Fort Worth Natural Gas Air Quality Study

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ABSTRACT

Natural gas production has increased significantly across the U.S. recently due to advances in drilling and extraction technology. One such technology, hydraulic fracturing, has been used extensively in and around the City of Fort Worth, Texas, where natural gas extraction in urban areas is prevalent. This increased activity has led to efforts by various stakeholders in understanding the scope and magnitude of associated air quality impacts affecting the City. In March 2010, the City commissioned an Air Quality Committee to design a study to address air quality impacts associated with this activity. This year-long study was comprised of four tasks - ambient air monitoring to measure air pollution levels near active well pads, natural gas compressor stations, and natural gas well hydraulic fracturing activities; point source testing to measure the pollutants emitted from these sites; air dispersion modeling conducted to estimate downwind impacts from these activities; and a public health evaluation of the study's findings.

Ambient air monitoring for nearly 140 pollutants was conducted at 8 locations over a 2-month period, and point source testing was conducted at nearly 400 sites over a 4-month period. The results of the point source testing were used to conduct air dispersion modeling to estimate air pollutant impacts resulting directly from natural gas exploration and production activities. The ambient air monitoring and air dispersion modeling data were then compared to both short and long-term health-based screening levels. These comparisons were used to provide the City of Fort Worth with feedback on the adequacy of their existing setback provisions, which limit how close natural gas well pads and compressor stations may be to residences and other publically accessible locations.

INTRODUCTION

Natural gas production has increased significantly across the U.S. in the last several years due to advances in drilling and extraction technology. One such technology, hydraulic fracturing, has been used extensively in the Barnett Shale region in north central Texas. Within the Barnett Shale is the City of Fort Worth (population of over 740,000 residents), where natural gas extraction in urban areas is prevalent. This increased activity has led to efforts by various stakeholders in understanding the scope and magnitude of associated air quality impacts affecting the City. In March 2010, the City commissioned an Air Quality Committee to design the parameters of a study to answer policy-relevant questions regarding natural gas activities within the City. The study was initiated in August 2010 with four general areas: air toxics

ambient monitoring; wellpad-specific point sources testing; dispersion modeling; and a health assessment.

This paper provides details on the primary activities conducted under the Fort Worth Natural Gas Air Quality Study (FWNGAQS) [1] – the ambient air monitoring program, the point source testing program, the air dispersion modeling that was conducted using the results of the point source testing, and a detailed assessment of the air toxics ambient monitoring and air dispersion modeling data with respect to potential public health impacts. The ambient air monitoring and dispersion modeling data were compared to both short and long-term health-based effects screening levels (ESLs) used by the Texas Commission on Environmental Quality (TCEQ) [2]. These comparisons were used to provide the City of Fort Worth with feedback on the adequacy of their existing setback provisions, which limit how close natural gas well pads and compressor stations may be to residences and other publically accessible locations.

METHODOLOGY

Point Source Testing

Point source testing under the FWNGAQS was conducted in two phases, with Phase I of the field work commencing in August of 2010 and lasting through October 2010, and Phase II occurring in January and February of 2011. Under the point source testing program, a total of 388 sites were tested, including well pads, compressor stations, processing facilities, a salt water treatment facility, drilling operations, fracking operations, and flowback/completion operations. These sources are described as follows:

- Well Pads – Comprising the largest group of sites visited, natural gas well pads typically contained several active wells, produced water storage tanks, separators, and metering runs (piping). Approximately one-third (123) of the well pads also had lift compressors used to increase a well's gas production rate. Emission sources typically related with well pads include equipment leaks, produced water and condensate storage and loading, and lift compressors. The amount of condensate production and related emissions are usually dependant on whether the produced gas is wet or dry gas.
- Compressor Stations – Compressor stations contain one or more large (generally 250 horsepower (hp) or greater) line compressors which provide the necessary pressure to move the natural gas through many miles of transmission lines. The most significant emissions from compressors stations are usually from combustion at the compressor engines or turbines. Other emissions sources may include equipment leaks, storage tanks, glycol dehydrators, flares, and condensate and/or wastewater loading. None of the compressor stations visited included turbines.
- Processing Facilities – Processing facilities generally remove impurities from the natural gas, such as carbon dioxide, water, and hydrogen sulfide. These facilities may also be designed to remove ethane, propane, and butane fractions from the natural gas for downstream marketing. Processing facilities are usually the largest emitting natural gas-related point sources including multiple emission sources such as, but not limited to equipment leaks, storage tanks, separator vents, glycol dehydrators, flares,

condensate and wastewater loading, compressors, amine treatment and sulfur recovery units. The Processing Plant visited did not have a sulfur recovery unit.

- Saltwater Treatment Facility – The single saltwater treatment facility permitted for operation within the City's boundaries uses underground injection to dispose of well production liquids such as oilfield brine, drilling mud, fracture materials, and well treatment fluids. Emission sources typically related with salt water treatment facilities include equipment leaks, storage tanks, and generators.
- Drilling Operation – Drilling of a new well is typically a two to three week process from start to finish and involves several large diesel-fueled generators. Other emission sources related to drilling operations may include equipment leaks and waste storage.
- Fracking Operation – Fracking is the high pressure injection of water mixed with sand and a variety of chemical additives into the well to fracture the shale and stimulate natural gas production from the well. Fracking operations can last for several weeks and involve many large diesel-fueled generators. Other emission sources related to fracking operations may include equipment leaks and waste storage.
- Flowback/Completion – Flowback is a well completion activity that occurs following the conclusion of a fracking operation. Flowback thus entails the removal of fracking fluids from the well in preparation either for a subsequent phase of treatment or for cleanup and returning the well to production. Similar to fracking operations, other related emission sources may include equipment leaks and waste storage.

Figure 1 locates each site on an overlay map of Fort Worth.

