Cherokee Nation Air Quality Monitoring Report

Final Report

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1.0 Introduction

Cherokee Nation is sovereign tribal land located in northeast Oklahoma. The Cherokee Nation Environmental Program (CNEP) is responsible for environmental compliance and monitoring for the area. CNEP conducted ambient air sampling in the community of Cherokee Heights over an 18-month period, from September 2006 through March 2008, focusing on Volatile Organic Compounds (VOC). This report summarizes the spatial and temporal characteristics of the ambient monitoring data collected at the CNEP site in Oklahoma; integrates the VOC concentrations with emissions, meteorological, and risk information; and compares the results to similar analyses performed on data obtained from sites in the nearby city of Tulsa (ODEQ, 2008).

The remainder of this report is organized as follows: Section 2.0 characterizes the monitoring sites discussed in this report; Section 3.0 characterizes meteorological conditions observed during the study; Section 4.0 describes the analytical method; Section 5.0 summarizes the central tendencies and data distribution of the VOC measurements taken at CNEP and the Tulsa sites; Section 6.0 discusses the measurement precision of the VOC concentrations from CNEP; Section 7.0 presents BTEX concentration profiles for the monitoring sites; Section 8.0 identifies the pollutants of interest for CNEP and the Tulsa sites using a risk-based screening approach; Section 9.0 explores the statistical relationship between the pollutants of interest concentrations and select meteorological parameters; Section 10.0 compares the measurements and corresponding time-period averages to various health benchmarks; Section 11.0 summarizes key findings in this report; Section 12.0 presents recommendations for ambient monitoring in the future; and lastly, Section 13.0 is a list of references used throughout the report.

2.0 Site Characterization

This section characterizes the Cherokee Heights and Tulsa monitoring sites by providing geographical and physical information about the location of the sites and the surrounding areas. For record keeping and reporting purposes, each site was assigned:

- A unique four-letter site code – used to track samples from the monitoring sites to the ERG laboratory; and

- A unique nine-digit AQS site code – used to index monitoring results in EPA's Air Quality Subsystem (AQS) database.

This report cites the four-letter site code when presenting selected monitoring results. The Cherokee Nation site is called CNEP, while the three Tulsa sites are TOOK, TSOK, and TUOK. The nine-digit AQS code for each site is presented in Table 1.

Figure 1 shows all four monitoring sites in relation to each other, whereas Figures 2 through 5 are composite satellite images retrieved from Google™ Maps showing the monitoring sites in their urban and rural locations. Table 1 describes the area surrounding each monitoring site and provides supplemental geographical information such as land use, location setting, and locational coordinates.

The CNEP monitoring site was established in the tribal community of Cherokee Heights, about halfway between the towns of Pryor and Locust Grove, in northeastern Oklahoma. Due to the rural nature of the area, a close-in satellite map is not available. However, Figure 2 does show the major topographic features of the area, including a branch of the Grand River from Lake Hudson. The immediate area is rural and agricultural. An industrial park is located to the west of the community.

TOOK is located in West Tulsa, on the southwest side of the Arkansas River. The site is located in the parking lot of the Public Works building. The surrounding area is primarily industrial. As shown in Figure 3, an oil refinery is located just south of the site and another refinery is located to the northwest of the site. The monitoring site is positioned between the Arkansas River and I-244, which runs parallel to Southwest Boulevard (which is pictured in Figure 3). A rail yard is located on the opposite side of I-244.

TSOK is located in central Tulsa, north of Exit 6 on I-244 and west of US-75. The site is located on the property of Oklahoma State University's Tulsa campus, as shown in Figure 4.

