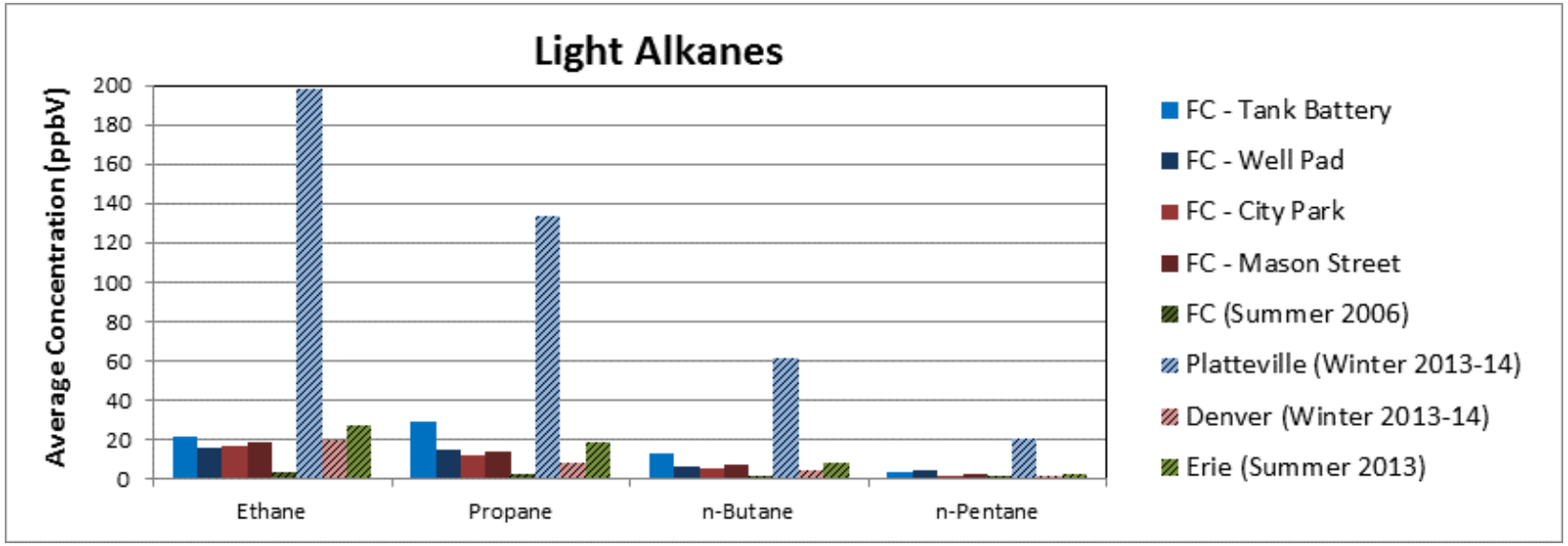

Figure 3-12. Regional comparison of average light alkane concentrations.

3.3.3 Screening Level Comparison for HAPS

National ambient air quality standards do not exist for VOCs or HAPs, but the EPA has developed a screening level methodology to evaluate potential exposures of public health concern based on air monitoring data for HAPs. EPA has also developed Air Toxics Risk Assessment procedures and risk factors for both acute and chronic exposures to HAPs. In addition, exposure levels and thresholds developed by from the Agency for Toxic Substances and Disease Registry (ATSDR), the Occupational Safety and Health Administration (OSHA), the California Air Resources Board (CARB), the National Institute for Occupational Safety and Health (NIOSH), and others can be used to determine potential risks from exposure to air toxics.

A comparison of air monitoring results to published air toxic screening levels is presented here using guidance published by the EPA in the document *A Preliminary Risk-Based Screening Approach for Air Toxics Monitoring Data Sets (October 2010)*, including May 9, 2014 updates to the data tables from that report. This information is presented for relative comparison purposes only and is not intended to imply that a screening level risk analysis or a comprehensive risk assessment was completed for this project.

Of the 79 VOC compounds measured at sites in Fort Collins, eight (8) compounds had chronic inhalation screening values available from the 2010 EPA guidance. For data collected between November 2013 and January 2014, each pollutant's measured concentration was compared to its associated chronic inhalation screening value. Tables 3-5 through 3-8 present the HAPs compounds measured for each site, and indicate the number of detections, the screening value used, and number of samples above screening values.

For the Fort Collins sites, two (2) of the measured HAPs, 1,3-butadiene and benzene, had 24-hour averages measured above screening values. Both of these compounds measured higher at the downtown site than at the NE Fort Collins sites. Additionally, of the HAPS measured, only n-hexane measured higher at the NE Fort Collins sites than the downtown sites, but measurements of n-hexane were well below the screening level.

Note that the screening level comparison presented here is not a substitute for a thorough risk assessment. These comparisons are designed to be very conservative, and represent comparisons of 24-hour averages to values that were designed for evaluation of chronic risks, which assume a lifetime of exposure. Because these comparisons are very conservative, pollutants that measure above these chronic screening levels do not necessarily pose a health risk.

Table 3-5
Tank Battery
HAPs Summary
11/24/2013-1/23/2014

Pollutant	Number Detections	Min.	Max.	Avg *	Chronic Inhalation Screen Value ($\mu g/m^3$)	No. of Samples Above Screen Value
		($\mu g/m^3$)				
1,3-Butadiene	2	0.03	0.06	0.03	0.033	1
Benzene	5	0.23	0.38	0.27	0.128	5
Ethylbenzene	5	0.02	0.11	0.05	0.4	0
m-Xylene/p-Xylene	5	0.06	0.25	0.13	10	0
Isopropylbenzene	0	ND	ND	0.01	40	0
n-Hexane	5	0.42	2.78	1.23	70	0
Styrene	0	ND	ND	0.03	100	0
Toluene	5	0.19	0.68	0.37	500	0

*Averages are adjusted for non-detects (ND) using ½ of the minimum detection limit.

Table 3-6
Well Pad
HAPs Summary
11/24/2013-1/23/2014

Pollutant	Number Detections	Min.	Max.	Avg *	Chronic Inhalation Screen Value ($\mu g/m^3$)	No. of Samples Above Screen Value
		($\mu g/m^3$)				
1,3-Butadiene	2	0.03	0.04	0.03	0.033	1
Benzene	5	0.17	0.31	0.23	0.128	5
Ethylbenzene	5	0.02	0.12	0.05	0.4	0
m-Xylene/p-Xylene	5	0.05	0.26	0.13	10	0
Isopropylbenzene	0	ND	ND	0.01	40	0
n-Hexane	5	0.27	1.90	0.76	70	0
Styrene	0	ND	ND	0.03	100	0
Toluene	5	0.16	1.03	0.42	500	0

*Averages are adjusted for non-detects (ND) using ½ of the minimum detection limit.

Table 3-7
City Park
HAPs Summary
11/24/2013-1/23/2014

Pollutant	Number Detections	Min.	Max.	Avg *	Chronic Inhalation Screen Value ($\mu g/m^3$)	No. of Samples Above Screen
		($\mu g/m^3$)				
1,3-Butadiene	5	0.03	0.13	0.06	0.033	4
Benzene	5	0.31	0.69	0.41	0.128	5
Ethylbenzene	5	0.05	0.20	0.10	0.4	0
m-Xylene/p-Xylene	5	0.17	0.71	0.32	10	0
Isopropylbenzene	0	ND	ND	0.01	40	0
n-Hexane	5	0.39	0.76	0.55	70	0
Styrene	0	ND	ND	0.03	100	0
Toluene	5	0.40	1.57	0.72	500	0

*Averages are adjusted for non-detects (ND) using ½ of the minimum detection limit.

Table 3-8
Mason Street
HAPs Summary
11/24/2013-1/23/2014

Pollutant	Number Detections	Min.	Max.	Avg *	Chronic Inhalation Screen Value ($\mu g/m^3$)	No. of Samples Above Screen
		($\mu g/m^3$)				
1,3-Butadiene	5	0.03	0.15	0.07	0.033	4
Benzene	5	0.30	0.79	0.43	0.128	5
Ethylbenzene	5	0.05	0.26	0.12	0.4	0
m-Xylene/p-Xylene	5	0.15	0.81	0.38	10	0
Isopropylbenzene	1	0.01	0.01	0.01	40	0
n-Hexane	5	0.36	0.99	0.68	70	0
Styrene	0	ND	ND	0.03	100	0
Toluene	5	0.35	1.71	0.80	500	0

*Averages are adjusted for non-detects (ND) using ½ of the minimum detection limit.

4.0 Conclusions

A short term air quality monitoring study was conducted at three sites near oil and gas activities in NE Fort Collins and two sites in downtown Fort Collins to collect baseline data representative of current air quality conditions in these areas.

Meteorological conditions, including wind speed and direction, were continuously monitored at the three sites near oil and gas development. The predominant wind direction for all three locations was from the north-northwest with typical wind speeds in the 1-4 m/s range. Winds were light and conditions were stagnant during sampling episodes with the highest VOC concentrations.

Hydrogen sulfide was continuously monitored at three sites near existing oil and gas development to address neighborhood concerns and odor complaints associated with this pollutant. Hydrogen sulfide was not detected at a level above 0.5 ppm at any of the monitoring sites. Although hydrogen sulfide odor can be detected below this level, concentrations typically associated with health impacts were not observed during this project.

A number of volatile organic compounds were sampled at four locations for five 24-hour sampling episodes. The air samples were analyzed for eighty different compounds. Benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations at the four locations were compared as this group of pollutants are related to urban environments influenced by motor vehicle emissions, and can also be related to gas extraction and processing operations. BTEX concentrations were found to be slightly higher at the two downtown locations than the oil and gas sites. This may indicate that concentrations at the downtown sites are more influenced by motor vehicle emissions and other industrial processes typical of an urban setting than the more rural locations where the oil and gas sites were located.

Concentrations of light alkanes and methane were also evaluated for differences between the downtown sites and the oil and gas sites. Ethane, propane, and n-butane concentrations were slightly higher at the tank battery site than the other three locations. Concentrations of these compounds at this site may be influenced by truck loading operations from the oil product storage tanks or other venting sources. No significant difference in methane concentrations between the four sites was observed, indicating that site concentrations are likely influenced by regional background methane concentrations.

BTEX, light alkane, and methane concentrations were also compared to three other recent studies that included measurements of these compounds in the Front Range region. Measurements from the Fort Collins study were lower than measurement of the same compounds during the same period at Denver and Platteville sites.

Hazardous air pollutant concentrations from the four locations were compared to risk based screening level concentrations published in EPA guidance. The purpose of this comparison was to provide a relative comparison of the 24-hour sampling concentrations to conservative lifetime exposure levels. A health impacts analysis was not performed nor was a risk assessment conducted as part of this project. Two HAPs were measured at concentrations above the

screening levels; 1,3-butadiene and benzene, and higher concentrations of these pollutants were measured at the downtown sites than the oil and gas sites.

Appendix A

Air Monitoring Plan

CITY OF FORT COLLINS
Monitoring Plan

H_2S and VOC
Air Monitoring Project
November 15, 2013 – February 15, 2014

Prepared by

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November 20, 2013

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1.0 BACKGROUND

The City of Fort Collins in engaging in a short term (90-day) air quality monitoring effort designed to help characterize ambient air quality in and around existing oil and gas operations within City limits. While current oil and gas development within City limits is limited, technology innovations have prompted increased development in surrounding communities, which has in turn increased concerns about air quality effects related to oil and gas operations. This monitoring project has been designed to address requests by City Council to provide information regarding current air quality conditions and pollutants of concern in the area of existing oil and gas operations, and help provide a starting point to begin to address citizen inquiries and concerns. Note that this effort is not a comprehensive monitoring effort, as it will represent only select pollutants over a 90-day period. Additionally, the current effort will not address potential health effects for monitored concentrations, but will provide preliminary analysis for possible future health related analysis.

The monitoring effort will begin November 15, 2013 and is scheduled to continue for 90-days through February 15, 2014. The study will focus on characterizing concentrations of Hydrogen Sulfide (H_2S) and concentrations of specific Volatile Organic Compounds (VOCs) commonly associated with oil and gas operations, to include methane (CH_4) and some hazardous air pollutants (HAPs). This monitoring plan addresses all monitoring and data analysis procedures applied for this study, and procedures have been designed to meet protocols established by the US Environmental Protection Agency (EPA). Participants in this monitoring effort are listed below.

- The City of Fort Collins is the prime authority for this monitoring effort. City staff will provide site operators to deploy and retrieve canister samples. The City will also provide final data and report review.
- Memorial Resource Development LLC (MRD) will also provide final data and report review. The City and MRD will fund the program jointly.
- Air Resource Specialists, Inc. (ARS) is the primary contractor, and will coordinate all aspects of the monitoring effort. ARS is responsible for the installation of monitoring equipment, calibration of continuous air quality instrumentation, data collection and validation for continuous parameters, and coordination of canister sampling. ARS will also provide a final written data report along with validated data files.
- Eastern Research Group, Inc. (ERG) will support canister sample analysis, including canister preparation, shipping, receiving and processing of samples.

2.0 OBJECTIVES

This air monitoring project has been designed to help characterize the ambient air quality in and around existing oil and gas operations within Fort Collins city limits. This short-term study will include continuous monitoring of Hydrogen Sulfide (H_2S) and meteorology, and will also include several discreet 24-hour air samples that will be analyzed for a number of speciated volatile organic compounds (VOCs) commonly associated with oil and gas activity. To ensure scientifically defensible data, monitoring systems will adhere to operational protocols established and accepted by the EPA. The objectives of this study include:

- Document and characterize local scale concentrations of air pollutants typically associated with oil and gas development, including H_2S and VOCs concentrations. These data will be used to provide the citizens of Fort Collins and the Fort Collins City Council with a point of reference to develop a better understanding of air quality conditions in the vicinity of existing oil and gas operations.
- Begin to address concerns expressed by Council and citizens regarding the current status of air quality in neighborhoods surrounding existing oil and gas operations, and to advise on how the City can best manage impacts of air pollution caused by development.

This study was also designed, in part, to comply with select components of an Operator Agreement, originally drafted May 29, 2013 between the City of Fort Collins and Prospect Energy, governing the Fort Collins Field and Undeveloped Acreage (UDA) west of Anheuser-Busch (available at http://www.fcgov.com/oilandgas/). Although the agreement was originally drafted between the City and Prospect Energy, an affiliate of Memorial Resource Development (MRD), Memorial Production Partners LP, acquired Prospect Energy on October 1, 2013. As successors to Prospect Energy, requirements in the Operator's Agreement also extend to MRD. The following objectives are specific to requirements in the Operator's Agreement:

- Augment "snapshot" measurements currently made by the Operators using hand-held H_2S monitoring instruments, as per the Amended Oil and Gas Operator Agreement (see Appendix A, Paragraph 21, Subparagraph j), with more robust H_2S measurements that include better temporal and spatial resolution, and include meteorological measurements to better characterize pollutant transport.
- Fulfill, in part, baseline monitoring requirements in the City's Oil and Gas Operator Agreement (see Appendix A, Paragraph 21, Subparagraph h), which specifies that the city shall monitor "air quality" for a 5-day sampling period, at sampling locations to include upwind and downwind of the oil and gas development area, in City Park and at one additional location in downtown Fort Collins.

3.0 SITE LOCATIONS

This section describes the monitoring locations and rationale for site selection for this effort. Selected monitoring sites include three locations in and around northeast Fort Collins oil and gas operations, and two sites in downtown Fort Collins. Table 3-1 presents the coordinates for the selected monitoring sites. Additional site selection and description details are described in this section.

Table 3-1
Site Locations

Site Name	Latitude (°N)	Longitude (°W)
Well Pad, NE Fort Collins	40° 37’ 45”	105° 02’ 39”
Hearth Fire, NE Fort Collins	40° 37’ 56”	105° 03’ 12”
Tank Battery, NE Fort Collins	40° 38’ 16”	105° 03’ 60”
City Park, downtown Fort Collins	40° 35’ 00”	105° 06’ 17”
Mason Street, downtown Fort Collins	40° 34’ 17”	105° 04’ 46”

3.1 NORTHEAST FORT COLLINS SITES

Site locations in NE Fort Collins were selected to represent concentrations of H_2S and VOCs near existing oil and gas operations in the City. Figure 3-1 presents a map of the Oil and Gas Fields which overlap Fort Collins city limits in the northeastern most part of the city. Potential sites were limited to oil and gas areas within city limits and the growth management area.

For siting considerations, predominant wind direction in the area was assessed using a representative site. To represent the NE Fort Collins oil and gas development area, nearby meteorological data were obtained from CSU’s Agriculture, Research Development and Education Center (ARDEC) research site near the Budweiser plant, approximately 2 miles east of the eastern boundary of the oil and gas field (data available from http://aes-ardec.agsci.colostate.edu/). Figure 3-2 presents quarterly wind roses constructed from wind speed and direction measurements at the ARDEC site in 2012. The wind roses show that the predominant winds at the site from the North, with some northwesterly and southeasterly flow.