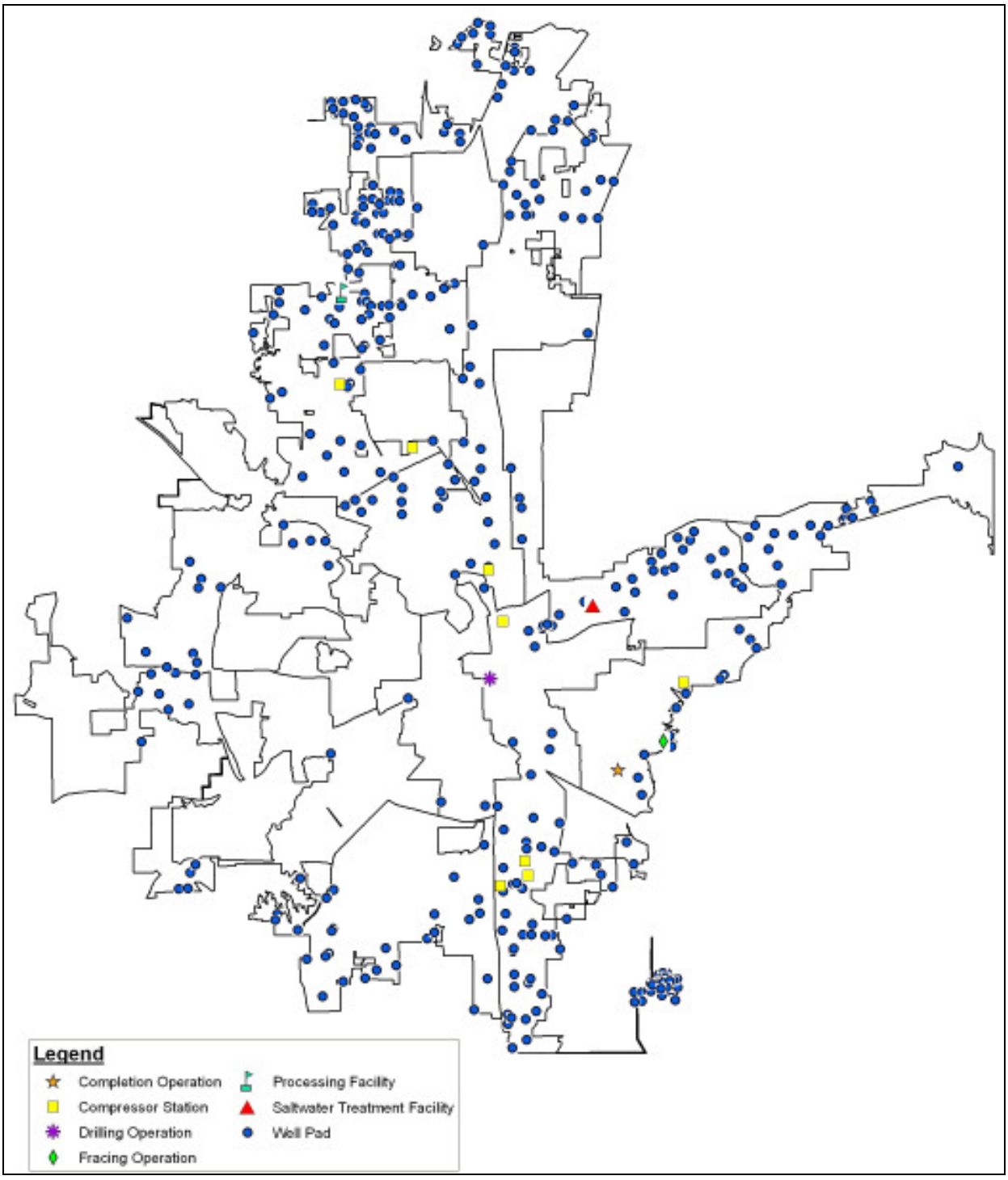

Figure 1. Point Source Survey Sites (August 2010 – February 2011)

At each site, emissions from storage tank thief hatches and pressure relief vents, pneumatic valve controllers, separators, valves, flanges, compressor engines, glycol dehydrators, and natural gas piping were evaluated. The point source surveys were carried out by two teams of two persons each. Each team utilized FLIR™ Infrared (IR) Cameras, toxic vapor analyzers, Bacharach™ Hi

Flow Samplers, and Summa Passivated Stainless Steel Canisters to locate and quantify air emissions. The equipment is described as follows:

- **FLIR™ Infrared Camera:** The IR camera enables rapid detection of large emission sources (for instance, sources with concentrations > 10,000 ppmv). Moreover, the infrared camera is well suited to detecting methane emissions, the largest constituent of natural gas, as well as ethane, propane, and butane. All infrared camera imaging was performed by trained Level 1 or Level 2 Thermographers.
- **Thermo Environmental ™ Toxic Vapor Analyzer:** The TVA is a portable, battery-powered, intrinsically safe, hydrocarbon analyzer with a measurement range extending from 0.5 ppmv (parts per million by volume) to 50,000 ppmv hydrocarbon. This instrument was used to screen a random selection of site valves and connectors for leaks below the detection limit of the IR camera. It was also used to measure emissions detected with the camera although in most cases these measurements resulted in a "flame-out" of the analyzer (that is, a reading greater than 50,000 ppmv).
- **Bacharach™ Hi Flow Sampler:** The Hi Flow Sampler is a portable, intrinsically safe instrument designed to measure the rate of gas leakage around various pipe fittings, valve packings and compressor seals found at natural gas facilities. Because of its high flow rate (8 to 10 SCFM), the Hi Flow Sampler is able to completely capture any gas emitting from a component. The rate of the gas leak is determined by accurately measuring the flow rate of the sampling stream and the natural gas concentration.
- **Summa Passivated Stainless Steel Canisters:** Evacuated, six-liter, canisters were used to collect gas samples from selected emission points for VOC and HAP analysis by GC/MS and for methane analysis by gas chromatography with a thermal conductivity detector (TCD). Canisters were shipped to the field office in a pre-cleaned, evacuated condition. Completed canisters were returned within several days of sample collection to a lab for analysis.