Table 1. Geographical Information for the Oklahoma Monitoring Sites

Site Code	AQS Code	Location	County	Micro- or Metropolitan Statistical Area	Latitude and Longitude	Land Use	Location Setting	Description of the Immediate Surroundings
CNEP	40-097-9014	Cherokee Heights	Mayes	Not in an MSA	36.2284, -95.25	Agricultural	Rural	The Cherokee Nation's Environmental Program (CNEP) established this ambient air monitoring site on tribal trust land at the Cherokee Heights community in 2004. The purpose of this sampling project is to obtain additional data about the concentrations of VOCs in ambient air at the Pryor site and in the adjacent Cherokee Heights tribal community. This site is approximately 3.8 miles from the coal-fired power plant, 1.5 miles from the gas-fired power plant, and 0.75 mile from the sewage lagoon of the industrial park. Current instrumentation at the site includes the following: R & P TEOM for continuous PM10 measurement (Federal Equivalent Method), R & P TEOM with FDMS for continuous $PM_{2.5}$ measurement (the FDMS includes reference flow to account for volatile loss), R & P 2025 sequential sampler for $PM_{2.5}$ (Federal Reference Method), API gaseous monitors for NO_x, NOy, ozone, and SO_2, and MetOne meteorological instruments for wind speed, wind direction, ambient temperature, and relative humidity.
TOOK	40-143-0235	Tulsa	Tulsa	Tulsa, OK	36.126945, -95.998941	Industrial	Urban/City Center	This site is located approximately ¾ mile east of I-244. It is primarily located in an industrial area with Sun Refinery approximately 2 miles NW and Sinclair Refinery approximately ¼ mile South of site. It contains SO_2, H_2S, TSP Metals, and Toxics (VOC and Carbonyl).

Table 1. Geographical Information for the Oklahoma Monitoring Sites (Continued)

Site Code	AQS Code	Location	County	Micro- or Metropolitan Statistical Area	Latitude and Longitude	Land Use	Location Setting	Description of the Immediate Surroundings
TSOK	40-143-0172	Tulsa	Tulsa	Tulsa, OK	36.164435, -95.985204	Residential	Suburban	The Greenwood site is located approximately 200 yards N-NE of I-244 on the Oklahoma State University at Tulsa Campus. It is primarily neighborhood scale with no major industry nearby. A railroad track switching site is located approximately 50 ft. SE of the site. It contains TSP Metals and Toxics (VOC and Carbonyl).
TUOK	40-143-0191	Tulsa	Tulsa	Tulsa, OK	36.141697, -95.983793	Residential	Urban/City Center	This site is located approximately 50 ft. south of Highway 51, a major crosstown expressway. It is primarily neighborhood scale with no major industry nearby and influenced primarily by downtown traffic. It contains CO, PM_{10}, TSP Metals, and Toxics (VOC and Carbonyl).