Along with considerations for wind direction, potential monitoring site locations were constrained to secure areas in close proximity to oil and gas operations, the availability of access roads, minimal obstacles to the wind, and close proximately to residential areas where pollutant exposer concerns are the greatest. Site locations were not limited by available power, as all sites were configured to run remotely using solar panels and batteries, as described in Section 4.0.

Figure 3-3 shows the three monitoring locations selected in NE Fort Collins overlaid with a wind rose located at the ARDEC site showing winds measured between November 15, 2012

and February 15, 2013 (consistent with the proposed November, 2013 through February, 2014 monitoring period). All sites were selected cooperatively with City of Fort Collins staff, and all sites are located within the secure fence-lines used for oil and gas operations in the area. Figures 3-4 through 3-6 shows zoomed in satellite views of the monitoring locations indicating the proximately to oil and gas operations and surrounding neighborhoods. The sites are labeled as follows:

- Well Pad site (WPFC): The Well Pad site is located just north of the Richard's Lake subdivision, in an open field with an active well pad.
- Hearth Fire site (HFFC): The Hearth Fire site is located within the Hearth Fire subdivision, in a fenced area with an active well.
- Tank Battery site (TBFC): The Tank Battery site is located near some of the production infrastructure, including the storage tanks.

All three of these sites were configured to monitor continuous H_2S and meteorology. The Well Pad and Tank Battery sites, which are approximately orientated along with the northwesterly/southeasterly wind flow, will also include VOC samples.

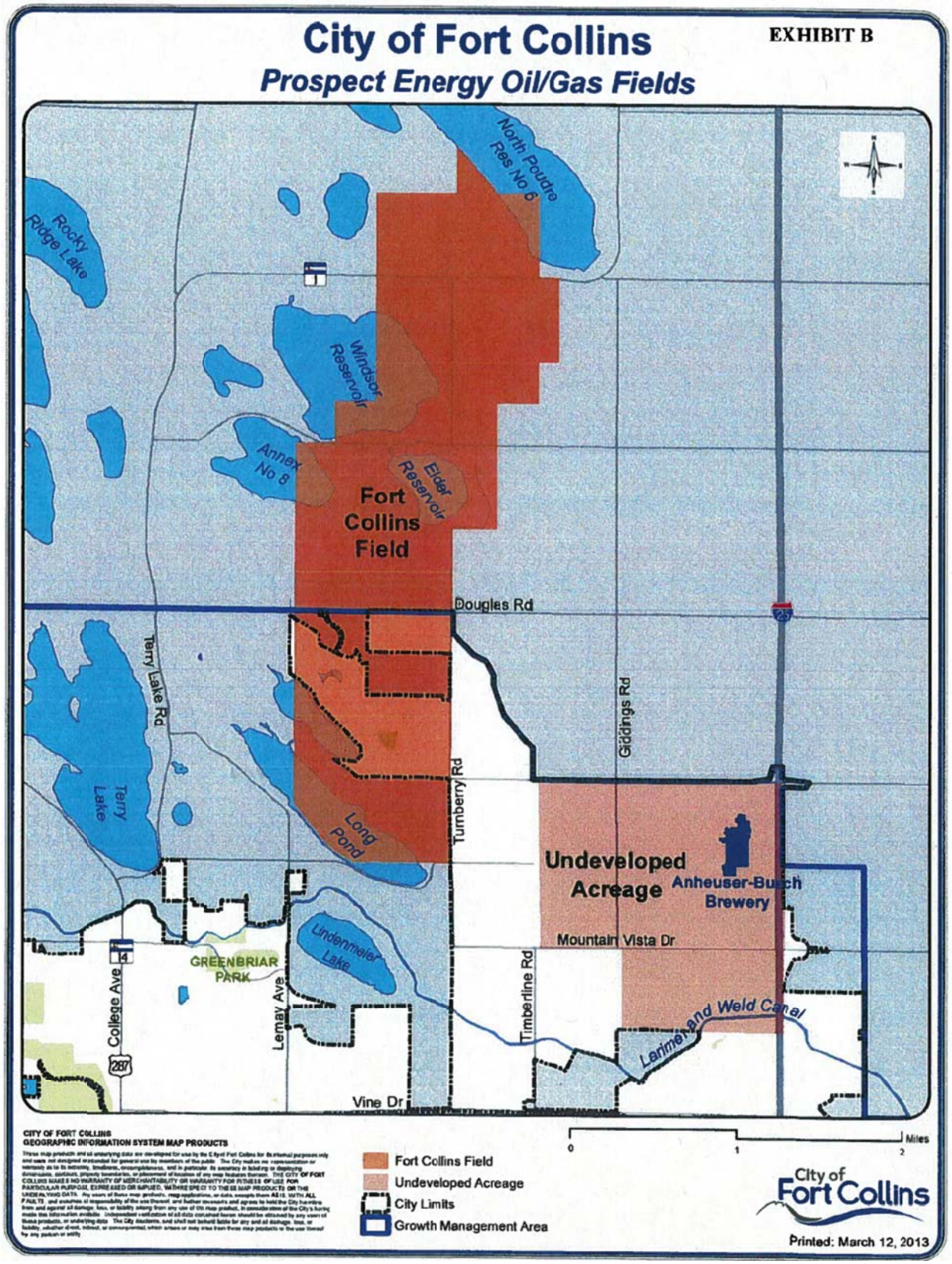


Figure 3-1. Map of Oil and Gas Fields in Northeast Fort Collins.

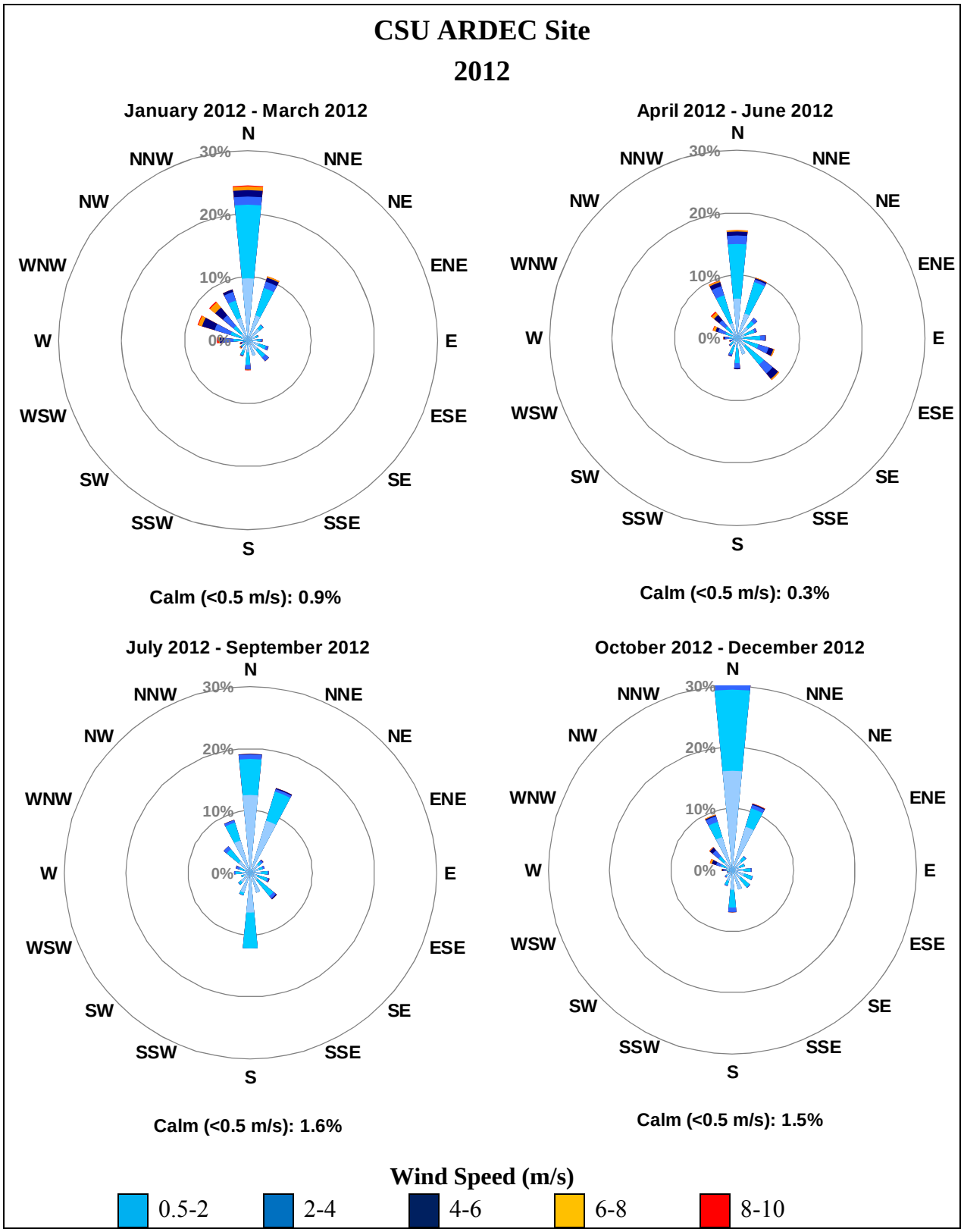


Figure 3-2. 2012 Wind Roses For the CSU ARDEC Site in Northeast Fort Collins.

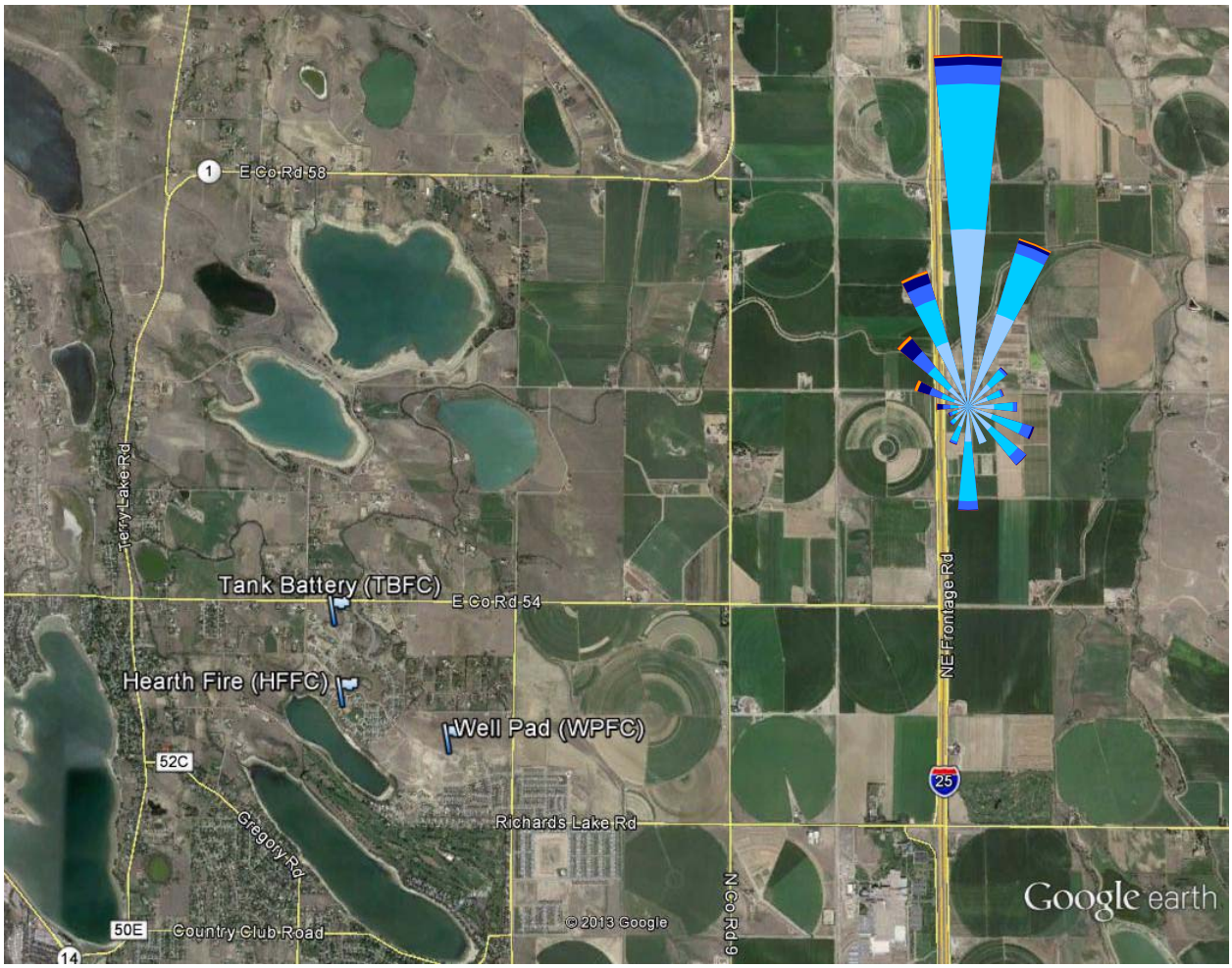


Figure 3-3. NE Fort Collins Monitoring Locations Depicted With a Wind Rose Showing Predominant Wind Direction Measured at the Nearby CSU ARDEC Site Between November 2012 and February 2013.

Figure 3-4. The Well Pad (WPFC) Site in NE Fort Collins.

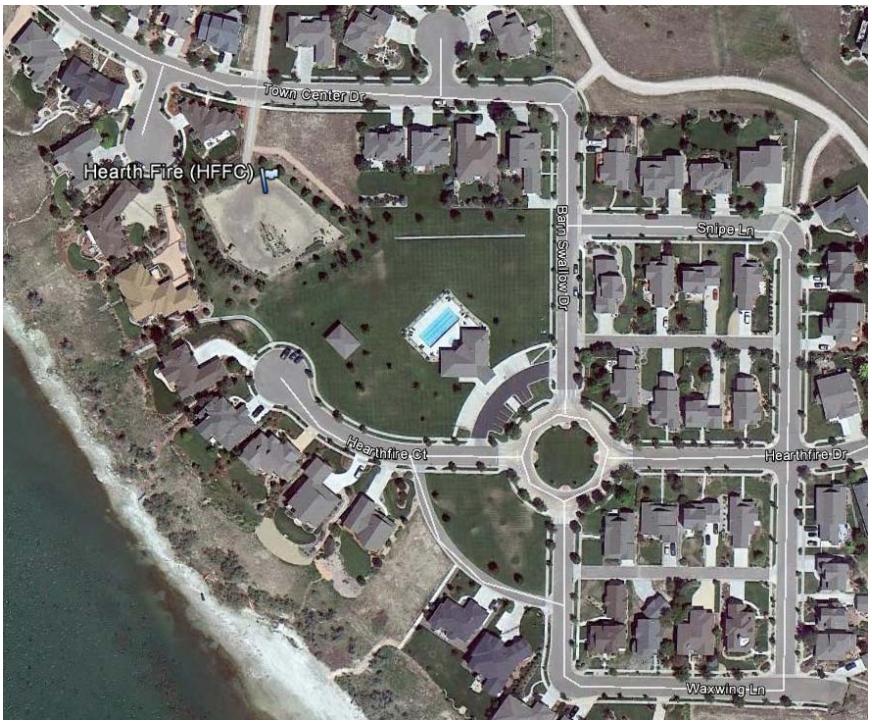


Figure 3-5. The Hearth Fire (HFFC) Site in NE Fort Collins.

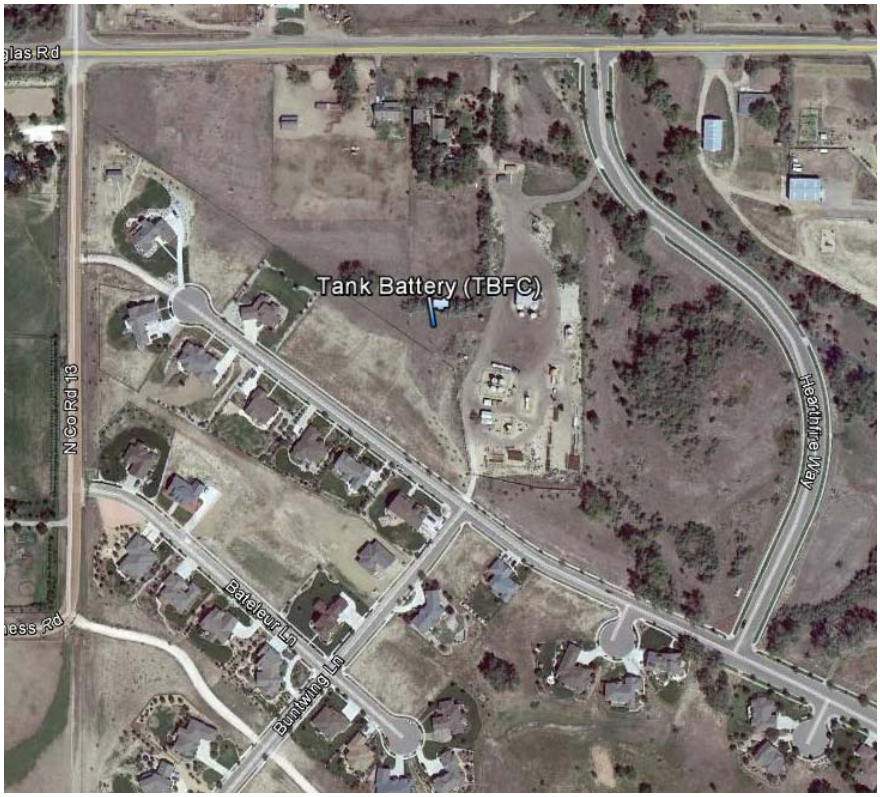


Figure 3-5. The Tank Battery (TBFC) Site in NE Fort Collins.