Emission estimates of over 90 pollutants from over 10,000 emission points were obtained from the point source testing task, including benzene, carbon disulfide, formaldehyde, toluene, and xylene. Total speciated emissions were calculated for each site using direct and indirect calculation methodologies. Direct emission calculations were based upon the analytical results of the canister samples. Indirect emission measurements were derived from several sources including the emission results from the canister sampling, correlation equations, calculated surrogate emission rates, EPA emission factors, and engine emission data for both natural gas and diesel powered engines. Each site's total emissions were calculated as a combination of direct and indirect emissions results.

Table 1 lists the average and maximum emission rates by site type for the sites with continuous (annual) operations. Annual estimates were not compiled for the sites with short-term, pre-production activities (drilling, fracking, flowback/completion). For the sites presented in Table 1, emissions based on conditions at the time of testing were extrapolated over a one year period (i.e. tons per year) to obtain an annual estimate. The average and maximum values are the same for processing and saltwater treatment facilities because only one of each was surveyed.

Table 1. Average and Maximum Point Source Emission Rates by Site Type[a]

Site Type	TOC (tons/yr)		VOC (tons/yr)		HAP (tons/yr)		Criteria Pollutants[a] (tons/yr)	
	Average	Max	Average	Max	Average	Max	Average	Max
Well Pad	16	445	0.07	8.6	0.02	2	-0-	-0-
Well Pad with Compressor(s)	69	430	2	22	0.9	8.8	16	236
Compressor Station	90	276	16	43	9.4	25	167	571
Processing Facility	1,293	1,293	80	80	47	47	1,128	1,128
Saltwater Treatment Facility	0.3	0.3	<0.01	<0.01	<0.01	<0.01	-0-	-0-

[a] Criteria Pollutants include VOC, PM, SO_2, CO and NO_x from engine exhausts.

The following points provide general and specific conclusions drawn from the results of the point source testing, including some specific observations made while conducting the field work.

- A total of 2,126 emission points were identified in the four month field study: 192 of the emission points were Valves, 644 were Connectors and 1,290 were classified as Other Equipment. 1,330 emission points were detected with the IR camera (i.e. high level emissions); 796 emission points were detected by Method 21 screening (i.e. low level emissions).
- At 96 sites, no emissions were detected by the IR camera. In general these were smaller sites containing less equipment (tanks, wellheads, separators, and metering runs). Of these 96 sites, 82% contained 3 wells or less.
- The Total Organic Compound (TOC), Volatile Organic Compound (VOC) and Hazardous Air Pollutant (HAP) emissions were calculated on an annual basis for each site as the sum of 1) direct canister sample results; 2) adjusted canister results using correlation equations; 3) tank and non-tank surrogate emission profiles; 5) engine emission data; and 6) default zero emission factors. Emissions associated with tank unloading, tank flashing, well snubbing, glycol reboilers, flares or any type of maintenance/repair activities were not included in the calculated site emissions profiles.
- Emissions from lift compressors have a significant impact on well pad emissions. Most lift compressors are mobile and are moved from site to site as needed. The addition of a lift compressor to a well pad site has the effect of raising TOC emissions four-fold while releasing on an annual basis an average 16 tons/yr of criteria pollutants.
- The largest source of fugitive emissions detected with the IR camera was leaking tank thief hatches. Emissions were detected at 252 tank thief hatches resulting in a combined TOC emission rate of 4,440 tons/yr. Some of these emissions were due to the operators simply leaving the hatches unsecured as shown in Figure 2 below. Many others, however, appeared to be due to lack of proper maintenance.

Figure 2. Thief Hatch Left Open

- Pneumatic Valve Controllers were the most frequent emission sources encountered at well pads and compressor stations (see Figure 3 below). These controllers use pressurized natural gas to actuate separator unloading valves. Under normal operation a pneumatic valve controller is designed to release a small amount of natural gas to the atmosphere during each unloading event. Due to contaminants in the natural gas stream, however, these controllers eventually fail (often within six months of installation) and begin leaking natural gas continually. The emissions from the 489 failed pneumatic valve controllers detected by the point source team result in a combined TOC emission rate of 3,030 tons per year.

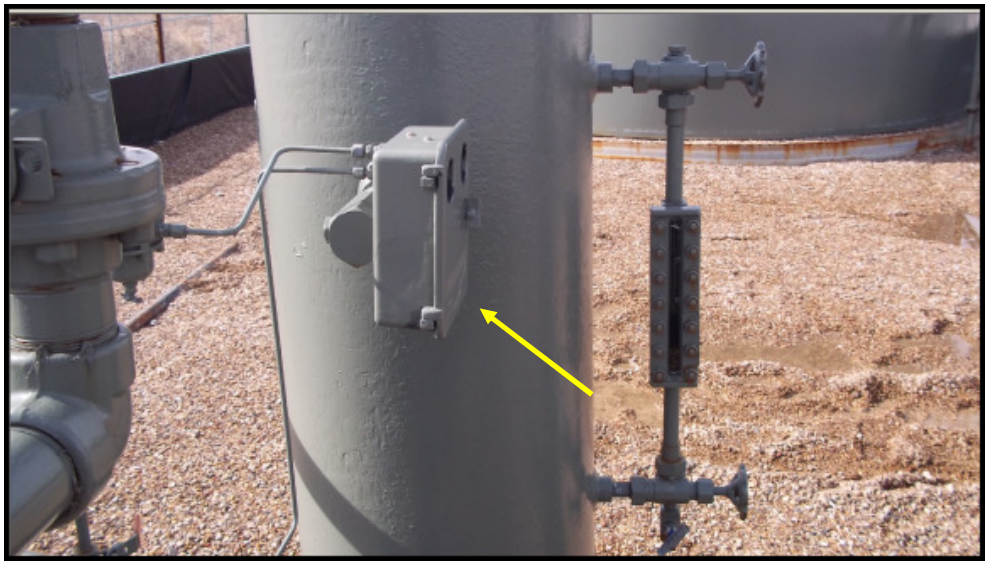

Figure 3. Pneumatic Valve Controller on Separator

- Emissions from 175 storage tank vents (see Figure 4 below) were detected by the IR camera accounting for a combined total of 2,061 tons of TOC/yr. In numerous instances several tanks would be manifold to one vent controlled by a pressure relief valve. In these cases, continuous emissions from the vent indicated a failure of the pressure relief valve.