Figure 1. Oklahoma Monitoring Sites

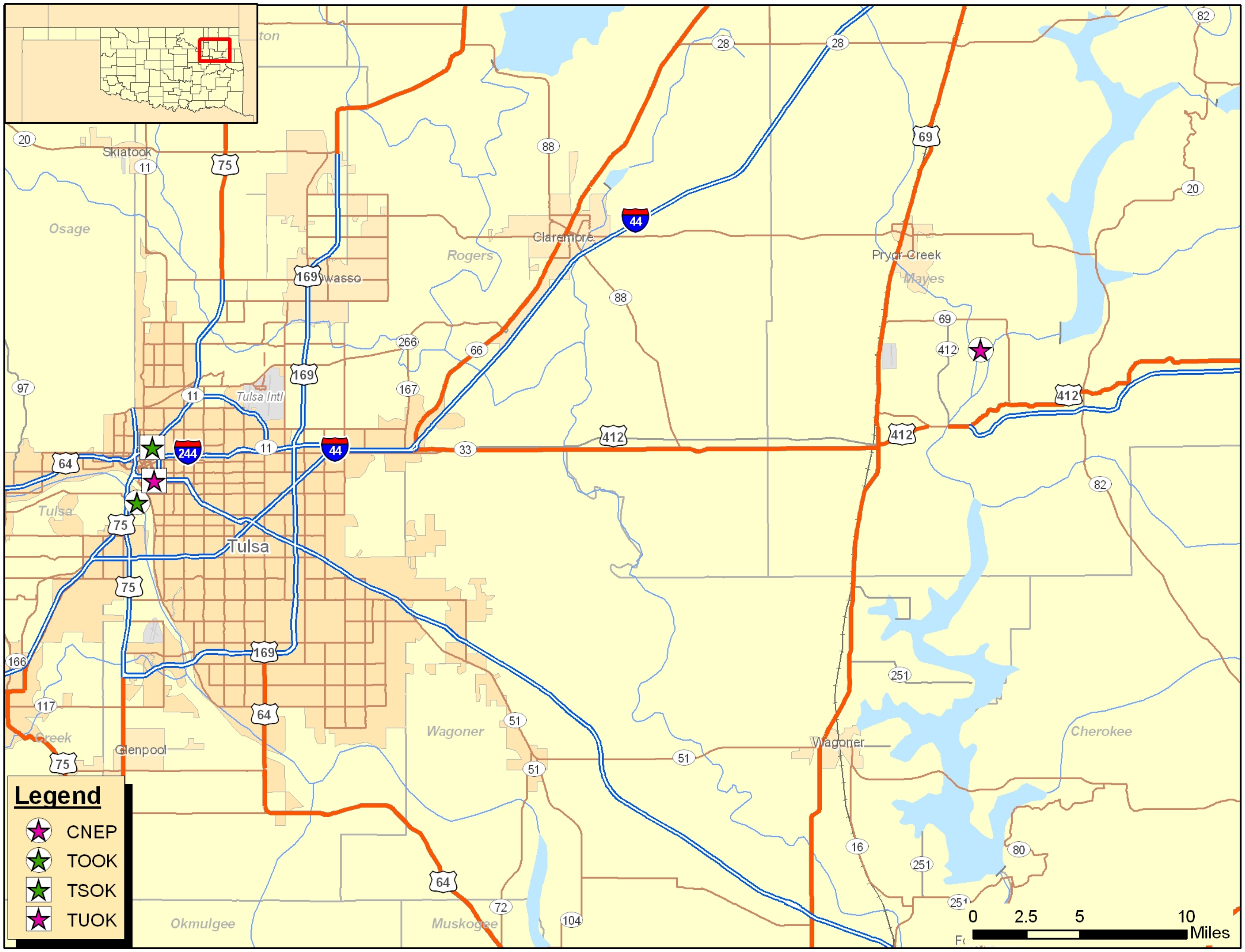

Figure 2. Cherokee Heights, Oklahoma (CNEP) Monitoring Site

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Scale: 3cm = 1 mile

Figure 3. Tulsa, Oklahoma (TOOK) Monitoring Site

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Scale: 3cm = 200m

Figure 4. Tulsa, Oklahoma (TSOK) Monitoring Site

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Scale: 3cm = 200m

Figure 5. Tulsa, Oklahoma (TUOK) Monitoring Site

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Scale: 3cm = 100m

Roberts Park is located to the north of the site and a railroad switching station is located in close proximity to the monitoring site. Much of the surrounding area is residential.