3.2 DOWNTOWN FORT COLLINS SITES

Site locations in downtown Fort Collins were selected to represent VOC concentrations near more urban Fort Collins sources for reference as compared to the VOC samples in and near oil and gas operations. As per the May 29, 2013 Operator's Agreement, sites were selected to satisfy requirements for "Baseline Air Quality Monitoring" over a five day sampling period at sampling locations to include City Park and "one location downtown, such as New Belgium Brewery or Wild Boar Coffee" (see Appendix A, Paragraph 21, Subparagraph h). Sites within these constraints were also required to be in secure areas, with availability of access roads, and minimal obstacles to the wind.

Figure 3-6 shows the two (2) monitoring locations selected in downtown Fort Collins, which were selected cooperatively with City of Fort Collins staff. Figures 3-7 and 3-8 show zoomed in satellite views of the downtown monitoring locations, which are labeled as follows:

- City Park (CPFC) Site: The location chosen for the city park site was the City Park pool. The pool is not in use during the winter season, so it offered a secure fenced location.
- Mason Street (MSFC) Site: A downtown location was chosen existing particulate monitoring run by the Colorado Department of Health and Environment (CDPHE) because the location offered additional parameter monitoring, and secure access. This

location was chosen as opposed to New Belgium Brewery or Wild Boar Coffee locations suggested in the Operator's Agreement.

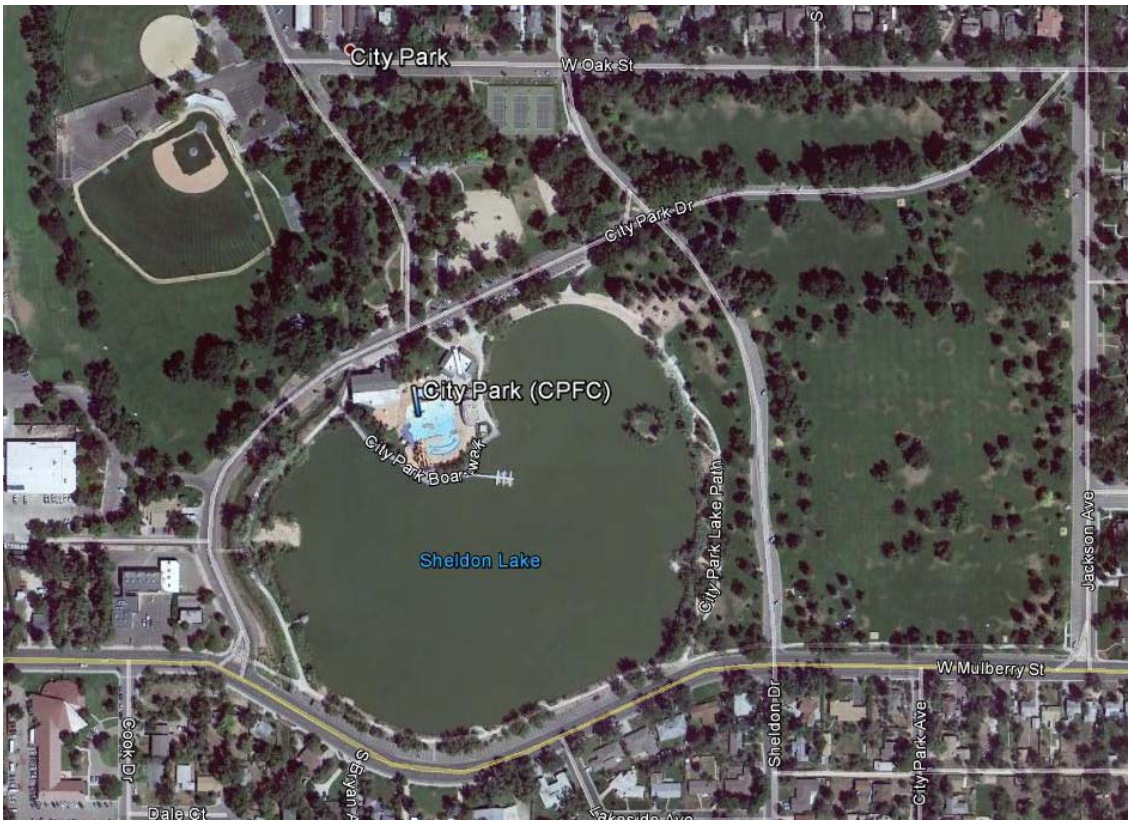


Figure 3-5. The City Park (CPFC) Site in downtown Fort Collins.

Figure 3-5. The Mason Street (MSFC) Site in downtown Fort Collins.

4.0 MONITORING PROCEDURES

For this study, ARS will install and operate equipment at five monitoring sites for a 90-day period, to include:

- Three stations near oil and gas operations in Fort Collins equipped to continuously monitor meteorology (including wind speed and wind direction) and H_2S, with VOC samples collected at two of these locations.
- Two stations with VOC samples at the downtown Fort Collins locations.

Specific monitoring procedures are presented in this section.

4.1 CONTINUOUS HYDROGEN SULFIDE (H_2S) AND METEOROLOGICAL MONITORING

The TBFC, HFFC and WPFC stations in NE Fort Collins will monitor H_2S and meteorological parameters using a system of stations that was previously procured and assembled at ARS headquarters for Denbury Resources, Inc., and leased as per a separate agreement between Denbury and the City for the duration of this monitoring effort. These systems were designed to be rugged, reliable, and equipped with Environmental Protection Agency (EPA) prevention of significant deterioration (PSD) grade meteorological sensors. The primary component of these systems are continuous H_2S monitors, with meteorological parameters including wind speed, wind direction, temperature and relative humidity.

Table 4-1 presents a list of equipment and measurement methods used for this study, along with performance specifications. Note that detection of an H_2S odor (normally described as resembling a rotten egg smell) may not coincide with a sensor response. The H_2S sensors used for this study were originally configured to trigger alarms at levels considered harmful to human health, where a low alarm level for personal exposure monitors might be typically be set to somewhere between 5 and 10 ppm. Odors from H_2S can be detected at levels lower than 0.5 ppm, which may be reported as 0 ppm due to analyzer detection limits.

All ARS standard operating procedures for installation, verification and operation of air quality and meteorological parameters are fully documented, as listed in Appendix B. General procedures include:

- All equipment will be calibrated upon installation according to EPA guidelines, and a final calibration check will be performed before removal at the end of the study period
- All calibration and verification results will be fully documented in field log sheets
- ARS will perform monthly H_2S calibration checks using an H_2S reference standard

Continuous data from these stations will be downloaded daily by ARS staff via a radio telemetry system via IP Cellular Modems. Data are reviewed each business day to assess the

operational integrity of the systems. If any data inconsistences or suspected instrument issues are noted during data review, ARS will assess necessary corrective actions and notify City staff.

Figure 4-1. Hydrogen Sulfide and Meteorolgical Monitoring Station.

Table 4-1

Equipment and Measurement Methods

Continuous Air Quality Parameters

Parameter	Sample Height	Manufacturer/ Model	Averaging Period	Measurement Range	Accuracy	Measurement Method
Hydrogen Sulfide (H_2S)	1 meter (HFFC and TBFC) or 3 meter (WPFC)	Millennium II Transmitter and H_2S Sensor Model: ST322X-100-ASSY	1-hour	0-50 ppm	± 1.0 ppm	Electrochemical Sensor
Ambient Temperature (AT)	1 meter (HFFC and TBFC) or 3 meter	R.M. Young 41342VC	1-hour	-50°C – 50°C	± 0.3 (at 0°C)	Platinum resistive temperature devise (RTD)
Relative Humidity (RH)	1 meter (HFFC and TBFC) or 3 meter	Rotronics HC2S3	1-hour	0-100%	± 2% (at 20°C)	Hygromer
Vector Wind Speed (VWS)	1 meter (HFFC and TBFC) or 3 meter	R.M. Young 05305	1-hour	0-45 m/s	± .2 m/s or 1% of FS	Propeller, Starting threshold = 0.58 m/s
Vector Wind Direction (VWD)	1 meter (HFFC and TBFC) or 3 meter	R.M. Young 05305	1-hour	0-360°	± 3%	Vane
Standard Deviation of Wind Direction (SDWD)	1 meter (HFFC and TBFC) or 3 meter	N/A	1-hour	N/A	N/A	Calculated from wind direction using Yamartino method

4.2 VOC MONITORING

Monitoring for Speciated Non-Methane Organic Carbon compounds (SNMOCs), a subset of volatile organic compounds (VOCs) and the additional analysis of methane (CH_4) will conducted at the HFFC and TBFC sites in NE Fort Collins, and at both downtown site. A list of SNMOC compounds measured is presented in Appendix A. Five canister samples will be collected at each site on EPA's 1/12 day sampling schedule. Canisters will be analyzed at ERG laboratories following EPA's Compendium Methods TO-12, augmented with CH_4 analysis. Specific VOC parameters analyzed will include:

- BTEX compounds, which consist of benzene, toluene, ethyl-benzene and xylenes. These are parameters of interest because they are part of a subset of VOC compounds designated by the EPA as hazardous air pollutants (HAPs).
- Light alkanes, including ethane, propane, iso/n-butane and iso/n-pentane, which are

primary components of natural gas and gasoline vapors. These compounds are not considered HAPs, but in large concentrations can contribute to odor issues and have potential to contribute to ozone formation.

- Methane (CH_4), which is not considered a HAP, but is associated with oil and gas development, and of interest because of its potential as a greenhouse gas.

ARS will facilitate the collection and analysis of 22 24-hour integrated volatile organic compound (VOC) samples which will include 5 events at each of 4 sites, and 2 collocated/duplicate samples. Siltek® evacuated stainless steel canisters will be manually deployed at each monitoring site every 12 days on the EPA prescribed 1/12 day schedule, as shown in Figure 4-2 for 2013. Samples will begin on November 24, 2013, and continue through January 11, 2014 to include sample dates of 11/24, 12/6, 12/18, 12/30 and 1/11. ARS proposes to subcontract laboratory analysis of VOC compounds to the Eastern Research Group, Inc. (ERG) laboratories, who also provide VOC analysis support as part of the larger EPA Urban Air Toxics Monitoring Program (UATMP) and National Air Toxics Trends Station (NATTS) Networks. Complete references for ERG laboratory methods are provided in Appendix C. General procedures include:

- City staff will be responsible for deploying and retrieving the canister samples. Canisters will be shipped by ERG to ARS headquarters in Fort Collins, where City staff will retrieve canisters for deployment. City staff will return canisters and chain-of-custody forms to ARS headquarters, and ARS will ship to ERG. ARS will fully train City staff for deployment of canisters following the canister deployment protocol provided in Appendix D. ARS will provide all support equipment, forms and other supplies.
- Sample canisters will be shipped to ERG labs after sampling as soon as practical after collection, typically within 24 hours. Canisters will be analyzed at ERG using GC/FID analysis with MSD verification following TO-12 guidelines for SNMOC compounds. Canister samples will also be analyzed following ASTM D1946 methodology using GC/FID analysis for CH_4. ERG will provide validated final data concentration files to ARS and City staff.

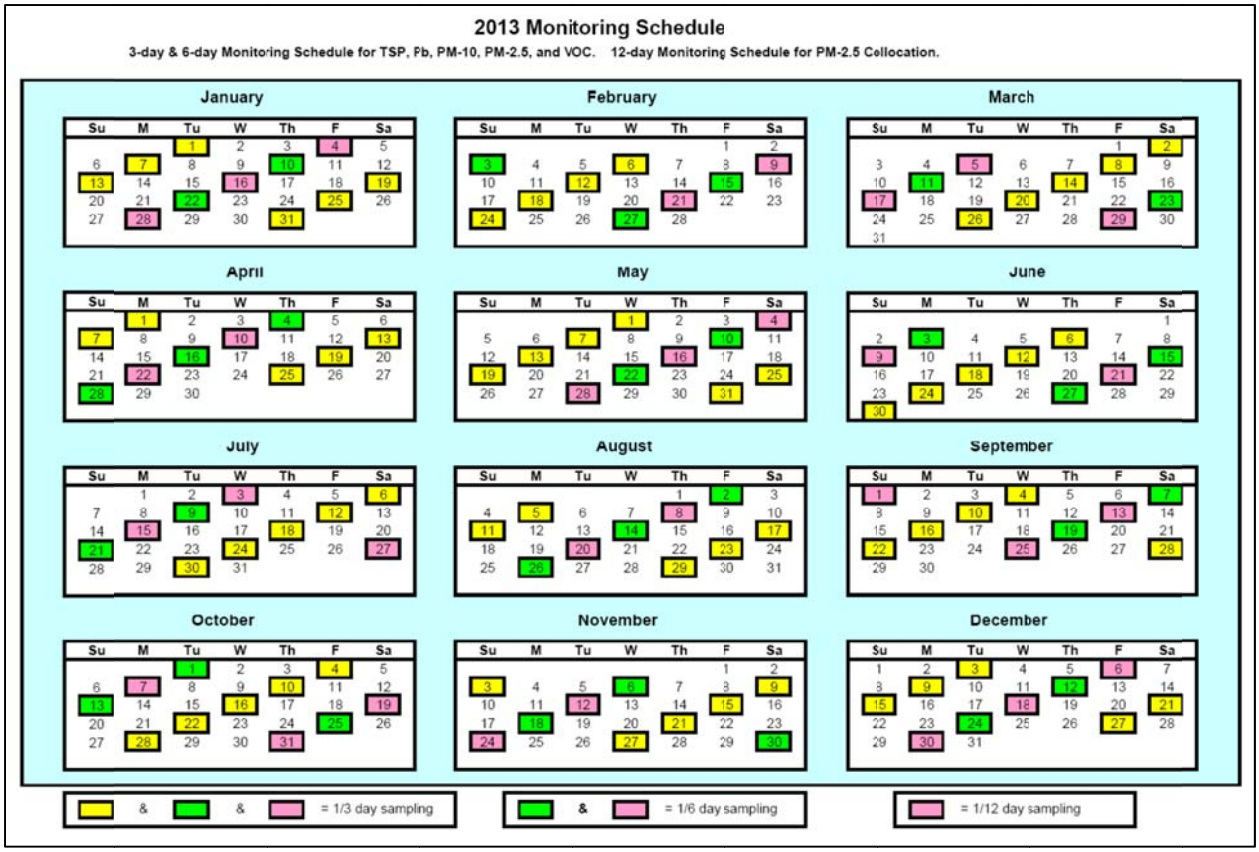


Figure 4-2. EPA 2013 Monitoring Schedule, Where 1/12 day prescribed sample dates are shown in pink.

5.0 DATA ANALYSIS, EVALUATION AND REPORTING

To ensure scientifically defensible data, all data analysis and evaluation will follow EPA protocols where applicable. For continuous parameters (H_2S and meteorology) ARS will apply fully documented data management techniques to yield the highest quality data collection and validation. References to ARS data validation methods are listed in Appendix B, where data are validated to Final (Level-1) validation as described in SOP 3450, *Ambient Air Quality and Meteorological Monitoring Data Validation*. Meteorological data for the PSD-grade monitoring stations are validated according to PSD guidelines at ARS, where specific validation criteria are listed in Table 5-1.

All VOC canister sample analysis and evaluation is managed at the ERG analytical laboratory according to ERG quality assurance documentation listed in Appendix C. Laboratory procedures for follow EPA Compendium Methods TO-12 for SNMOC analysis and method ASTM D1946 for CH_4 analysis.

ARS will provide a brief written data summary report and associated digital data files to City staff within 90-days of project completion. Only validated data, as per ARS SOP 3450, *Ambient Air Quality and Meteorological Monitoring Data Validation* (listed in Appendix B), will be provided in the final report. Data analysis provided in the report will include:

- Final validated data and concentrations for each measured pollutant, provided in both report tables and in separate digital files.
- Time series plots including meteorology, H_2S, and VOCs.
- Wind roses for the entire period and wind roses for high and low H_2S and VOC periods.
- Reports will also include copies of field documentation including log sheets, calibration results, quality control checks, and descriptions of maintenance performed.