Figure 4. Storage Tank Vent

- Emissions from 257 leaking natural gas pressure regulators (see Figure 5 below) accounted for a combined TOC total of 608 tons/yr.

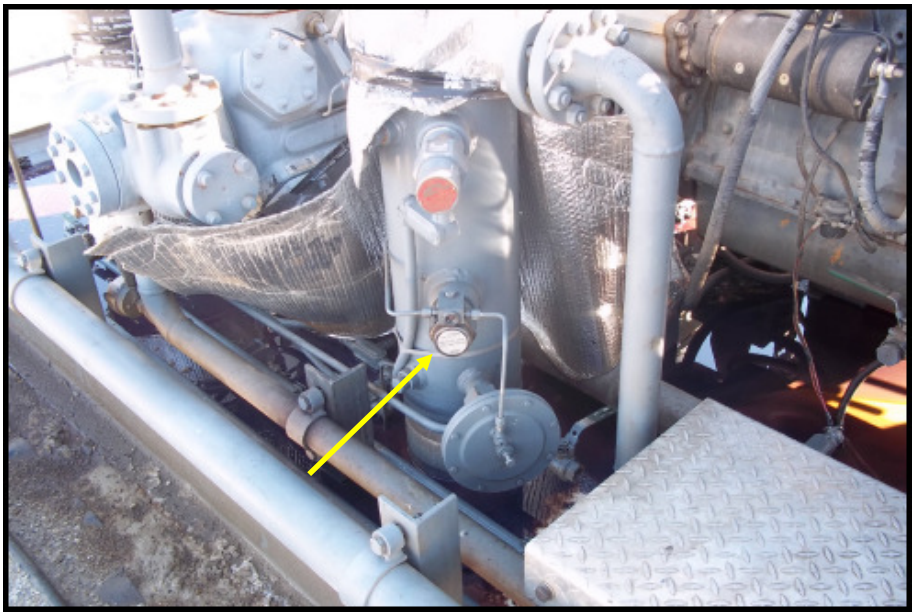

Figure 5. Natural Gas Pressure Regulator

- Fifty-five (55) instances of emissions from miscellaneous equipment were detected, accounting for a combined TOC emission rate of 731 tons/yr. Miscellaneous equipment includes pinholes, compressor shafts, sumps, knock-out pots, underground piping, glycol contactor controllers, pressure indicators, and quite frequently, holes or breaks in the tank roofs (see Figure 6 below).

Figure 6. Hole in Tank Roof - Miscellaneous Emission Source

- No natural gas emissions associated with drilling and fracking activities were detected by the IR camera. Engine emissions associated with these activities were estimated based upon vendor data tables. Emissions were detected from a well completion activity. Emissions were also detected at the Salt Water Treatment facility but the Evaporative Unit was not able to be tested since it was out of service the entire time of the point source survey.
- Although there was little difference in average TOC emissions between Dry and Wet Gas sites, average VOC and HAP emissions from Wet Gas sites proved to be significantly higher as would be expected due to the additional storage and loading of condensate at Wet Gas sites.
- Five sites had predicted cumulative VOC emissions greater than the permitting trigger level of 25 tons/yr and or CO emissions greater than the major source threshold of 250 tons/yr.
- A Well Pad located at 10590 Chapin Road had the highest VOC emissions among well pads (22 tons/yr). This site had only a single well, with two tanks. However, it also had one large line compressor (Caterpillar G-399). Twelve (12) emission points were detected at this site with the IR camera: 5 in the area of the separators, 3 on the tanks, and 4 at the compressor.

Ambient Air Monitoring

ERG conducted ambient air monitoring at 8 different locations around the City of Fort Worth over a two-month period in September and October of 2010. The ambient air monitoring program measured levels of nearly 140 pollutants (including over 40 Hazardous Air Pollutants (HAPs)), and resulted in the generation of over 15,000 data points for this study. ERG's success rate at sample collection for this effort was over 95%, with 169 out of a possible 176 samples being collected.

Prior to field deployment, an *Ambient Air Monitoring Plan*[3] was developed which identified the goals and objectives of the ambient air monitoring network, provided technical background information needed to identify candidate monitoring site locations, specified the technical approach used to focus the list of candidate monitoring sites, and provided the final list of sites used in the study. Also, prior to implementation of the monitoring study, an approved Level 1 *Ambient Air Monitoring Quality Assurance Project Plan (QAPP)*[4] was developed which provided specific information on the sampling protocols, sampling analyses, and data reporting.

Several data sources were used to locate potential monitoring sites:

- Windroses**:** Prior to site selection, meteorological data from forty-three meteorological stations in and around the City of Fort Worth were constructed. Twenty-one of these stations are National Weather Service (NWS) stations, while twenty-two are non-NWS meteorological stations that were identified in EPA's Air Quality Subsystem (AQS). Hourly meteorological wind speed and wind direction data were parsed into five windrose categories: 1) historical; 2) 2009 Annual; 3) August historical; 4) September historical; and 5) October historical. Windrose was created using LAKES software.[5]
- Well Information: Well location data were provided by the COFW in GIS format.[6] The well information by locations of active wells (density) and by production were reviewed. Production data was obtained from the Texas Railroad Commission (TRC), and matched back to each well by API ID. Well densities are primarily in the north and south of the City, while higher levels of production are in the western, northern, and eastern portions of the City.
- City-Owned Buildings: Another set of information used to identify potential monitoring sites were the locations of city-owned buildings, such as fire departments, police departments, water towers, libraries, community centers, and other administrative buildings. This data was provided by the COFW.[6]
- Other Information**:** The final sets of information used to identify potential monitoring sites were emission inventory data from EPA's National Emission Inventory[8] and roadway data from ESRI's ARCGIS 9.2 system.