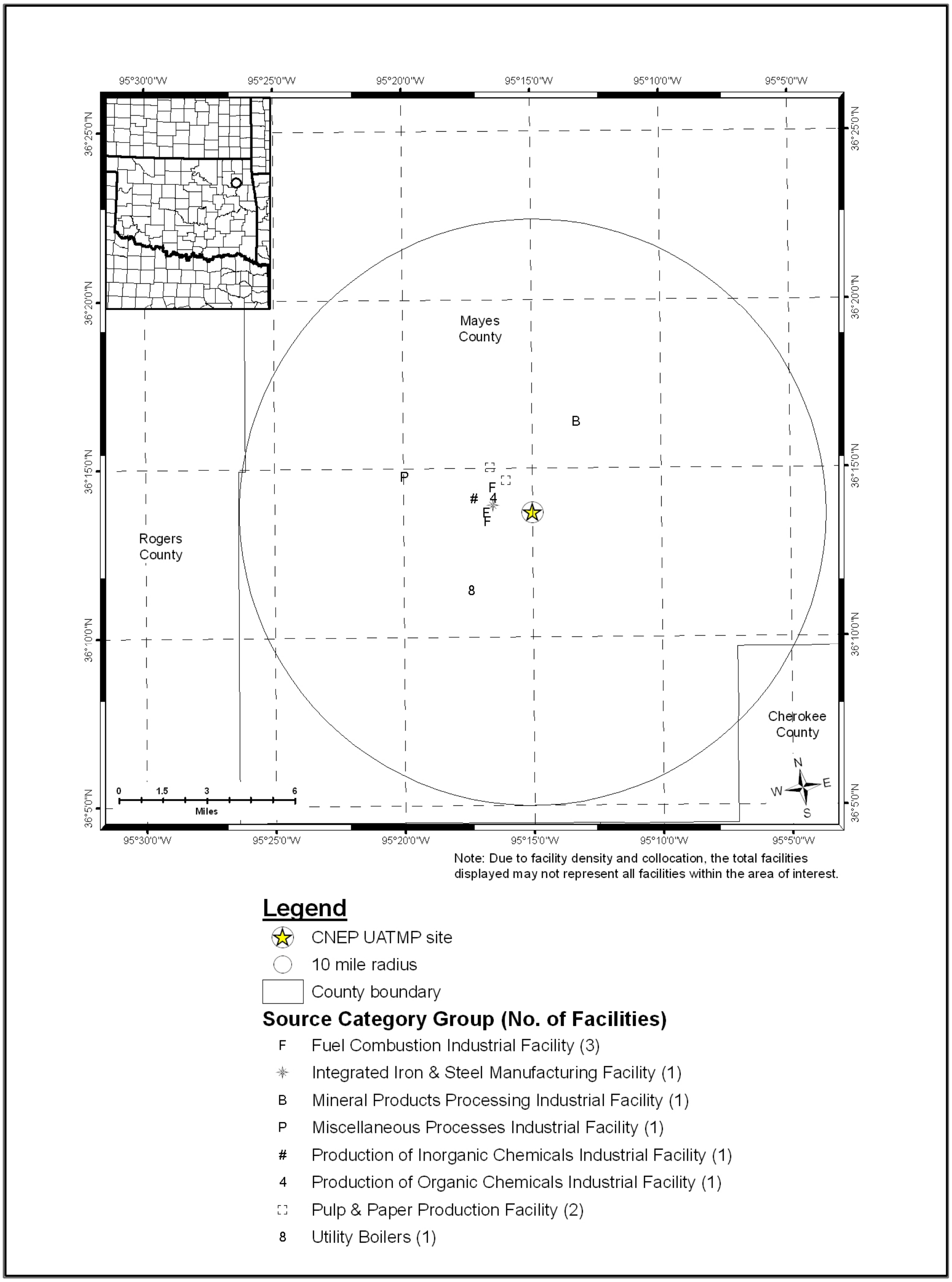
TUOK is located just on the opposite side of the Arkansas River from TOOK, in downtown Tulsa. The site is located just south of the US-64/US-75/Highway 51 interchange, as shown in Figure 5. Although commercial areas are located immediately to the west, the surrounding areas are primarily residential.

The proximity of the monitoring locations to different emissions sources, especially industrial facilities and heavily traveled roadways, likely explains the observed spatial variations in ambient air quality. Figures 6 and 7 identify point source emission locations within 10 miles of each site as reported in the 2002 National Emission Inventory (NEI) for point sources (EPA, 2006a).

Figure 6 shows that eleven point sources are located within 10 miles of CNEP. The majority of the sources are to the west and northwest of the site, including source categories such as fuel combustion and chemical production. Figure 7 shows that the three Tulsa sites are within 5 miles of each other, and are surrounded by more point sources than CNEP. Most of the emission sources are located along a line running northeast-southwest across Tulsa County. Fabricated metal production and surface coating processes have the highest number of emission sources surrounding the Tulsa sites.

Table 2 presents information related to mobile source activity, such as population (county and 10-mile population), daily traffic passing by the monitors, vehicle miles traveled (VMT), and estimated vehicle ownership information for the areas surrounding the monitoring sites. County-level vehicle registration and population data for Tulsa and Mayes County were obtained from the Oklahoma Tax Commission and the U.S. Census Bureau, respectively, and is reflective of 2007. Table 2 also includes a vehicle registration to county population ratio (vehicles per person), which may provide insight on the density of motor vehicle activity for each county. In addition, the population within 10 miles of each site is presented. An estimate of 10-mile vehicle

Figure 6. Facilities Located Within 10 Miles of CNEP



Note: Due to facility density and collocation, the total facilities displayed may not represent all facilities within the area of interest.