Note that, while the proposed work will not directly consider potential health impacts of monitored parameters, these data will be available for possible future health impact assessments. For this analysis, per direction by City staff, ARS will report concentrations using any requested metrics that may be comparable to risk analysis thresholds (e.g., EPA defined risk-based screening thresholds for air toxics).

Table 5-1

Calibration and Validation Criteria – Continuous Parameters

Measurement	Calibration Method	Frequency	Criteria	EPA Acceptance Criteria	ARS Calibration Acceptance Criteria	ARS Validation Acceptance Criteria
H_2S	Collocated comparisons to a reference standard	Monthly	Concentration Difference	N/A	≤ ± 1 ppm	≤ ± 5 ppm
Temperature	Collocated comparisons to a certified transfer standard	Upon install and removal	Temperature Difference	≤ ± 0.5ºC	≤ ± 0.5ºC	≤ ± 0.5 ºC
Relative Humidity	Collocated comparisons to a certified transfer standard	Upon install and removal	Relative Humidity Difference	≤ ±7%	≤± 5%	≤± 7%
Wind Speed	Rotational rate at zero and five upscale speed levels using a selectable speed anemometer drive, starting threshold test with torque wheel	Upon install and removal	Difference	<± 0.2 m/s	<± 0.2 m/s	<± 0.2 m/s
Wind Direction	Alignment using two landmarks, orientation to true north, and linearity with a directional protractor, starting threshold test with torque wheel	Upon install and removal	Reference Alignment Difference	N/A	≤±2º	N/A
			Total Alignment Difference	≤± 5º	≤± 5º	≤± 5º
			Linearity	N/A	≤± 5º	≤± 5º
			Starting Threshold	N/A	Manufacturer Specification	

Meteorological monitoring follows PSD requirements, in accordance with *EPA QA Handbook for Air Pollution Measurement Systems: Vol IV.*

APPENDIX A – MONITORING PLAN

SNMOC TARGET COMPOUNDS

ERG Application of EPA TO-12 Canister Analysis

SNMOC[(5)] Target Compounds

Compound	
Ethylene	2,3-Dimethylpentane
Acetylene	3-Methylhexane
Ethane	1-Heptene
Propylene	2,2,4-Trimethylpentane
Propane	*n*-Heptane
Propyne	Methylcyclohexane
Isobutane	2,2,3-Trimethylpentane
Isobutene	2,3,4-Trimethylpentane
1-Butene	Toluene
1,3-Butadiene	2-Methylheptane
n-Butane	3-Methylheptane
trans-2-Butene	1-Octene
cis-2-Butene	*n*-Octane
3-Methyl-1-Butene	Ethylbenzene
Isopentane	*m,p*-Xylene
1-Pentene	Styrene
2-Methyl-1-Butene	*o*-Xylene
n-Pentane	1-Nonene
Isoprene	*n*-Nonane
trans-2-Pentene	Isopropylbenzene
cis-2-Pentene	*n*-Propylbenzene
2-Methyl-2-Butene	α-Pinene
2,2-Dimethylbutane (Neohexane)	*m*-Ethyltoluene
Cyclopentene	*p*-Ethyltoluene
4-Methyl-1-Pentene	1,3,5-Trimethylbenzene
2,3-Dimethylbutane	*o*-Ethyltoluene
Cyclopentane	β-Pinene
2-Methylpentane (Isohexane)	1,2,4-Trimethylbenzene
3-Methylpentane	1-Decene
2-Methyl-1-Pentene	*n*-Decane
1-Hexene	1,2,3-Trimethylbenzene
2-Ethyl-1-Butene	*m*-Diethylbenzene
n-Hexane	*p*-Diethylbenzene
trans-2-Hexene	1-Undecene
cis-2-Hexene	*n*-Undecane
Methylcyclopentane	Dodecene
2,4-Dimethylpentane	*n*-Dodecane
Benzene	Tridecene
Cyclohexane	*n*-Tridecane
2-Methylhexane (Isoheptane)	Total NMOC

APPENDIX B – MONITORING PLAN

AIR RESOURCE SPECIALISTS, INC.

Quality Assurance Documents
(Continuous Air Quality and Meteorological Parameters)

The following standard operating procedures (SOPs), technical instructions (TIs), and checklist instructions (CIs) are used in executing this program. Note that project-specific documents have not been written; this project relies in part on SOPs, TIs, and CIs that have been prepared to support other field studies. The general policies and instructions outlined in these procedures, however, are relevant to the current monitoring effort, and as such, the listed SOPs, TIs, and CIs are suitable for this particular study. Copies of all the following documents are available from ARS upon request.

Number	Title	Regulatory Citation
SOP 3001	**Procedures for Quarterly Maintenance to an Ambient Air Monitoring Station (Version 0.1, January 2008)**	EPA QA Handbook for Air Pollution Measurement Systems Vol. II, Section 11.0
SOP 3050	**Siting of Ambient Air Quality Monitoring Stations (Version 0.2, November 2009)**	EPA QA Handbook for Air Pollution Measurement Systems Vol. II, Section 6.0
SOP 3100	**Calibration of Ambient Air Quality Analyzers (Version 2.3, November 2009)**	EPA QA Handbook for Air Pollution Measurement Systems Vol. II, Section 12.0 40 CFR 50
SOP 3150	**Calibration and Routine Maintenance of Meteorological Monitoring Systems (Version 3.6 November 2009)**	EPA QA Handbook for Air Pollution Measurement Systems Vol. IV
TI 3150-2113	Calibration and Routine Maintenance of R.M. Young Temperature/Delta Temperature Systems (Version 0.3, June 2002)	EPA QA Handbook for Air Pollution Measurement Systems Vol. IV, Section 3.0
CI 3176-3121	Weekly Station Visit: Relative Humidity Sensor (Vaisala) (Version 2, January 2011)	EPA QA Handbook for Air Pollution Measurement Systems Vol. IV, Section 5.0
SOP 3350	**Collection of Ambient Air Quality and Meteorological Monitoring Data and Site Documentation (Version 1.6, October 2013)**	EPA QA Handbook for Air Pollution Measurement Systems Vol. II, Section 5.0 and 14.0
TI 3350-4000	Collection of Ambient Air Quality and Meteorological Monitoring Data via Modem (Version 3.0, October 2013)	EPA QA Handbook for Air Pollution Measurement Systems Vol. II, Section 14.0
SOP 3450	**Ambient Air Quality and Meteorological Monitoring Data Validation (Version 3.1, October 2013)**	EPA QA Handbook for Air Pollution Measurement Systems Vol. II, Section 17.0
TI 3450-5000	Ambient Air Quality and Meteorological Monitoring Data – Level 0 Validation (Version 1.8, October 2013)	Guidance on Environmental Data Verification and Data Validation **(QA/G-8)**
TI 3450-5010	Ambient Air Quality and Meteorological Monitoring Data – Preliminary Validation (Version 2.1, October 2013)	Guidance on Environmental Data Verification and Data Validation **(QA/G-8)**
TI 3450-5020	Ambient Air Quality and Meteorological Monitoring Data – Final Validation (Version 3.1, October 2013)	Guidance on Environmental Data Verification and Data Validation **(QA/G-8)**
SOP 3650	**IMC Staff's Maintenance Responsibilities for the Ambient Air Quality Data Base Management System (AQDBMS) (Version 2.3, March 2012)**	EPA QA Handbook for Air Pollution Measurement Systems Vol. II, Section 14.0

APPENDIX C – MONITORING PLAN

EASTERN RESEARCH GROUP

Quality Assurance Documents
(VOC Canisters Samples)

The following quality assurance manuals will be used in executing this program. These documents were written by the analytical laboratory, Eastern Research Group and their general policies and instructions are applied to the Fort Collins VOC sampling effort. Copies of all the following documents are available from ERG upon request.

Number	Title
ERG-MOR-024	Standard Operating Procedure for Preparing, Extracting, and Analyzing DNPH Carbonyl Cartridges by Method TO-11A
ERG-MOR-045	Standard Operating Procedure for Sample Receipt at the ERG Chemistry Laboratory
ERG-MOR-046	Field Procedure for Collecting Speciated and/or Total Nonmethane Organic Compounds Ambient Air Samples Using the ERG SNMOC Sampling System
ERG-MOR-047	Field Procedure for Collecting Ambient Carbonyl Compounds Samples Using the ERG C Sampling System
ERG-MOR-060	Standard Operating Procedure for PDFID Sample Analysis by Method TO-12
ERG-MOR-061	Standard Operating Procedure for Standard Preparation Using Dynamic Flow Dilution System
ERG-MOR-062	Standard Operating Procedure for Sample Canister Cleaning
ERG-MOR-079	Standard Operating Procedure for Sample Login to the Laboratory Information Management System

APPENDIX D – MONITORING PLAN

CANISTER SAMPLING FIELD PROTOCOL

Standard Operation Procedures for Monitoring SNMOC in Ambient Air Using the EPA Compendium Method TO-12

Required Equipment:

1. TO-Can Canisters (1 per site)
2. flow controllers (1 per site)

Vacuum Range: 29.9 to 7 in Hg

Sample Time: 1440 min (24-hr)

Air Volume: 4 to 6 L

Sampling Procedure:

Sample Start-up Procedures

1. Begin recording the "Lab Pre-Sample" section of the Toxics/SNMOC Sample Data Sheet

    - Site Codes: Well Pad = WPFC, Tank Battery = TBFC, Mason St. = MSFC, City Park = CPFC
    - City/State: Fort Collins, CO
    - AQS Code: N/A
    - Collection Date: The date sample is started
    - Options: SNMOC is 'Yes'. Toxics is 'No'
    - Canister Number: Record the number from outside the canister
    - Lab Initial Can Pressure: Will be filled out by lab
    - Date Can Cleaned: Will be filled out by lab
    - Cleaning Batch Number: Will be filled out by lab
    - Duplicate Event: 'Yes' or 'No'
    - Duplicate Can Number: Record canister number from the corresponding duplicate canister

2. Remove gold cap from canister using a wrench. Save and store.
3. Remove silver caps from both ends of the flow controller. Save and store.
4. Connect the flow controller to the canister and tighten screw using a wrench
5. Begin recording the "Field Setup" section of the Toxics/SNMOC Sample Data Sheet

    - Operator: Operator's Last Name
    - Sys#: PR number from flow regulator
    - Setup Date: The date sample was started. Also record time sample was started.
    - Field Initial Can Pressure: Record from pressure meter after flow controller is turned 'on'
    - MFC Setting: Leave Blank
    - Elapsed Timer Reset: N/A
    - Canister Valve Opened: Write 'Yes' after flow controller is turned 'on'

6. Set canister on a flat surface approximately ½ to 1 m off the ground/rooftop

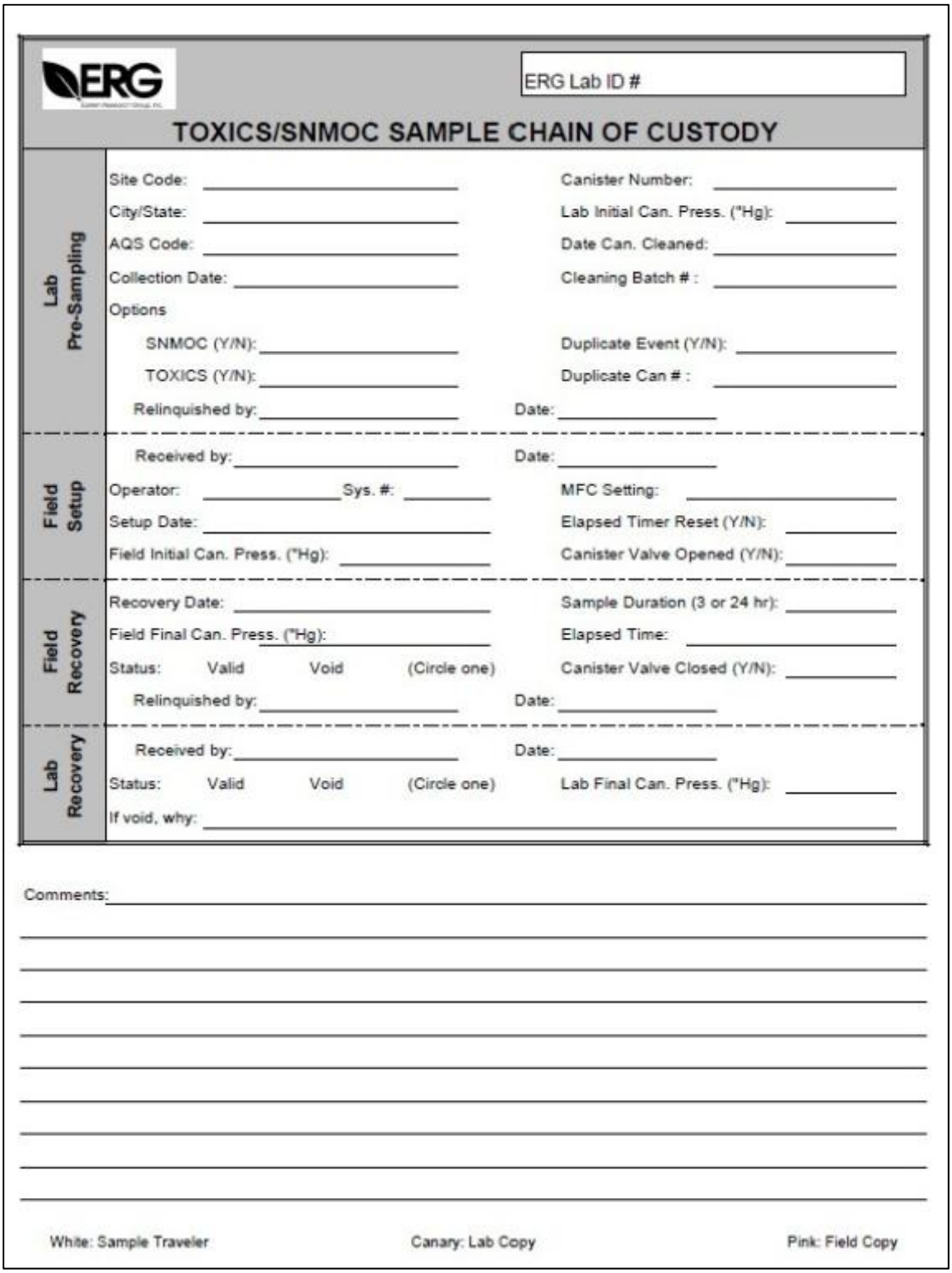
7. Turn dial counterclockwise (on) until a vacuum is established and finish recording information in the "Field Setup" section of the Toxics/SNMOC Sample Data Sheet

Sample Recovery Procedures

1. Begin recording the "Field Recovery" section of the Toxics/SNMOC Sample Data Sheet

    - Recovery date: The date sample ended. Also record time sample ended.
    - Field Final Can Pressure: Record from pressure meter before flow controller is turned 'off'
    - Sample Duration: Write "24" if a successful sample was achieved
    - Elapsed Time: Calculate total elapsed time (min) from start and end times
    - Canister Valve Opened: Write 'Yes' after flow controller is turned 'off'

2. Turn dial clockwise (off) and finish recording information in the "Field Setup" section of the Toxics/SNMOC Sample Data Sheet