The final selection of eight monitoring sites occurred in two phases. In Phase 1, the locations of active and permitted natural gas activities, compressor stations, city property, nearby roadways, meteorological stations, and other features were overlaid to show natural gas activities in relation to residences, schools, businesses, existing (non-natural-gas) emission sources, and city-owned property. Monitoring on city-owned property was desirable for several reasons, including ensuring that the project team had site access seven days a week, maintaining the security of project staff and sampling equipment, and maintaining the integrity of the air sample by limiting

the chance of vandalism or other tampering. During Phase 1, 20 potential monitoring site locations were identified.

In Phase 2, project staff visited each potential site to evaluate its suitability as a possible monitoring site location. During these visits, project staff interviewed site personnel and inspected the property, taking particular notice of potential obstructions (trees, buildings, etc.) or limitations (not enough land, no power, etc.) that would disqualify sites. At the end of Phase 2, and after consultation with city staff, eight locations were identified as suitable for inclusion in the ambient air monitoring network. These sites are listed below in Table 2 and Figure 7.

Table 2. Final Ambient Air Network Monitoring Sites

Site ID	Site Type (Dates)	Pollutants Sampled	Sampler Type	Coordinates
S-1	Background (9/4/10-10/31/10)	VOC/SNMOC	Vacuum-regulated	32° 49.114'N 97° 02.953'W
S-2	Mobile sources (9/7/10-10/31/10)	VOC/SNMOC	Vacuum-regulated	32° 33.379'N 97° 13.164'W
S-3A	Pre-production (9/16/10-10/10/10)	VOC/SNMOC	Vacuum-regulated	32° 45.897'N 97° 15.763'W
S-3B	Pre-production (10/13/10-10/28/10)	VOC/SNMOC	Vacuum-regulated	32° 46.569'N 97° 29.638'W
S-4	High-level activity (9/4/10-10/31/10)	VOC/SNMOC/ Carbonyls	Automated, mass-flow	32° 47.249'N 97° 19.715'W
S-5	High-level activity (9/4/10-10/31/10)	VOC/SNMOC/ Carbonyls	Automated, mass-flow	32° 59.044'N 97° 23.131'W
S-6	Moderate-level activity, fence line (9/4/10-10/31/10)	VOC/SNMOC/ Methane	Vacuum-regulated	32° 33.37'N 97° 18.820'W
S-7	Moderate-level activity, fence line (9/10/10-10/31/10)	VOC/SNMOC/ Methane	Vacuum-regulated	32° 34.223'N 97° 18.815'W

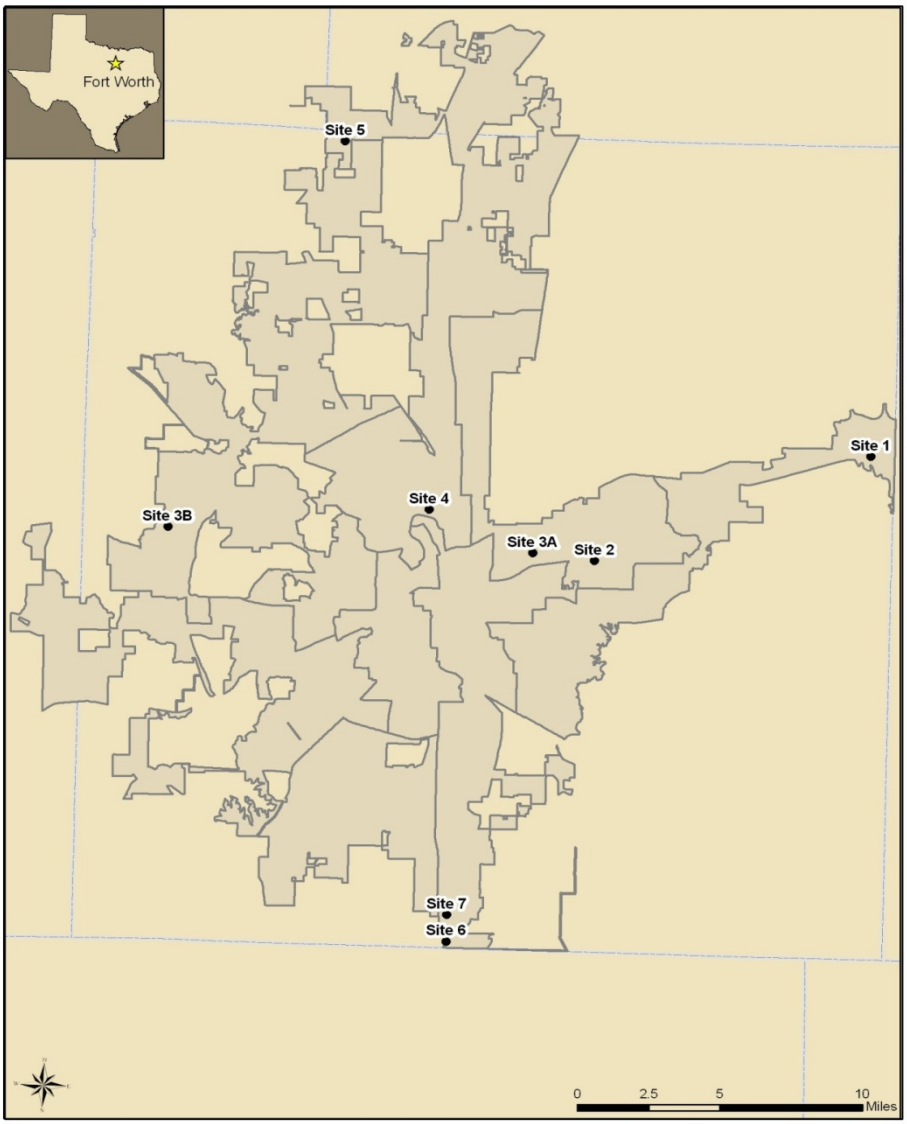

Figure 7. Ambient Air Monitoring Sites

At each of the eight sites, ambient air samples were collected once every three days. This schedule ensured that samples were collected on both weekdays and weekend days. The schedule provided some insights on how air quality varies by day of the week—an important consideration given that traffic patterns and other emission sources can vary from one day to the next. The collection and analysis of ambient air monitoring samples for this study was performed in accordance with: ERG's Concurrent Method of EPA Compendium Methods TO-15 and speciated nonmethane organic compounds or SNMOCs (to address benzene and ethane),[7] TO-11A (to address formaldehyde),[8] and TO-14 (to address methane).[9]