Figure 7. Facilities Located Within 10 Miles of TOOK, TSOK, and TUOK

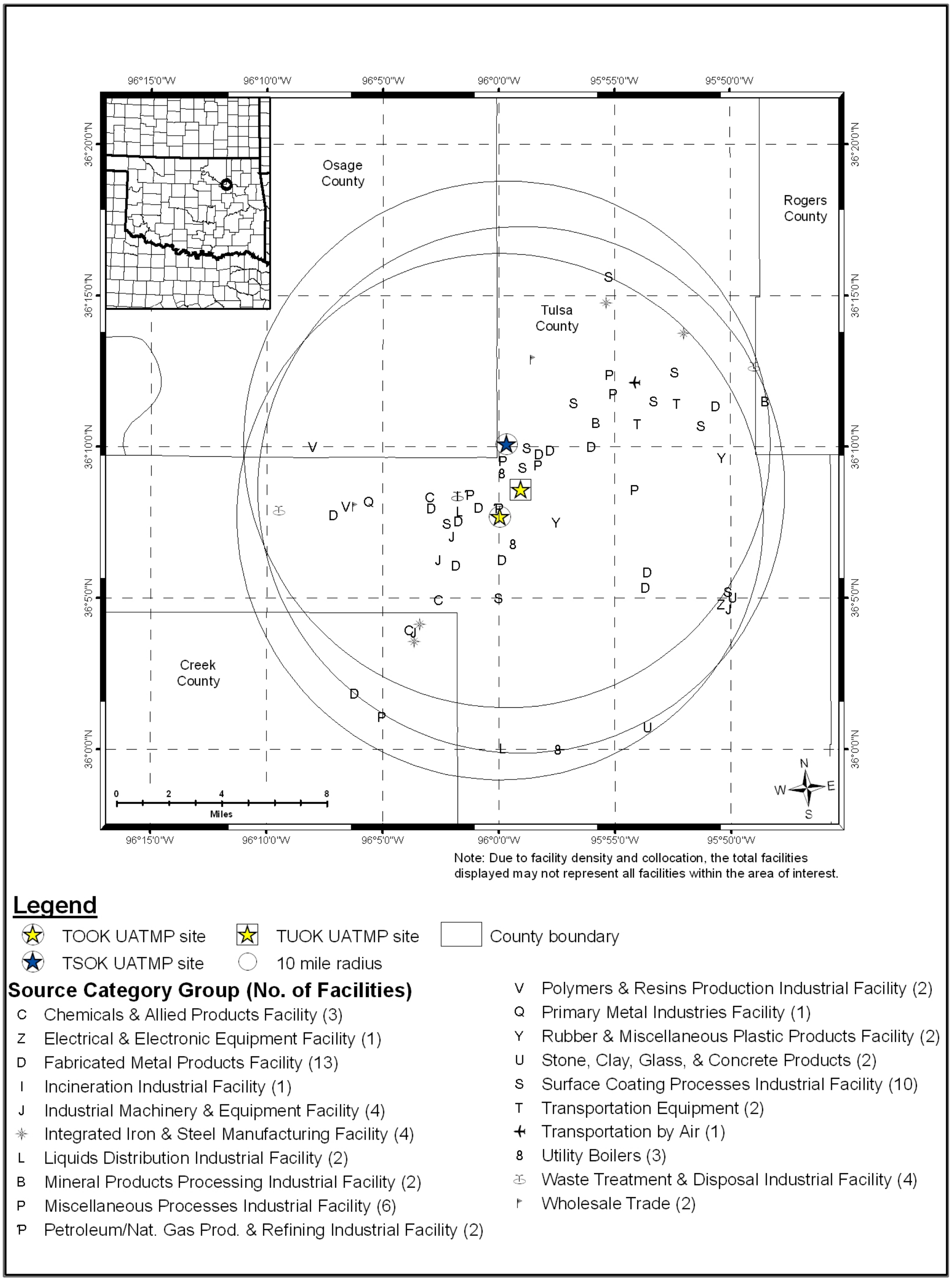


Table 2. Population, Motor Vehicle, and Traffic Information near the Oklahoma Monitoring Sites

Site	2007 Estimated County Population	Number of Vehicles Registered	Vehicles per Person (Registration: Population)	Population Within 10 Miles[1]	Estimated 10 mile Vehicle Ownership	Daily Average Traffic Data[2]	VMT (thousand miles)
CNEP	39,627	29,398	0.74	29,152	21,627	5	NA
TOOK	585,068	506,011	0.86	461,773	399,376	67,092	20,904
TSOK	585,068	506,011	0.86	337,331	291,749	33,800	20,904
TUOK	585,068	506,011	0.86	463,689	401,033	45,300	20,904

[1] http://zipnet.htm

[2] Daily Average Traffic Data reflects data from AQS (CNEP) and 2006 data from the Oklahoma DOT (TOOK, TSOK, TUOK)

registration was calculated by applying the vehicles per person ratio to the 10-mile population surrounding the monitor.