ERG Lab ID #

TOXICS/SNMOC SAMPLE CHAIN OF CUSTODY

Lab Pre-Sampling

Site Code: _____ Canister Number: _____

City/State: _____ Lab Initial Can. Press. ("Hg): _____

AQS Code: _____ Date Can. Cleaned: _____

Collection Date: _____ Cleaning Batch # : _____

Options

SNMOC (Y/N): _____ Duplicate Event (Y/N): _____

TOXICS (Y/N): _____ Duplicate Can # : _____

Relinquished by: _____ Date: _____

Field Setup

Received by: _____ Date: _____

Operator: _____ Sys. #: _____ MFC Setting: _____

Setup Date: _____ Elapsed Timer Reset (Y/N): _____

Field Initial Can. Press. ("Hg): _____ Canister Valve Opened (Y/N): _____

Field Recovery

Recovery Date: _____ Sample Duration (3 or 24 hr): _____

Field Final Can. Press. ("Hg): _____ Elapsed Time: _____

Status: Valid Void (Circle one) Canister Valve Closed (Y/N): _____

Relinquished by: _____ Date: _____

Lab Recovery

Received by: _____ Date: _____

Status: Valid Void (Circle one) Lab Final Can. Press. ("Hg): _____

If void, why: _____

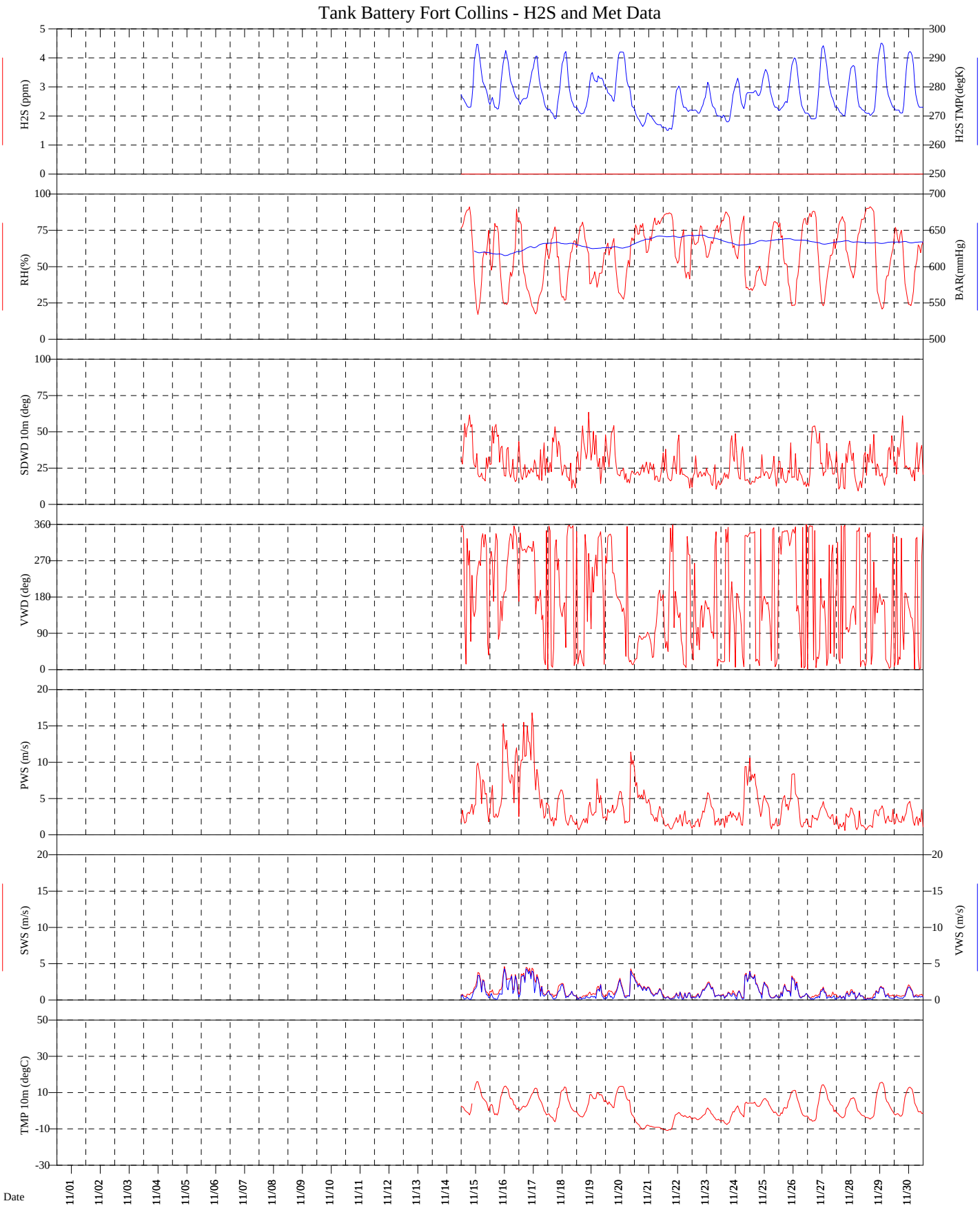
Comments: _____

White: Sample Traveler Canary: Lab Copy Pink: Field Copy

Example SNMOC Canister Chain-of-Custody Form

Appendix B

Time Series Plots for Hourly Data
November 15, 2013 - February 15, 2014


Tank Battery Fort Collins - H2S and Met Data
H2S (ppm)
H2S TMP(degK)
RH(%)
BAR(mmHg)
SDWD 10m (deg)
VWD (deg)
PWS (m/s)
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VWS (m/s)
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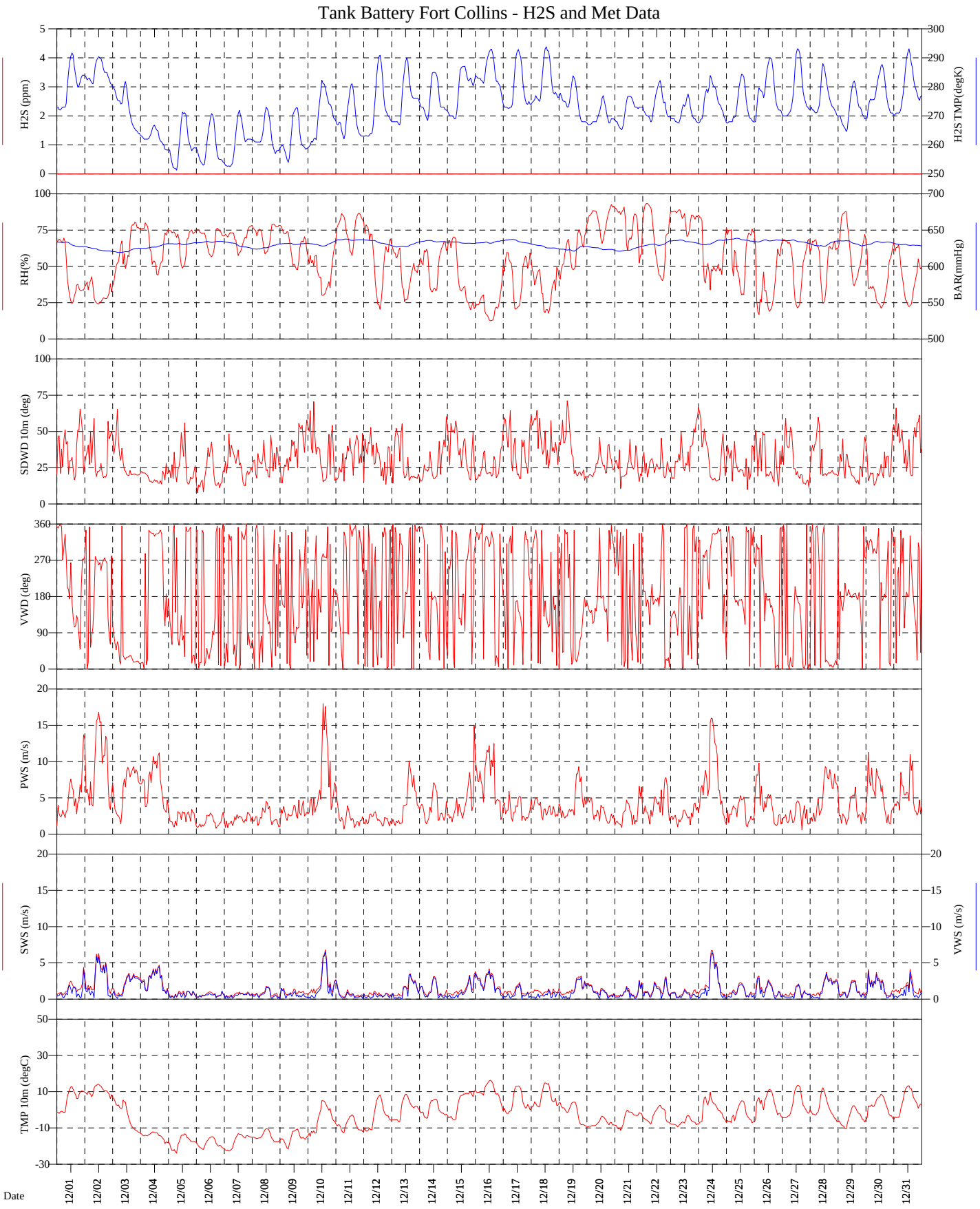
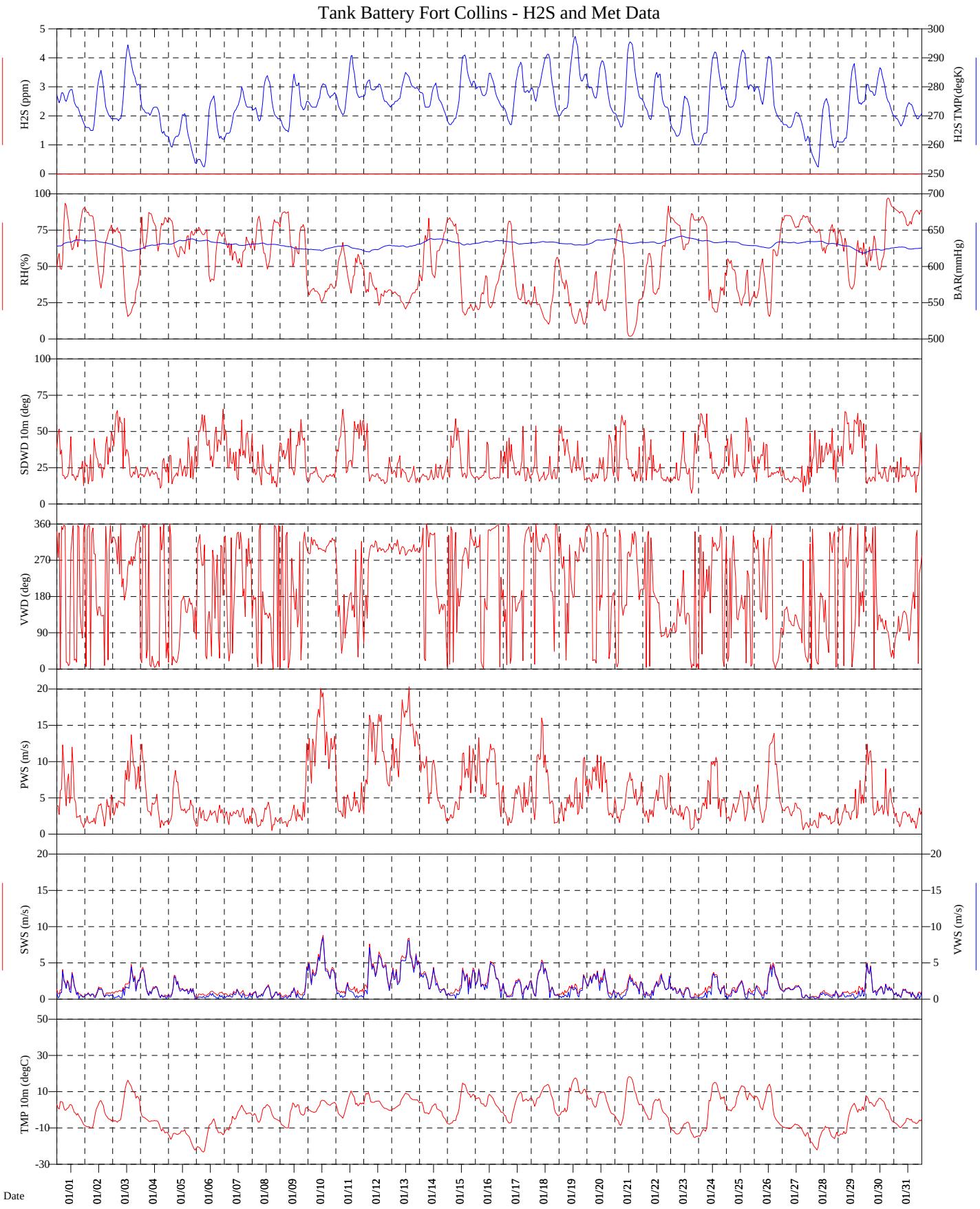