Sampling at Sites S-1 through S-3, S-6, and S-7 was conducted using vacuum-regulated systems. These systems were battery-operated/passive and used pre-cleaned SUMMA® canisters to collect VOC and methane samples. Sampling at Sites S-4 and S-5 was conducted using two automated, mass-flow control systems. These systems are electrically powered and used pre-cleaned, evacuated SUMMA® canisters to collect VOC samples and 2,4-dinitrophenylhydrazine (DNPH)

cartridges to collect carbonyl samples. All seven systems incorporated digital timers to ensure that 24-hour integrated samples were obtained. Site 3 was split into two different locations (noted as S-3A and S-3B in Table 2) in an attempt to quantify natural gas pre-production activities (drilling, fracturing, etc.) occurring during the study period.

The samples obtained at Sites S-1 through S-5 were analyzed at Eastern Research Group's (ERG's) laboratory in Morrisville, North Carolina, while the samples obtained at Sites S-6 and S-7 were analyzed at TestAmerica's™ laboratory in Austin, Texas. Target VOCs and SNMOCs and their corresponding method detection limits (MDLs) are presented in the Ambient Air Monitoring Plan[1] prepared for the project. Over 140 pollutants were identified and quantified for this study.

The following pollutants were identified as "key' based on prevalence and potential risk at the measured concentrations: acetaldehyde, benzene, 1,3-butadiene, carbon tetrachloride, *p*-dichlorobenzene, formaldehyde, and tetrachloroethylene. The following observations were made for each key pollutant:

- The average acetaldehyde concentration at Site S-4 was considerably higher than the average acetaldehyde concentration at Site S-5.
- The average benzene concentration at Site S-4 was considerably higher than all other average benzene concentrations at the other sites. The average benzene concentrations at Sites S-6 and S-7 were also considerably lower than those for Sites S-1, S-2, S-3A, and S-5. See Figure 8 below.

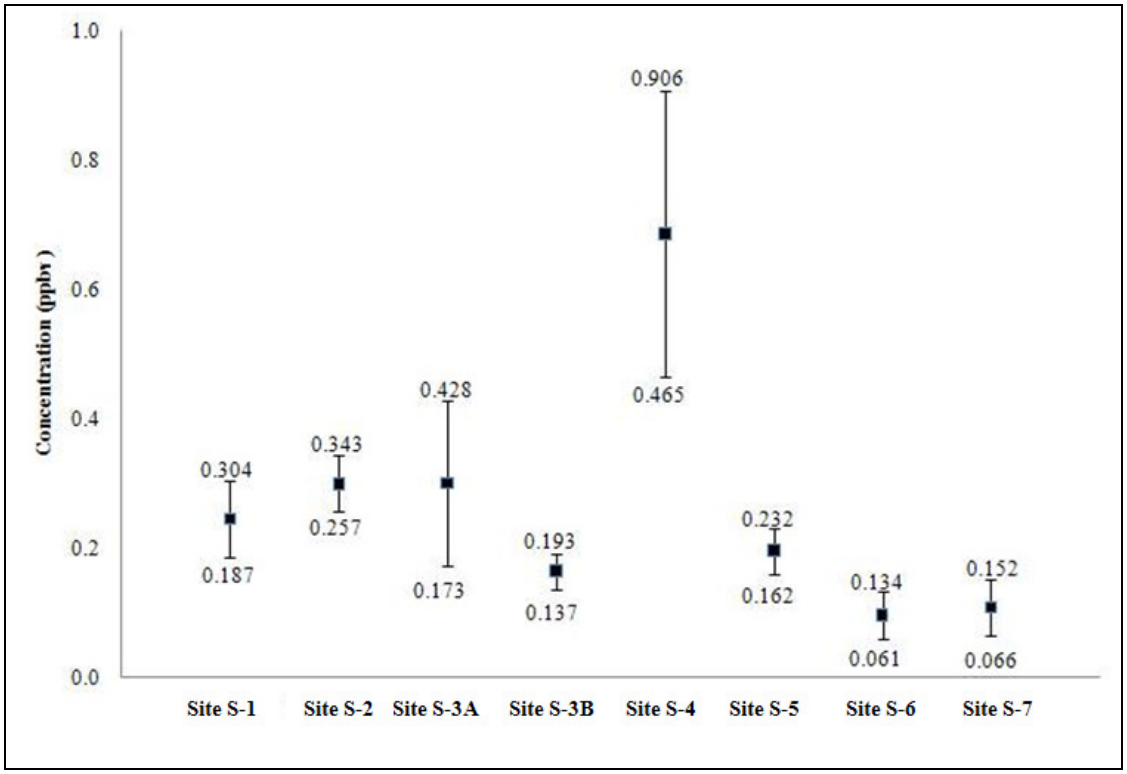

Figure 8. Benzene Concentrations By Site

- The average 1,3-butadiene concentrations at Sites S-2 and S-4 were considerably higher than the average 1,3-butadiene concentration at Site S-5.
- The highest average carbon tetrachloride concentration (Site S-1) was only slightly higher than the average carbon tetrachloride concentration at the lowest site (Site S-6). See Figure 9 below.