Table 2 shows that the Mayes County (CNEP) 2007 population is significantly lower than the Tulsa County 2007 population. This is also true of the 10-mile population. The Mayes County 2007 vehicle registration and 10-mile estimated vehicle registration data are also significantly lower than similar information in Tulsa County. These observations are expected given the rural nature of the area surrounding CNEP compared to the urban location of the Tulsa sites.

Table 2 also presents traffic data. The values for the Tulsa sites reflect average annual daily traffic (AADT)[1], which is “the total volume of traffic on a highway segment for one year, divided by the number of days in the year,” and incorporates both directions of traffic (Florida, 2007). The traffic volumes or AADT for the Tulsa sites were obtained from the Oklahoma Department of Transportation (OKDOT) and were from nearby highways such as I-244 and I-75. AADT counts obtained were based on data from 2006.

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[1] Several limitations exist to obtaining the AADT near each monitoring site. AADT statistics are developed for roadways managed by different municipalities or government agencies, and for different road types such as interstates, state highways, or local roadways. AADT is not always available in rural areas or for secondary roadways. For monitoring sites located near interstates, the AADT for the interstate segment closest to the site was obtained. For other monitoring sites, the highway or secondary road closest to the monitoring site was used. Only one AADT value was obtained for each monitoring site.

The CNEP traffic volume was obtained from EPA's AQS database for a local street in the Cherokee Heights neighborhood. CNEP officials suggest that this estimate may be low. Traffic data in Mayes County is available from OKDOT, but the available roadways for the county are further from the CNEP monitoring site. Traffic on roadways such as state roads 69A and 412B, which lead into the Mid-America Industrial Park, experience heavier traffic, with AADTs in the thousands (6,000 and 2,900, respectively). The actual distance from the Mid-America Industrial Park to the Cherokee Heights neighborhood is just over a one mile, but is further traveling by roadway.

Table 2 indicates that the average daily traffic volume passing the CNEP site is considerably lower than each of the Tulsa sites. Of the three Tulsa sites, TOOK experiences the highest daily traffic, while TSOK experiences the least.

Lastly, Table 2 presents estimated Vehicles Miles Traveled (VMT) for the Tulsa area. VMT is the sum of distances traveled by all motor vehicles in a specified system of highways for a given period of time (Oregon, 2007). As such, VMT values tend to be rather large (in the millions). VMT data is available from the Federal Highway Administration (FHWA) by urban area (FHWA, 2006). The MSA designations are used to designate in which urban area each monitoring site resides. As such, VMT is not available for CNEP because it is not in an MSA. Table 2 shows that VMT for the Tulsa MSA is approximately 21 million miles, which is relatively low compared to other urban areas. For comparison purposes, VMT for the New York City area is 300 million miles.

3.0 Meteorological Characterization

The following sections characterize the meteorological conditions near the monitoring sites in Oklahoma on sampling days, as well as over the course of the 18-month sampling period.

3.1 Climate Summary

Cherokee Heights is located just west of the Grand River in northeast Oklahoma. The area is characterized by a continental climate, with warm and humid summers and cool winters. The region experiences ample rainfall, with spring as the wettest season. A southerly wind prevails, bringing warm, moist air northward from the Gulf of Mexico. Tulsa is also in northeast Oklahoma, approximately 30 miles west of Cherokee Heights, so the climate is much like that of Cherokee Heights. Oklahoma is part of "Tornado Alley", where severe thunderstorms are capable of producing strong winds and hail, and tornadoes are more prevalent than in other regions in the U.S. (Ruffner and Bair, 1987).

3.2 Meteorological Conditions During the Sampling Period

Hourly meteorological data at weather stations near these sites were retrieved for the entire monitoring period. These data were used to determine how meteorological conditions on sampling days vary from normal conditions throughout the period. Meteorological data were also used to calculate correlations between meteorological parameters and ambient air concentration measurements. The three closest National Weather Service (NWS) weather stations are Claremore Regional Airport, Richard Lloyd Jones Jr. Airport, and Tulsa International Airport (WBAN 53940, 53908, and 13968, respectively).

Table 3 presents average meteorological conditions of temperature (average maximum and average), moisture (average dew point temperature, average wet bulb temperature, and average relative humidity), pressure (average sea level pressure), and wind information (average scalar wind speed) on days samples were collected and for the entire period. Also included in Table 3 is the 95 percent confidence interval for each parameter. As shown in Table 3, average meteorological conditions on sampling days were fairly representative of average weather conditions throughout the period.