December 2013


Tank Battery Fort Collins - H2S and Met Data
H2S (ppm)
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RH(%)
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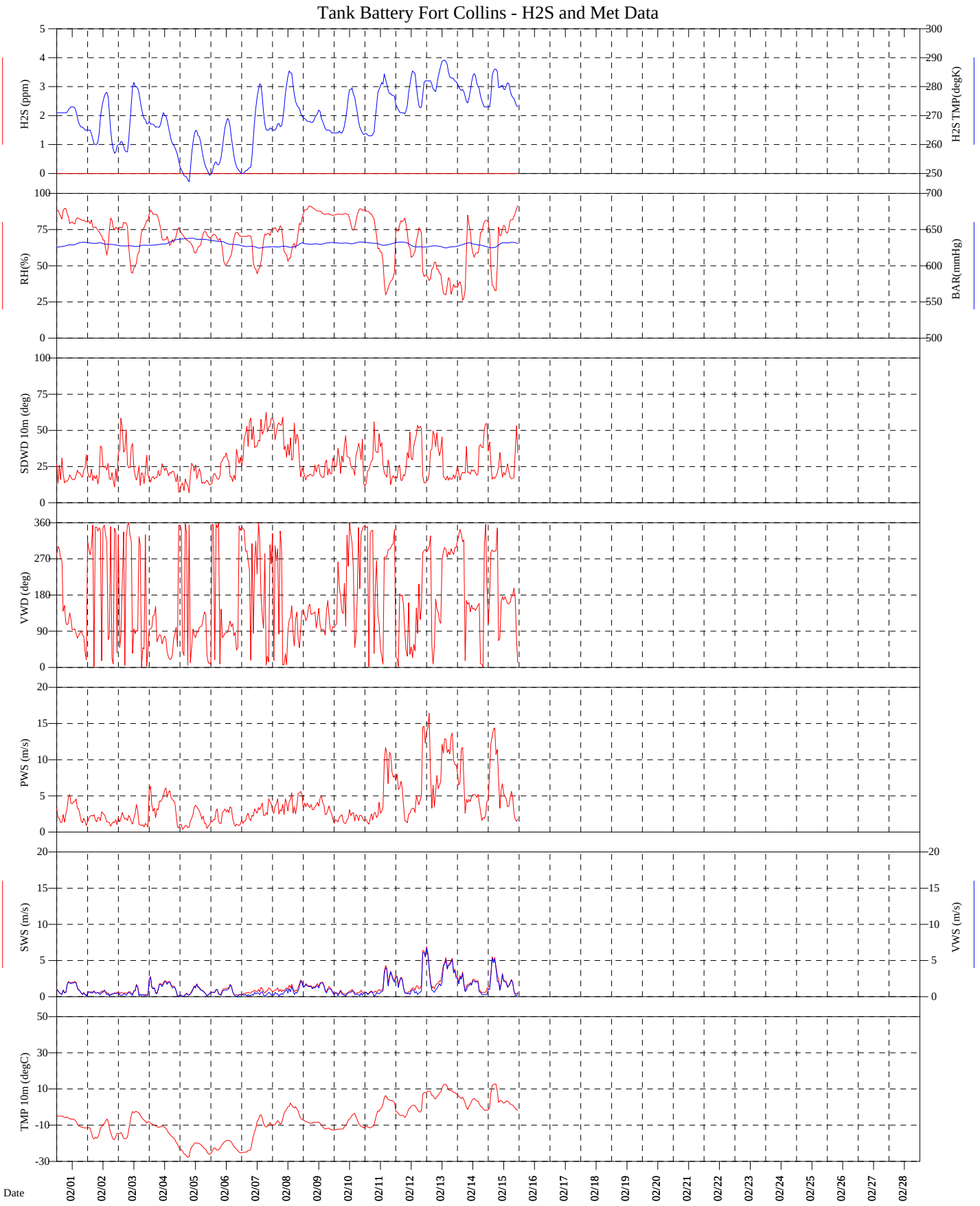
Tank Battery Fort Collins - H2S and Met Data
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BAR(mmHg)
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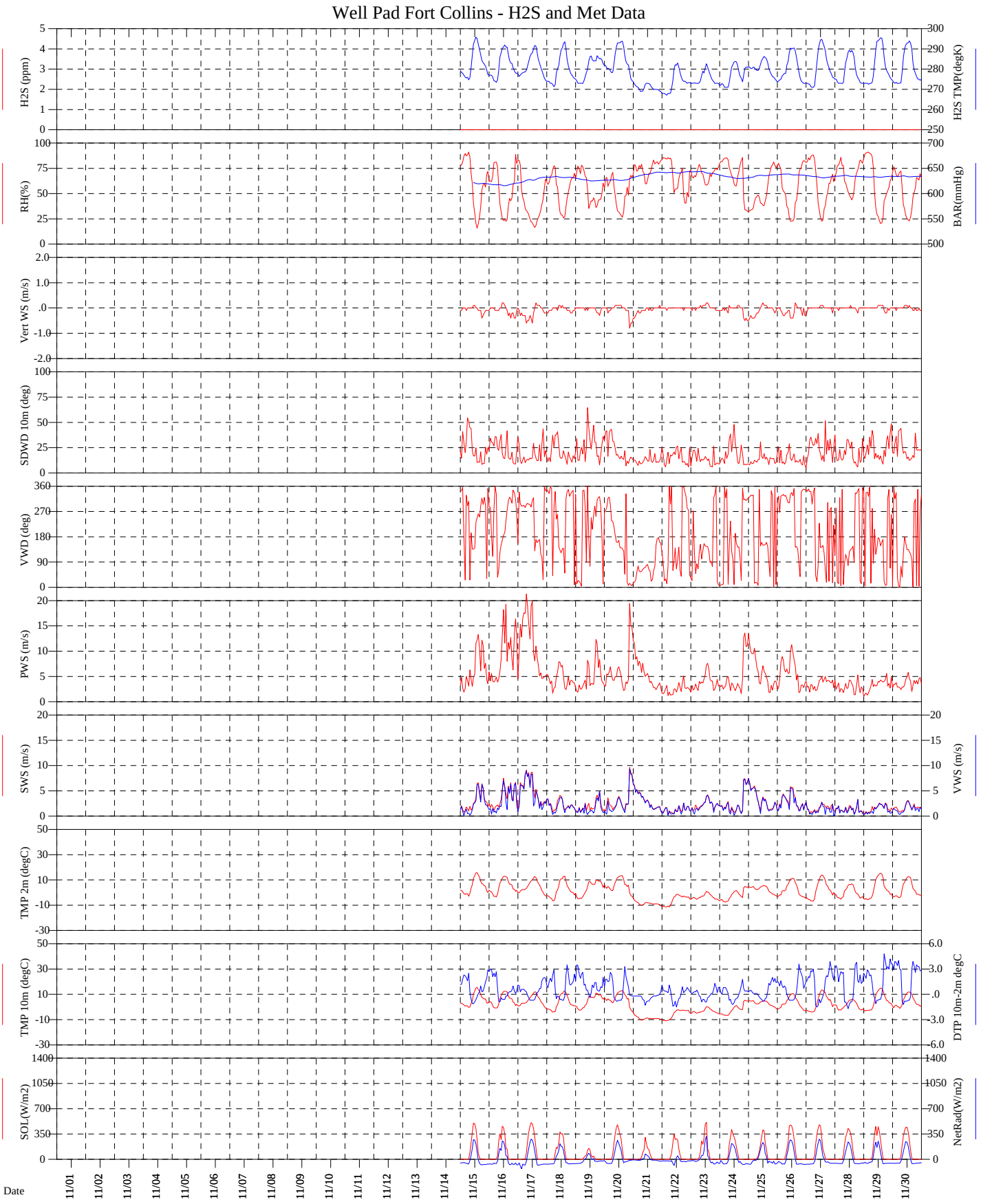
Well Pad Fort Collins - H2S and Met Data
H2S (ppm)
H2S TMP(degK)
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BAR(mmHg)
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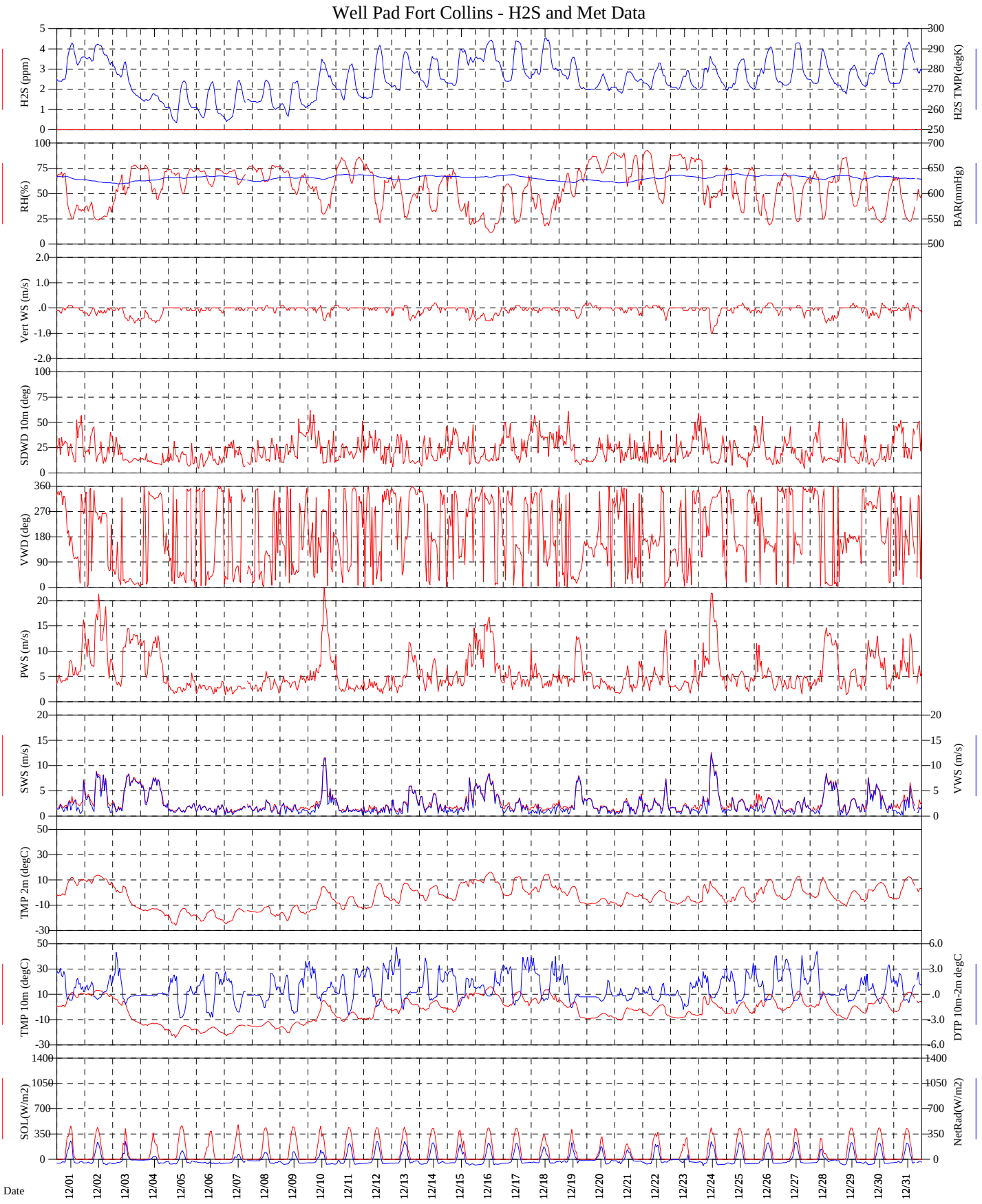
Well Pad Fort Collins - H2S and Met Data
H2S (ppm)
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RH(%)
BAR(mmHg)
Vert WS (m/s)
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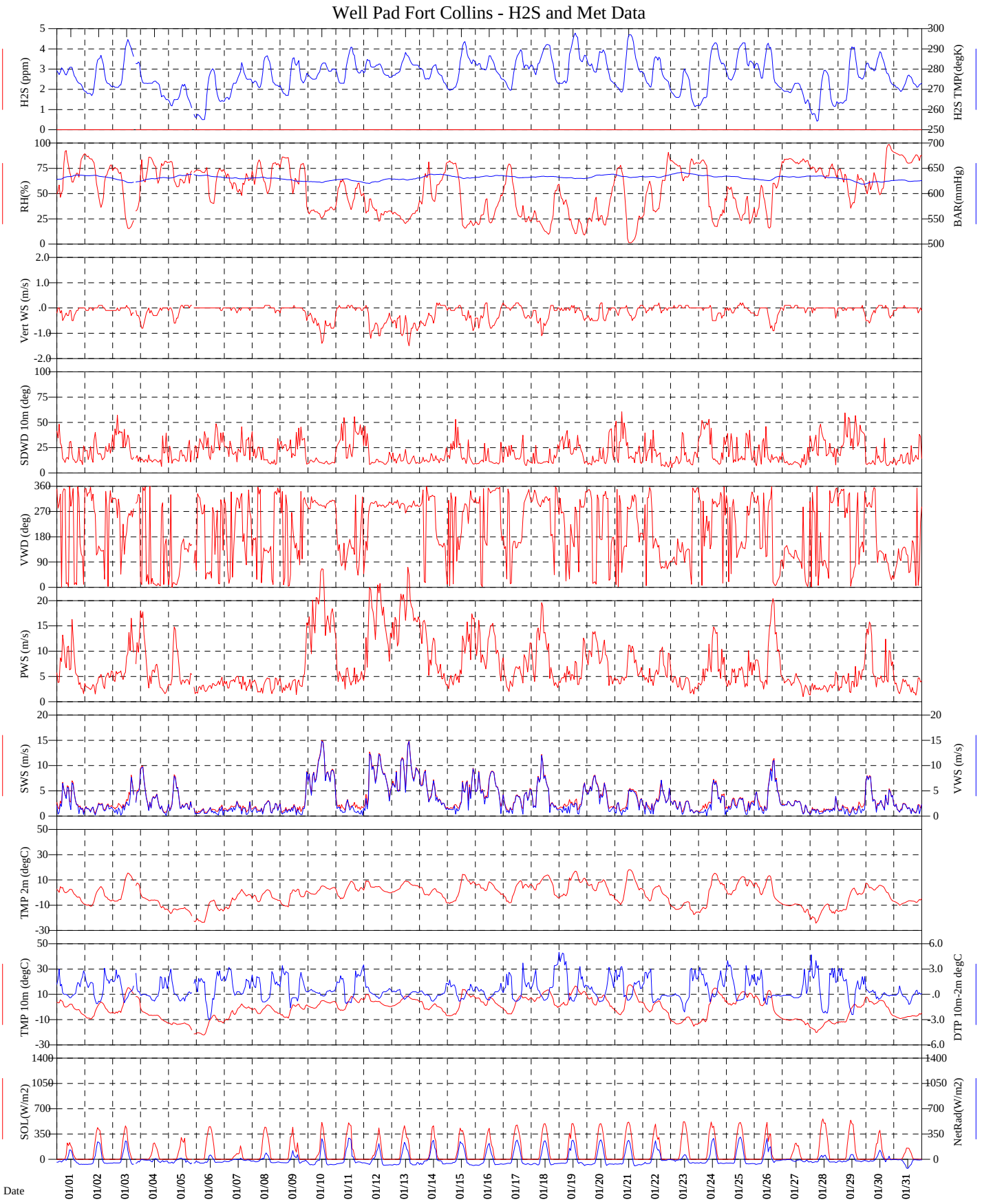
Well Pad Fort Collins - H2S and Met Data
H2S (ppm)
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BAR(mmHg)
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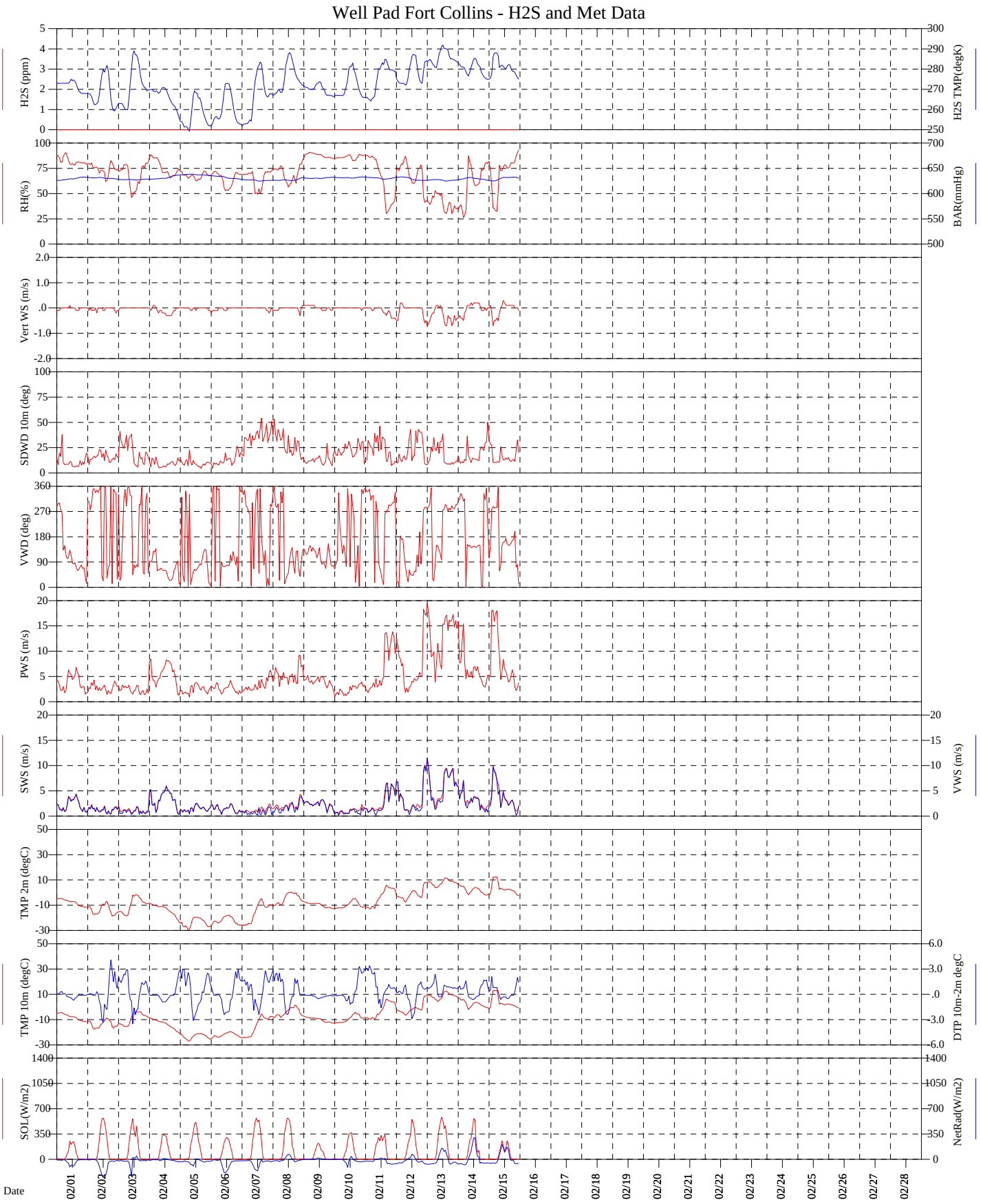
Well Pad Fort Collins - H2S and Met Data
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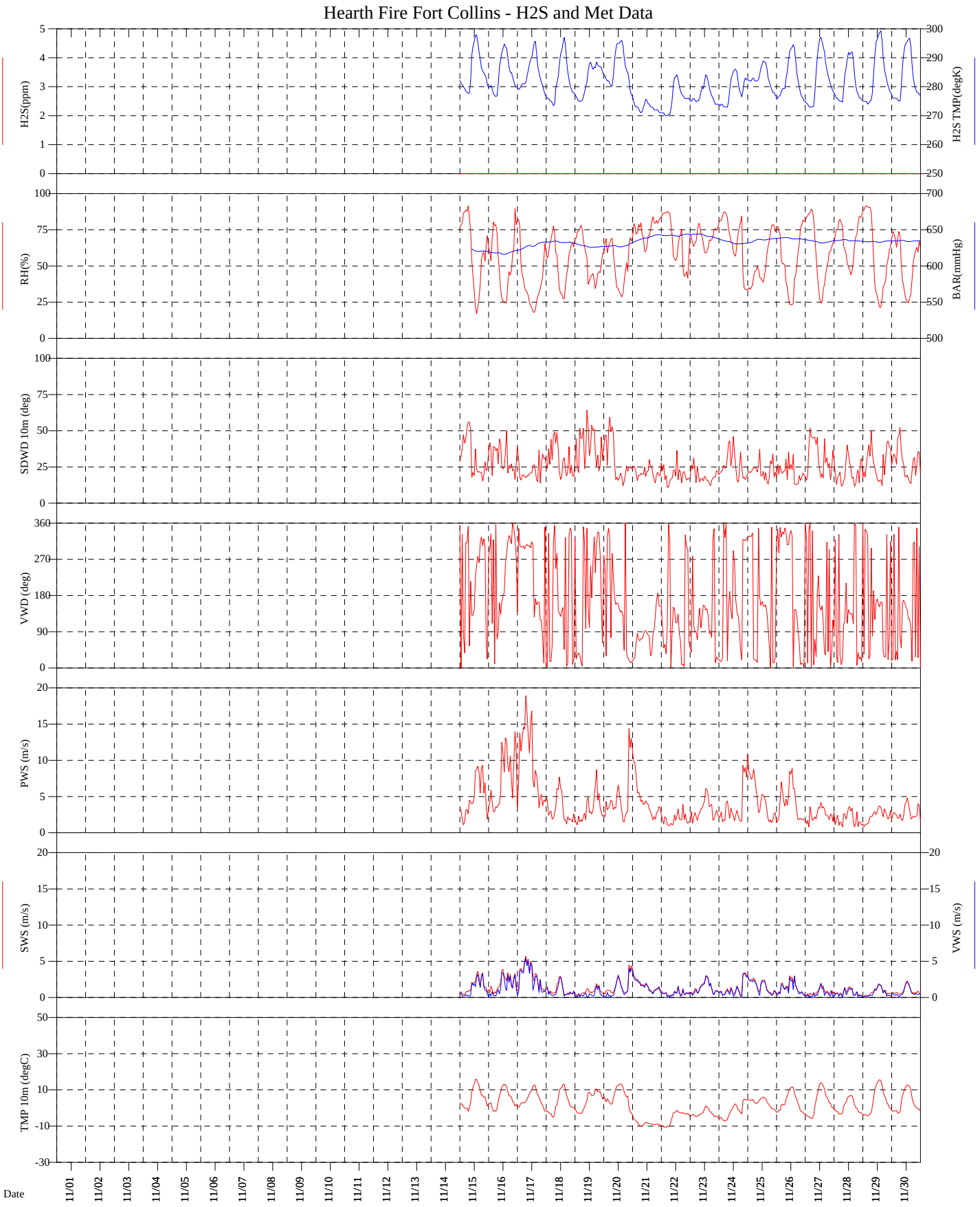
Hearth Fire Fort Collins - H2S and Met Data
H2S(ppm)
H2S TMP(degK)
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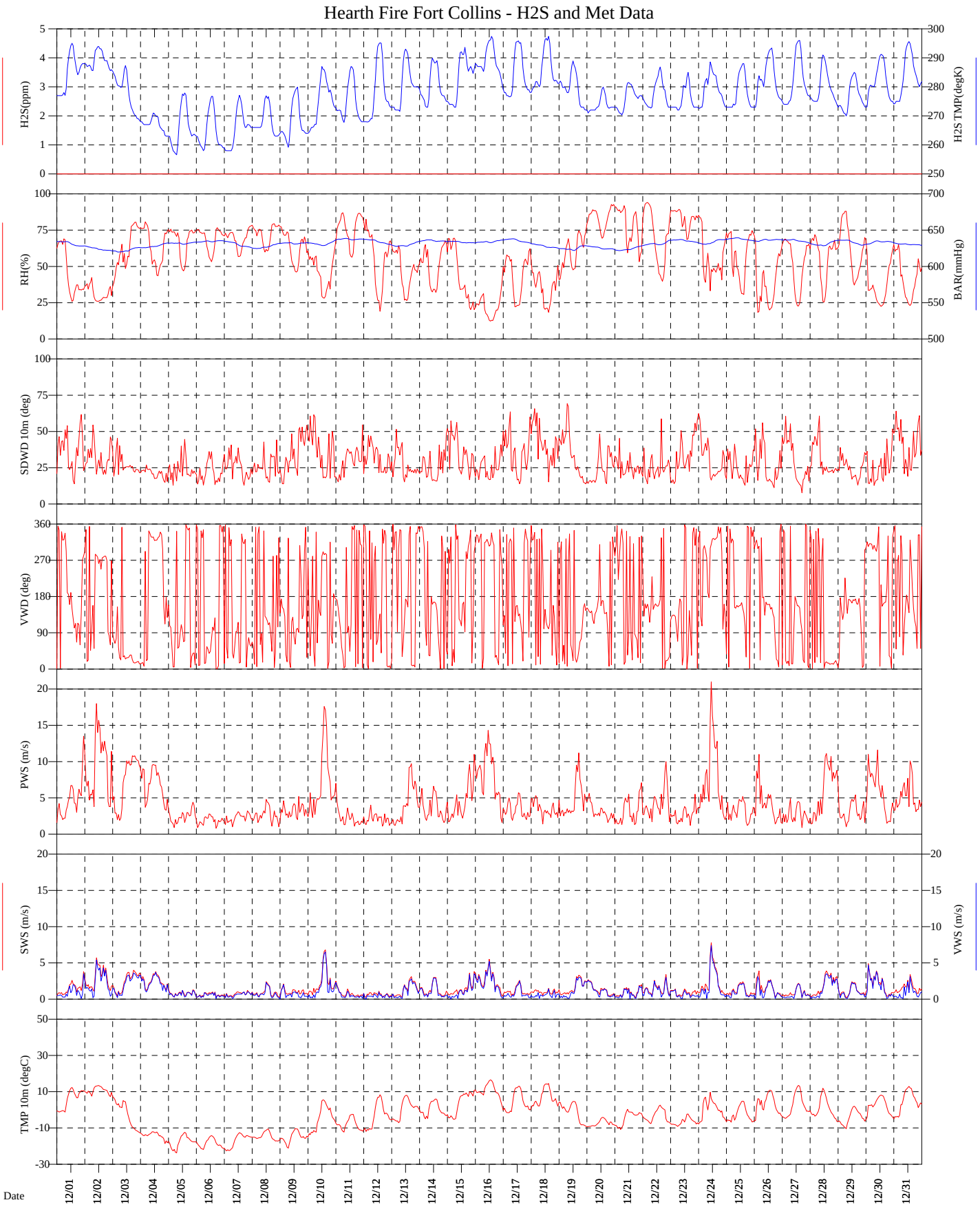
Hearth Fire Fort Collins - H2S and Met Data
H2S(ppm)
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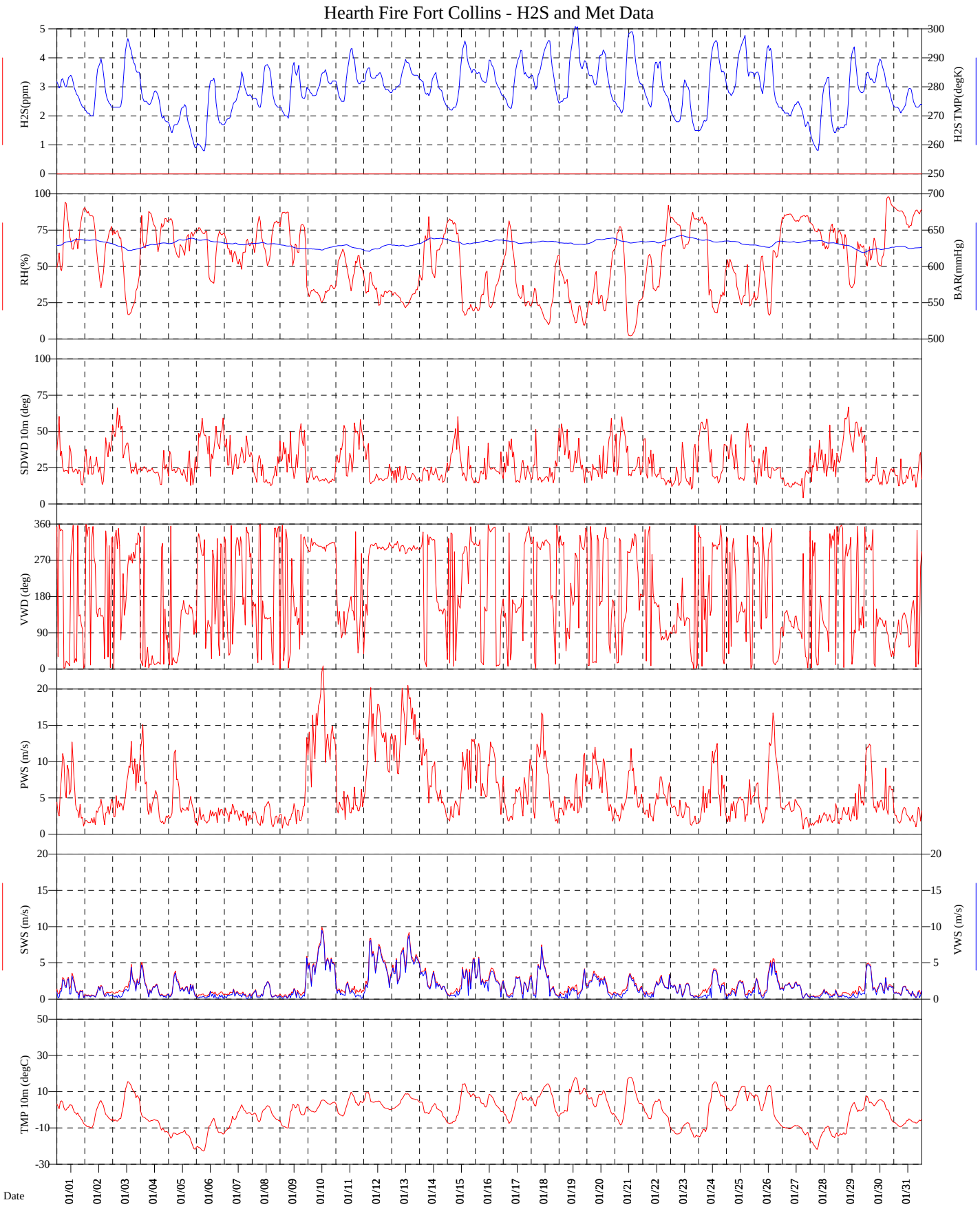
Hearth Fire Fort Collins - H2S and Met Data
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Hearth Fire Fort Collins - H2S and Met Data
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Appendix C