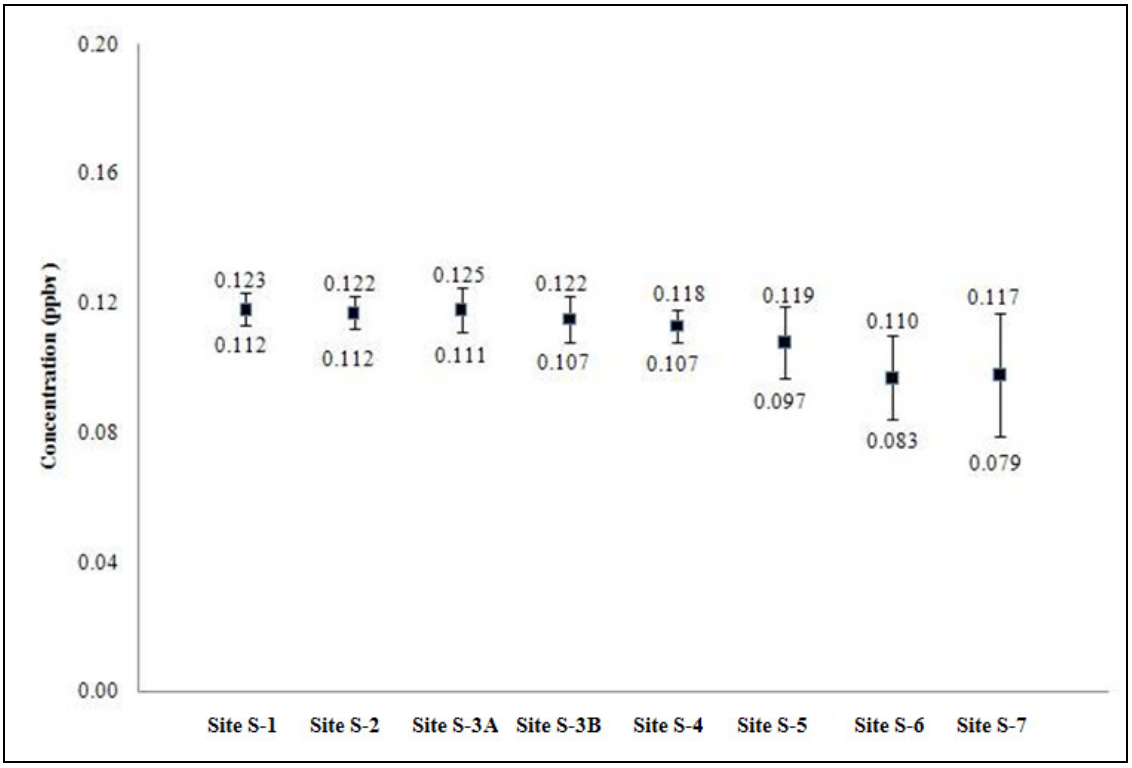

Figure 9. Carbon Tetrachloride Average Concentrations by Site

- There were no statistically significant differences in average *p*-dichlorobenzene concentrations across Sites S-1, S-2, S-3A, and S-4.
- There were no statistically significant differences in average formaldehyde concentrations across Sites S-4 and S-5.
- There were no statistically significant differences in average tetrachloroethylene concentrations across Sites S-1, S-2, S-3A, and S-4.

Key findings from the ambient monitoring study are as follows:

- 169 ambient air samples from 8 locations in Fort Worth were collected and analyzed, resulting in over 15,000 ambient air data points generated for this study.
- Concentrations measured at Site S-4 (located in a high-level activity area near compressor stations, well pads, and mobile sources) were generally higher than at other sites. For some of the key pollutants (acetaldehyde and benzene), concentrations at this site were considerably higher.
- Pollutant concentrations at Sites S-6 and S-7 (located in a medium-level activity area) were surprisingly low relative to other sites, especially given their close proximity to active well pad locations.

- Concentrations at Site S-1 ("background" site with no nearby natural gas well pads upwind) were generally similar to Site S-2 ("mobile sources" site). Concentrations at these two sites were slightly higher than Sites S-6 and S-7.
- Concentrations at the two "preproduction" sites did not display higher pollutant concentrations than the two monitoring stations designated as "background" and "mobile source" sites.

Air Dispersion Modeling

Point source testing conducted under the FWNGAQS identified numerous pollutants that natural gas exploration and production activities release to the air. Once emitted, these pollutants move through the air to downwind locations where residents can be exposed. ERG used the point source testing results and latest version of the AMS/EPA Regulatory MODel (AERMOD)[10], Version 11103, to estimate downwind pollutant concentrations for over 90 pollutants. Modeling was conducted for four different scenarios, including both average and maximum emission rates from well pads and compressor stations.

While the ambient air monitoring program provided an overall indicator of air quality at the monitoring location, the dispersion modeling results provided an estimate of the incremental air quality impacts caused by emissions from natural gas facilities. The modeling results provide perspective on air pollution levels at locations where, and at times when, ambient air samples were not collected. The results were used to assess whether the city's required setbacks (as published in City Ordinance No. 18449-02-2009) are adequately protective of public health.

The air dispersion modeling used in this study was based on the results of point source testing conducted at compressor stations, well pads, and other locations where natural gas extraction and processing occurs. Four different scenarios were modeled, representing the results of the point source testing for "average" sites, as well as "Worst-Case" sites. Figure 10 presents the results of air dispersion modeling conducted for Formaldehyde for Scenario 4 (Co-located Worst-Case Well Pad and Compressor Station).