3.3 Composite Back Trajectories for Sampling Days

A back trajectory traces the origin of an air parcel in relation to the location where it is currently being measured. The method of constructing a back trajectory uses the Lagrangian frame of reference. In simplest terms, an air parcel can be traced back one hour to a new point of reference based on the current measured wind speed and direction. At this new point of reference (that is now one hour prior to the current observation), the wind speed and direction are used again to determine where the air was one hour before. Back trajectory calculations are also

Table 3. Average Meteorological Conditions near the Oklahoma Monitoring Sites

Site	Closest NWS Station and WBAN	Average Type	Average Maximum Temperature (°F)	Average Temperature (°F)	Average Dew Point Temperature (°F)	Average Wet Bulb Temperature (°F)	Average Relative Humidity (%)	Average Sea Level Pressure (mb)	Average Scalar Wind Speed (kt)
CNEP	Claremore Regional Airport 53940	Sampling Day	65.12 ± 3.83	55.26 ± 3.61	43.47 ± 3.69	49.24 ± 3.51	68.00 ± 2.49	--[1]	6.61 ± 0.65
		18-Month Period	65.75 ± 1.50	55.15 ± 1.44	42.99 ± 1.52	49.14 ± 1.40	67.14 ± 0.99	--[1]	6.77 ± 0.28
TOOK	Richard Lloyd Jones Jr Airport 53908	Sampling Day	68.31 ± 3.79	57.68 ± 3.61	45.83 ± 3.69	51.61 ± 3.33	67.88 ± 2.18	1018.50 ± 1.36	5.68 ± 0.55
		18-Month Period	67.43 ± 1.50	56.36 ± 1.45	44.27 ± 1.53	50.30 ± 1.36	67.32 ± 0.97	1018.09 ± 0.57	5.72 ± 0.24
TSOK	Tulsa International Airport 13968	Sampling Day	67.93 ± 3.96	58.13 ± 3.81	45.16 ± 3.74	51.40 ± 3.42	65.16 ± 2.41	1017.27 ± 1.47	7.95 ± 0.66
		18-Month Period	67.14 ± 1.51	57.11 ± 1.47	43.98 ± 1.52	50.49 ± 1.35	64.79 ± 1.07	1016.94 ± 0.58	8.10 ± 0.29
TUOK	Richard Lloyd Jones Jr Airport 53908	Sampling Day	68.36 ± 3.80	57.56 ± 3.61	45.57 ± 3.69	51.43 ± 3.33	67.61 ± 2.18	1018.41 ± 1.37	5.66 ± 0.55
		18-Month Period	67.43 ± 1.50	56.36 ± 1.45	44.27 ±1.53	50.30 ± 1.36	67.32 ± 0.97	1018.09 ± 0.57	5.72 ± 0.24

[1] Sea level pressure was not recorded at the Claremore Regional Airport.

governed by other meteorological parameters, such as pressure and temperature. Each time segment is referred to as a “time step.” Although back trajectories may be modeled for up to 315 hours prior using surface and upper air meteorological observations, trajectories for this report were constructed for 24 hours to match the 24-hour VOC sample duration.

Gridded meteorological data and the model used for back trajectory analyses were prepared and developed by the National Oceanic and Atmospheric Administration (NOAA) using data from the NWS and other cooperative agencies. The model used is the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) (Draxler, R.R. and Rolph, G.D., 2003). Back trajectories were computed for each sampling day, and a composite back trajectory map was constructed for CNEP and each of the Tulsa monitoring sites using GIS software. Trajectories are modeled with an initial height of 250 meters above ground level (AGL). The value of the composite back trajectory map is the determination of a 24-hour airshed domain for each site. An airshed domain is the geographical area surrounding a site from which an air parcel may typically travel within the 24-hour time frame. Agencies can use the airshed domain to evaluate regions where long-range transport may affect their monitoring site.

Figures 8 through 11 are composite back trajectory maps for each of the monitoring sites for the days on which samples were collected in 2006 and 2007. Sample days for 2008 could not be included because the data was unavailable from NOAA. Each line represents the 24-hour trajectory along which a parcel of air traveled toward the monitoring site on a sampling day. Each concentric circle around the sites in Figures 8 through 11 represents 100 miles.