Methane and SNMOC Concentrations (24-Hour Averages)
November 24, 2013 - January 23, 2014

Table C-1
Methane Concentrations
November 24, 2013 – January 23, 2014

Site	Concentration (ppmV)					Average
	11/24/2013	12/18/2013	12/30/2013	1/11/2014	1/23/2014	
Tank Battery	2.23	2.52	2.59	2.22	2.61	2.43
Well Pad	1.86	2.24	2.2	2.32	2.04	2.13
City Park	2.38	2.41	2.57	2.2	2.18	2.35
Mason Street	2.39	2.55	2.13	2.64	2.26	2.40

Table C-2
City of Fort Collins SNMOC Monitoring
Tank Battery (TBFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	5	2	0.01	0.02	0.01
1,2,4-Trimethylbenzene (95-63-6)	5	5	0.03	0.09	0.06
1,3,5-Trimethylbenzene (108-67-8)	5	3	0.02	0.03	0.02
1,3-Butadiene (106-99-0)	5	2	0.03	0.06	0.03
1-Butene (106-98-6)	5	0		0.00	0.03
1-Decene (872-05-9)	5	0		0.00	0.02
1-Dodecene (112-41-4)	5	0		0.00	0.03
1-Heptene (592-76-7)	5	0		0.00	0.02
1-Hexene (592-41-6)	5	1	0.03	0.03	0.03
1-Nonene (124-11-8)	5	3	0.02	0.03	0.02
1-Octene (111-66-0)	5	3	0.02	0.04	0.02
1-Pentene (109-67-1)	5	5	0.02	0.06	0.03
1-Tridecene (2437-56-1)	5	0		0.00	0.02
1-Undecene (821-95-4)	5	1	0.01	0.01	0.02
2,2,3-Trimethylpentane (564-02-3)	5	1	0.02	0.02	0.02
2,2,4-Trimethylpentane (540-84-1)	5	0		0.00	0.01
2,2-Dimethylbutane (75-83-2)	5	5	0.02	0.04	0.03
2,3,4-Trimethylpentane (565-75-3)	5	4	0.01	0.04	0.02
2,3-Dimethylbutane (79-29-8)	5	5	0.05	0.15	0.10
2,3-Dimethylpentane (565-59-3)	5	5	0.03	0.19	0.09
2,4-Dimethylpentane (108-08-7)	5	5	0.02	0.08	0.04
2-Ethyl-1-butene (760-21-4)	5	0		0.00	0.02
2-Methyl-1-butene (563-46-2)	5	3	0.03	0.05	0.03
2-Methyl-1-pentene (763-29-1)	5	0		0.00	0.02
2-Methyl-2-butene (513-35-9)	5	1	0.03	0.03	0.02
2-Methylheptane (592-27-8)	5	5	0.03	0.22	0.09
2-Methylhexane (591-76-4)	5	5	0.10	0.41	0.25
2-Methylpentane (107-83-5)	5	5	0.41	1.12	0.84
3-Methyl-1-butene (563-45-1)	5	0		0.00	0.02
3-Methylheptane (589-81-1)	5	5	0.02	0.14	0.06
3-Methylhexane (589-34-4)	5	2	0.25	0.52	0.17
3-Methylpentane (96-14-0)	5	5	0.21	0.63	0.44
4-Methyl-1-pentene (691-37-2)	5	0		0.00	0.01
Acetylene (74-86-2)	5	5	0.53	0.94	0.73
a-Pinene (80-56-8)	5	0		0.00	0.01
Benzene (71-43-2)	5	5	0.23	0.38	0.27
b-Pinene (127-91-3)	5	0		0.00	0.02
cis-2-Butene (590-18-1)	5	2	0.02	0.03	0.02
cis-2-Hexene (7688-21-3)	5	0		0.00	0.02
cis-2-Pentene (627-20-3)	5	0		0.00	0.02
Cyclohexane (110-82-7)	5	5	0.26	1.02	0.54
Cyclopentane (287-92-3)	5	5	0.20	0.54	0.38

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-2 (continued)
City of Fort Collins SNMOC Monitoring
Tank Battery (TBFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Cyclopentene (142-29-0)	5	0		0.00	0.05
Ethane (74-84-0)	5	5	18.40	29.70	21.30
Ethylbenzene (100-41-4)	5	5	0.02	0.11	0.05
Ethylene (74-85-1)	5	5	1.10	2.34	1.71
Isobutane (75-28-5)	5	5	2.80	10.28	5.12
Isobutene (115-11-7)	5	0		0.00	0.02
Isobutylene (115-11-7)	5	0		0.00	0.02
Isopentane (78-78-4)	5	5	1.95	5.40	3.96
Isoprene (78-79-5)	5	3	0.03	0.04	0.03
Isopropylbenzene (98-82-8)	5	0		0.00	0.01
m-Diethylbenzene (141-93-5)	5	0		0.00	0.02
Methylcyclohexane (108-87-2)	5	5	0.19	1.23	0.53
Methylcyclopentane (96-37-7)	5	5	0.31	1.14	0.74
m-Ethyltoluene (620-14-4)	5	4	0.02	0.05	0.02
m-Xylene/p-Xylene (108-38-3/106-42-3)	5	5	0.06	0.25	0.13
n-Butane (106-97-8)	5	5	7.70	21.35	13.34
n-Decane (124-18-5)	5	4	0.03	0.07	0.03
n-Dodecane (112-40-3)	5	4	0.01	0.01	0.01
n-Heptane (142-82-5)	5	5	0.15	1.03	0.40
n-Hexane (110-54-3)	5	5	0.42	2.78	1.23
n-Nonane (111-84-2)	5	5	0.02	0.11	0.05
n-Octane (111-65-9)	5	5	0.06	0.45	0.19
n-Pentane (109-66-0)	5	5	2.12	5.64	3.68
n-Propylbenzene (103-65-1)	5	1	0.02	0.02	0.01
n-Tridecane (629-50-5)	5	0		0.00	0.01
n-Undecane (1120-21-4)	5	4	0.01	0.02	0.02
o-Ethyltoluene (611-14-3)	5	3	0.01	0.03	0.02
o-Xylene (95-47-6)	5	5	0.02	0.10	0.06
p-Diethylbenzene (105-05-5)	5	0		0.00	0.01
p-Ethyltoluene (622-96-8)	5	2	0.02	0.03	0.02
Propane (74-98-6)	5	5	19.03	43.67	28.67
Propylene (115-07-1)	5	5	0.24	0.63	0.38
Propyne (74-99-7)	5	0		0.00	0.02
Styrene (100-42-5)	5	0		0.00	0.03
Toluene (108-88-3)	5	5	0.19	0.68	0.37
trans-2-Butene (624-64-6)	5	1	0.07	0.07	0.02
trans-2-Hexene (4050-45-7)	5	0		0.00	0.02
trans-2-Pentene (646-04-8)	5	2	0.02	0.02	0.02

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-3
City of Fort Collins SNMOC Monitoring
Well Pad (WPFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	5	3	0.01	0.04	0.02
1,2,4-Trimethylbenzene (95-63-6)	5	5	0.03	0.09	0.06
1,3,5-Trimethylbenzene (108-67-8)	5	2	0.03	0.03	0.02
1,3-Butadiene (106-99-0)	5	2	0.03	0.04	0.03
1-Butene (106-98-6)	5	0		0.00	0.03
1-Decene (872-05-9)	5	0		0.00	0.02
1-Dodecene (112-41-4)	5	0		0.00	0.03
1-Heptene (592-76-7)	5	0		0.00	0.02
1-Hexene (592-41-6)	5	3	0.02	0.03	0.03
1-Nonene (124-11-8)	5	3	0.01	0.02	0.01
1-Octene (111-66-0)	5	3	0.02	0.03	0.02
1-Pentene (109-67-1)	5	4	0.03	0.07	0.04
1-Tridecene (2437-56-1)	5	0		0.00	0.02
1-Undecene (821-95-4)	5	0		0.00	0.03
2,2,3-Trimethylpentane (564-02-3)	5	0		0.00	0.01
2,2,4-Trimethylpentane (540-84-1)	5	0		0.00	0.01
2,2-Dimethylbutane (75-83-2)	5	4	0.03	0.33	0.09
2,3,4-Trimethylpentane (565-75-3)	5	3	0.01	0.05	0.02
2,3-Dimethylbutane (79-29-8)	5	5	0.03	0.08	0.06
2,3-Dimethylpentane (565-59-3)	5	5	0.03	0.13	0.06
2,4-Dimethylpentane (108-08-7)	5	5	0.01	0.04	0.02
2-Ethyl-1-butene (760-21-4)	5	0		0.00	0.02
2-Methyl-1-butene (563-46-2)	5	0		0.00	0.02
2-Methyl-1-pentene (763-29-1)	5	0		0.00	0.02
2-Methyl-2-butene (513-35-9)	5	2	0.05	0.07	0.04
2-Methylheptane (592-27-8)	5	4	0.02	0.05	0.03
2-Methylhexane (591-76-4)	5	5	0.07	0.39	0.23
2-Methylpentane (107-83-5)	5	5	0.26	0.62	0.47
3-Methyl-1-butene (563-45-1)	5	0		0.00	0.02
3-Methylheptane (589-81-1)	5	5	0.01	0.04	0.03
3-Methylhexane (589-34-4)	5	2	0.12	0.32	0.10
3-Methylpentane (96-14-0)	5	5	0.13	0.36	0.24
4-Methyl-1-pentene (691-37-2)	5	0		0.00	0.01
Acetylene (74-86-2)	5	5	0.46	1.31	0.73
a-Pinene (80-56-8)	5	2	0.03	0.03	0.02
Benzene (71-43-2)	5	5	0.17	0.31	0.23
b-Pinene (127-91-3)	5	0		0.00	0.02
cis-2-Butene (590-18-1)	5	3	0.02	0.03	0.02
cis-2-Hexene (7688-21-3)	5	0		0.00	0.02
cis-2-Pentene (627-20-3)	5	0		0.00	0.02
Cyclohexane (110-82-7)	5	5	0.16	0.52	0.26
Cyclopentane (287-92-3)	5	5	0.12	1.19	0.35