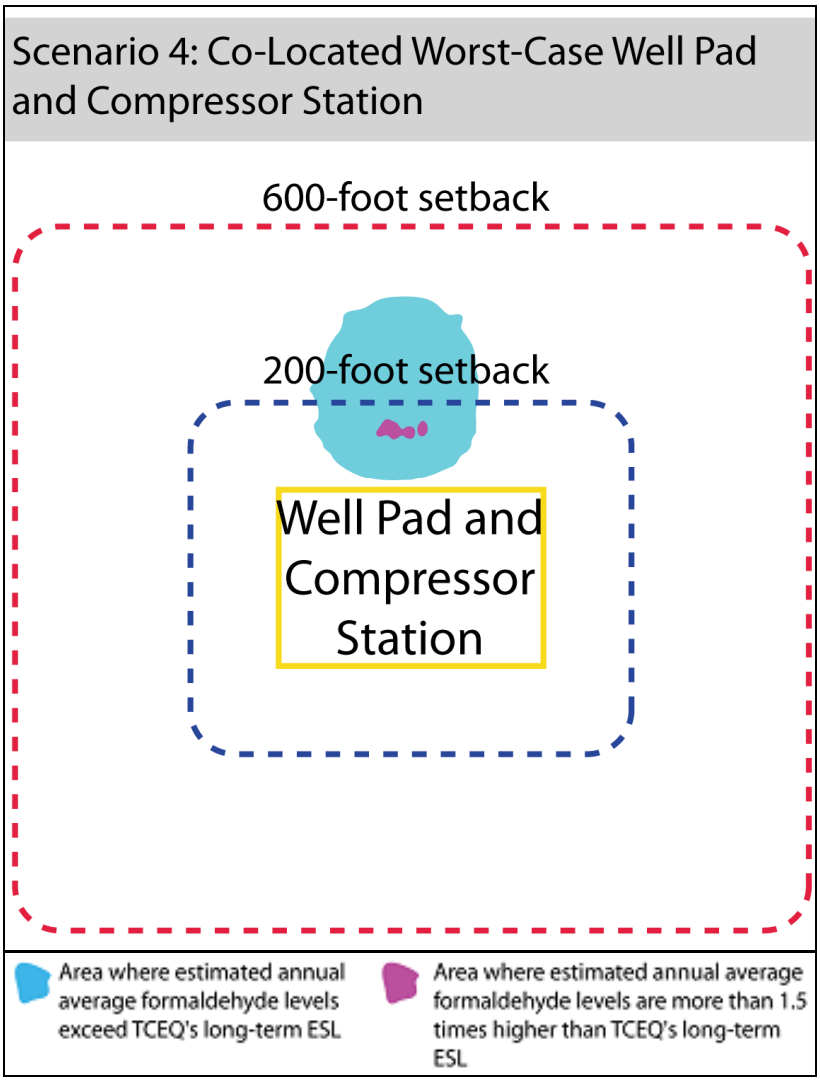

Figure 10. Air Dispersion Modeling results for Formaldehyde

Public Health Analysis

Collectively, the results of the air dispersion modeling and ambient air monitoring were evaluated and compared against health-based screening levels to determine potential public health impacts of natural gas exploration and production in Fort Worth. To ensure that screening levels are protective of public health, the agencies that derive these values set them at levels considerably lower than concentrations found to have been associated with adverse health effects. This means that residents are generally not expected to experience health effects when exposed to air pollution levels that are lower than health-based screening levels—but also that the levels are not thresholds for toxicity. Measured or modeled air pollution levels above a health-based screening level are not necessarily harmful, but they do require a more detailed evaluation to assess public health implications. Broadly speaking, the health-based screening levels were used to identify the subset of pollutants that required more thorough health evaluations.

The ambient air monitoring data and the dispersion modeling results were then analyzed from a public health perspective. This evaluation compared measured and modeled air pollution levels to the Texas Commission on Environmental Quality (TCEQ) health-based screening levels. First, ERG considered findings from the ambient air monitoring program, which did not reveal any evidence of pollutants associated with natural gas exploration and production activity reaching concentrations above applicable screening levels. The highest 24-hour average concentrations of all site-related pollutants were lower than TCEQ's health-based short-term screening levels, and the program-average concentrations of all site-related pollutants were lower than TCEQ's health-based long-term screening levels.

Next, ERG considered findings from the dispersion modeling analysis. The modeling analysis indicated that benzene emissions from storage tanks could lead to air pollution levels slightly higher than TCEQ's short-term ESL, but this occurred infrequently and only in very close proximity to the highest-emitting tanks. The modeling also indicated that sites containing multiple, large line engines can emit acrolein and formaldehyde at levels that would cause offsite ambient air concentrations to exceed TCEQ's short-term and long-term screening levels over various distances. For pollutants with air concentrations above the TCEQ screening levels, more detailed evaluations were presented, including a review of existing studies on these pollutants as well as comparisons to screening levels published by Agency for Toxic Substances and Disease Registry (ATSDR) and EPA.

CONCLUSIONS

Quantifying the extent to which natural gas exploration and production activity contributes to air quality is a complicated task, due to the confounding effect of other emission sources, such as motor vehicles, gasoline stations, and industrial sources. It is for this reason that the Fort Worth Natural Gas Air Quality Study considered two different approaches to evaluate air quality impacts from natural gas exploration and production activity.

First, ERG implemented an ambient air monitoring program. The ambient air monitoring data did not reveal any evidence of pollutants associated with natural gas exploration and production activity reaching concentrations above applicable screening levels: The highest 24-hour average concentrations of all site-related pollutants were lower than TCEQ's health-based short-term screening levels, and the program-average concentrations of all site-related pollutants were lower than TCEQ's health-based long-term screening levels.

Second, an air dispersion modeling analysis was used to estimate air quality impacts that can be attributed specifically to emissions from well pads and compressor stations. These estimates were derived from measured emissions for tanks and fugitive sources and estimated emissions from compressor engines. The model was run for four different equipment configurations at well pads and compressor stations, and some modeling scenarios were based on the highest emission rates measured during the point source testing program. The modeling analysis confirmed that benzene emissions from tanks could lead to air pollution levels slightly higher than TCEQ's short-term ESL, but this occurred infrequently and only in very close proximity to the highest-emitting tanks. The modeling also indicated that sites containing multiple, large line engines may emit acrolein and formaldehyde at levels that would cause offsite ambient air concentrations to exceed TCEQ's short-term and long-term screening levels over various distances. For all

remaining pollutants considered, the modeling found no evidence of short-term or long-term air quality impacts at levels of health concern.

ERG considered both the modeling and monitoring results when assessing the adequacy of Fort Worth's setback limits. The details of this analysis depend on multiple factors, including the pollutant, exposure duration, and well pad equipment configuration. Overall, ERG concluded that the 600-foot setback distances contained in City Ordinance No. 18449-02-2009 are adequately protective of public health.

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KEY WORDS

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