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-3 (continued)
City of Fort Collins SNMOC Monitoring
Well Pad (WPFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Cyclopentene (142-29-0)	5	0		0.00	0.05
Ethane (74-84-0)	5	5	11.60	23.85	16.20
Ethylbenzene (100-41-4)	5	5	0.02	0.12	0.05
Ethylene (74-85-1)	5	5	0.88	2.89	1.67
Isobutane (75-28-5)	5	5	1.80	7.52	3.45
Isobutene (115-11-7)	5	0		0.00	0.02
Isobutylene (115-11-7)	5	0		0.00	0.02
Isopentane (78-78-4)	5	2	1.18	8.20	1.88
Isoprene (78-79-5)	5	2	0.02	0.21	0.06
Isopropylbenzene (98-82-8)	5	0		0.00	0.01
m-Diethylbenzene (141-93-5)	5	0		0.00	0.02
Methylcyclohexane (108-87-2)	5	5	0.14	0.37	0.23
Methylcyclopentane (96-37-7)	5	5	0.16	0.46	0.31
m-Ethyltoluene (620-14-4)	5	3	0.02	0.05	0.03
m-Xylene/p-Xylene (108-38-3/106-42-3)	5	5	0.05	0.26	0.13
n-Butane (106-97-8)	5	5	4.50	8.72	6.24
n-Decane (124-18-5)	5	3	0.03	0.05	0.03
n-Dodecane (112-40-3)	5	3	0.01	0.01	0.02
n-Heptane (142-82-5)	5	5	0.10	0.30	0.17
n-Hexane (110-54-3)	5	5	0.27	1.90	0.76
n-Nonane (111-84-2)	5	5	0.02	0.04	0.03
n-Octane (111-65-9)	5	5	0.05	0.10	0.08
n-Pentane (109-66-0)	5	5	1.27	14.32	4.27
n-Propylbenzene (103-65-1)	5	1	0.01	0.01	0.01
n-Tridecane (629-50-5)	5	0		0.00	0.01
n-Undecane (1120-21-4)	5	4	0.01	0.02	0.01
o-Ethyltoluene (611-14-3)	5	2	0.01	0.02	0.01
o-Xylene (95-47-6)	5	5	0.02	0.10	0.06
p-Diethylbenzene (105-05-5)	5	0		0.00	0.01
p-Ethyltoluene (622-96-8)	5	3	0.01	0.03	0.02
Propane (74-98-6)	5	5	9.83	19.73	14.43
Propylene (115-07-1)	5	5	0.20	0.69	0.43
Propyne (74-99-7)	5	0		0.00	0.02
Styrene (100-42-5)	5	0		0.00	0.03
Toluene (108-88-3)	5	5	0.16	1.03	0.42
trans-2-Butene (624-64-6)	5	3	0.03	0.08	0.04
trans-2-Hexene (4050-45-7)	5	0		0.00	0.02
trans-2-Pentene (646-04-8)	5	3	0.01	0.02	0.02

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-4
City of Fort Collins SNMOC Monitoring
City Park (CPFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	5	3	0.02	0.05	0.02
1,2,4-Trimethylbenzene (95-63-6)	5	5	0.07	0.28	0.13
1,3,5-Trimethylbenzene (108-67-8)	5	5	0.03	0.10	0.05
1,3-Butadiene (106-99-0)	5	5	0.03	0.13	0.06
1-Butene (106-98-6)	5	0		0.00	0.03
1-Decene (872-05-9)	5	0		0.00	0.02
1-Dodecene (112-41-4)	5	0		0.00	0.03
1-Heptene (592-76-7)	5	0		0.00	0.02
1-Hexene (592-41-6)	5	1	0.02	0.02	0.03
1-Nonene (124-11-8)	5	2	0.01	0.01	0.01
1-Octene (111-66-0)	5	2	0.02	0.03	0.02
1-Pentene (109-67-1)	5	5	0.03	0.08	0.05
1-Tridecene (2437-56-1)	5	0		0.00	0.02
1-Undecene (821-95-4)	5	0		0.00	0.03
2,2,3-Trimethylpentane (564-02-3)	5	4	0.01	0.02	0.02
2,2,4-Trimethylpentane (540-84-1)	5	5	0.04	0.18	0.08
2,2-Dimethylbutane (75-83-2)	5	5	0.03	0.07	0.04
2,3,4-Trimethylpentane (565-75-3)	5	5	0.03	0.08	0.04
2,3-Dimethylbutane (79-29-8)	5	5	0.06	0.15	0.09
2,3-Dimethylpentane (565-59-3)	5	5	0.06	0.21	0.10
2,4-Dimethylpentane (108-08-7)	5	5	0.03	0.07	0.05
2-Ethyl-1-butene (760-21-4)	5	0		0.00	0.02
2-Methyl-1-butene (563-46-2)	5	3	0.05	0.11	0.05
2-Methyl-1-pentene (763-29-1)	5	0		0.00	0.02
2-Methyl-2-butene (513-35-9)	5	5	0.05	0.14	0.08
2-Methylheptane (592-27-8)	5	5	0.04	0.10	0.06
2-Methylhexane (591-76-4)	5	5	0.14	0.44	0.24
2-Methylpentane (107-83-5)	5	5	0.40	0.83	0.57
3-Methyl-1-butene (563-45-1)	5	0		0.00	0.02
3-Methylheptane (589-81-1)	5	5	0.03	0.10	0.05
3-Methylhexane (589-34-4)	5	2	0.23	0.51	0.17
3-Methylpentane (96-14-0)	5	5	0.20	0.49	0.30
4-Methyl-1-pentene (691-37-2)	5	0		0.00	0.01
Acetylene (74-86-2)	5	5	1.06	2.56	1.50
a-Pinene (80-56-8)	5	5	0.01	0.06	0.04
Benzene (71-43-2)	5	5	0.31	0.69	0.41
b-Pinene (127-91-3)	5	0		0.00	0.02
cis-2-Butene (590-18-1)	5	5	0.03	0.16	0.07
cis-2-Hexene (7688-21-3)	5	0		0.00	0.02
cis-2-Pentene (627-20-3)	5	3	0.02	0.04	0.02
Cyclohexane (110-82-7)	5	5	0.21	0.41	0.29
Cyclopentane (287-92-3)	5	5	0.11	0.21	0.15

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-4 (continued)
City of Fort Collins SNMOC Monitoring
City Park (CPFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Cyclopentene (142-29-0)	5	0		0.00	0.05
Ethane (74-84-0)	5	5	13.20	24.45	16.68
Ethylbenzene (100-41-4)	5	5	0.05	0.20	0.10
Ethylene (74-85-1)	5	5	1.64	4.96	2.88
Isobutane (75-28-5)	5	5	1.78	3.55	2.41
Isobutene (115-11-7)	5	0		0.00	0.02
Isobutylene (115-11-7)	5	0		0.00	0.02
Isopentane (78-78-4)	5	5	1.46	2.96	2.05
Isoprene (78-79-5)	5	5	0.02	0.06	0.03
Isopropylbenzene (98-82-8)	5	0		0.00	0.01
m-Diethylbenzene (141-93-5)	5	0		0.00	0.02
Methylcyclohexane (108-87-2)	5	5	0.13	0.30	0.22
Methylcyclopentane (96-37-7)	5	5	0.22	0.49	0.31
m-Ethyltoluene (620-14-4)	5	5	0.04	0.17	0.08
m-Xylene/p-Xylene (108-38-3/106-42-3)	5	5	0.17	0.71	0.32
n-Butane (106-97-8)	5	5	4.10	8.62	5.70
n-Decane (124-18-5)	5	5	0.02	0.06	0.04
n-Dodecane (112-40-3)	5	3	0.01	0.01	0.02
n-Heptane (142-82-5)	5	5	0.13	0.41	0.23
n-Hexane (110-54-3)	5	5	0.38	0.76	0.55
n-Nonane (111-84-2)	5	5	0.02	0.07	0.04
n-Octane (111-65-9)	5	5	0.07	0.16	0.10
n-Pentane (109-66-0)	5	5	1.34	2.62	1.89
n-Propylbenzene (103-65-1)	5	3	0.01	0.04	0.02
n-Tridecane (629-50-5)	5	0		0.00	0.01
n-Undecane (1120-21-4)	5	5	0.01	0.03	0.02
o-Ethyltoluene (611-14-3)	5	5	0.02	0.08	0.04
o-Xylene (95-47-6)	5	5	0.07	0.27	0.12
p-Diethylbenzene (105-05-5)	5	0		0.00	0.01
p-Ethyltoluene (622-96-8)	5	5	0.02	0.08	0.04
Propane (74-98-6)	5	5	8.73	18.17	11.81
Propylene (115-07-1)	5	5	0.37	1.18	0.67
Propyne (74-99-7)	5	0		0.00	0.02
Styrene (100-42-5)	5	0		0.00	0.03
Toluene (108-88-3)	5	5	0.40	1.57	0.72
trans-2-Butene (624-64-6)	5	5	0.03	0.19	0.10
trans-2-Hexene (4050-45-7)	5	0		0.00	0.02
trans-2-Pentene (646-04-8)	5	5	0.02	0.09	0.04

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-5
City of Fort Collins SNMOC Monitoring
Mason Street (MSFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	5	4	0.02	0.07	0.03
1,2,4-Trimethylbenzene (95-63-6)	5	5	0.06	0.33	0.15
1,3,5-Trimethylbenzene (108-67-8)	5	5	0.02	0.12	0.06
1,3-Butadiene (106-99-0)	5	5	0.03	0.15	0.07
1-Butene (106-98-6)	5	0		0.00	0.03
1-Decene (872-05-9)	5	0		0.00	0.02
1-Dodecene (112-41-4)	5	0		0.00	0.03
1-Heptene (592-76-7)	5	0		0.00	0.02
1-Hexene (592-41-6)	5	3	0.02	0.04	0.03
1-Nonene (124-11-8)	5	5	0.01	0.03	0.02
1-Octene (111-66-0)	5	4	0.03	0.05	0.03
1-Pentene (109-67-1)	5	5	0.04	0.12	0.07
1-Tridecene (2437-56-1)	5	0		0.00	0.02
1-Undecene (821-95-4)	5	0		0.00	0.03
2,2,3-Trimethylpentane (564-02-3)	5	1	0.02	0.02	0.02
2,2,4-Trimethylpentane (540-84-1)	5	5	0.04	0.20	0.08
2,2-Dimethylbutane (75-83-2)	5	5	0.03	0.08	0.05
2,3,4-Trimethylpentane (565-75-3)	5	5	0.02	0.11	0.04
2,3-Dimethylbutane (79-29-8)	5	5	0.05	0.19	0.11
2,3-Dimethylpentane (565-59-3)	5	5	0.05	0.25	0.11
2,4-Dimethylpentane (108-08-7)	5	5	0.02	0.08	0.05
2-Ethyl-1-butene (760-21-4)	5	0		0.00	0.02
2-Methyl-1-butene (563-46-2)	5	5	0.03	0.14	0.07
2-Methyl-1-pentene (763-29-1)	5	0		0.00	0.02
2-Methyl-2-butene (513-35-9)	5	5	0.06	0.16	0.09
2-Methylheptane (592-27-8)	5	5	0.05	0.14	0.08
2-Methylhexane (591-76-4)	5	5	0.20	0.74	0.35
2-Methylpentane (107-83-5)	5	5	0.42	1.10	0.69
3-Methyl-1-butene (563-45-1)	5	0		0.00	0.02
3-Methylheptane (589-81-1)	5	5	0.03	0.12	0.06
3-Methylhexane (589-34-4)	5	2	0.21	0.65	0.19
3-Methylpentane (96-14-0)	5	5	0.19	0.63	0.36
4-Methyl-1-pentene (691-37-2)	5	0		0.00	0.01
Acetylene (74-86-2)	5	5	0.97	2.73	1.59
a-Pinene (80-56-8)	5	2	0.02	0.06	0.02
Benzene (71-43-2)	5	5	0.30	0.79	0.43
b-Pinene (127-91-3)	5	0		0.00	0.02
cis-2-Butene (590-18-1)	5	5	0.03	0.22	0.10
cis-2-Hexene (7688-21-3)	5	1	0.01	0.01	0.02
cis-2-Pentene (627-20-3)	5	4	0.02	0.06	0.03
Cyclohexane (110-82-7)	5	5	0.20	0.55	0.31
Cyclopentane (287-92-3)	5	5	0.14	0.28	0.18

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-5 (continued)
City of Fort Collins SNMOC Monitoring
Mason Street (MSFC)
11/25/2013-1/24/2014 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Cyclopentene (142-29-0)	5	0		0.00	0.05
Ethane (74-84-0)	5	5	14.20	28.30	18.61
Ethylbenzene (100-41-4)	5	5	0.05	0.26	0.12
Ethylene (74-85-1)	5	5	1.82	6.00	3.24
Isobutane (75-28-5)	5	5	1.94	4.50	3.06
Isobutene (115-11-7)	5	0		0.00	0.02
Isobutylene (115-11-7)	5	0		0.00	0.02
Isopentane (78-78-4)	5	1	1.62	1.62	0.33
Isoprene (78-79-5)	5	5	0.02	0.07	0.04
Isopropylbenzene (98-82-8)	5	1	0.01	0.01	0.01
m-Diethylbenzene (141-93-5)	5	0		0.00	0.02
Methylcyclohexane (108-87-2)	5	5	0.17	0.41	0.27
Methylcyclopentane (96-37-7)	5	5	0.23	0.61	0.39
m-Ethyltoluene (620-14-4)	5	5	0.03	0.20	0.09
m-Xylene/p-Xylene (108-38-3/106-42-3)	5	5	0.15	0.81	0.38
n-Butane (106-97-8)	5	5	4.65	10.88	7.26
n-Decane (124-18-5)	5	5	0.02	0.07	0.04
n-Dodecane (112-40-3)	5	3	0.01	0.03	0.02
n-Heptane (142-82-5)	5	5	0.15	0.52	0.28
n-Hexane (110-54-3)	5	5	0.36	0.99	0.68
n-Nonane (111-84-2)	5	5	0.02	0.08	0.04
n-Octane (111-65-9)	5	5	0.07	0.18	0.11
n-Pentane (109-66-0)	5	5	1.65	3.36	2.36
n-Propylbenzene (103-65-1)	5	2	0.02	0.05	0.02
n-Tridecane (629-50-5)	5	0		0.00	0.01
n-Undecane (1120-21-4)	5	5	0.01	0.04	0.02
o-Ethyltoluene (611-14-3)	5	5	0.01	0.09	0.04
o-Xylene (95-47-6)	5	5	0.06	0.31	0.14
p-Diethylbenzene (105-05-5)	5	0		0.00	0.01
p-Ethyltoluene (622-96-8)	5	5	0.02	0.09	0.04
Propane (74-98-6)	5	5	10.10	22.27	14.25
Propylene (115-07-1)	5	5	0.43	1.63	0.83
Propyne (74-99-7)	5	0		0.00	0.02
Styrene (100-42-5)	5	0		0.00	0.03
Toluene (108-88-3)	5	5	0.35	1.71	0.80
trans-2-Butene (624-64-6)	5	4	0.09	0.30	0.14
trans-2-Hexene (4050-45-7)	5	1	0.02	0.02	0.02
trans-2-Pentene (646-04-8)	5	5	0.02	0.11	0.05

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.