As shown, the composite back trajectory maps for all four monitoring sites were fairly similar, which is not unexpected given their fairly close proximity to one another. The bulk of the back trajectories originate from the south-southeast, south, and south-southwest of each of the monitoring sites. There is another cluster of back trajectories originating from the northwest of the sites. Several back trajectories originate over 800 miles from the sites.

Figure 8. Composite Back Trajectory Map for CNEP

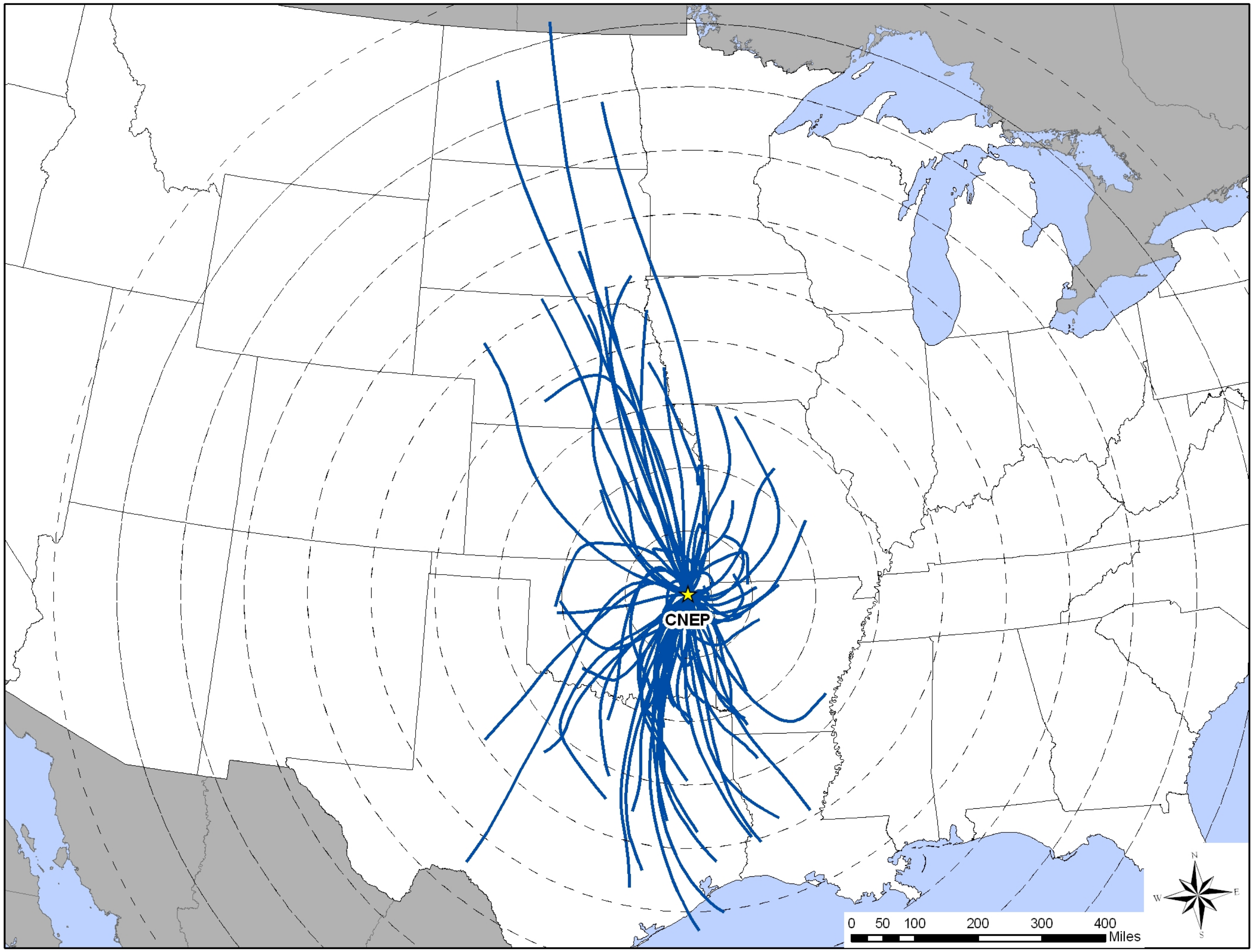


Figure 9. Composite Back Trajectory Map for TOOK

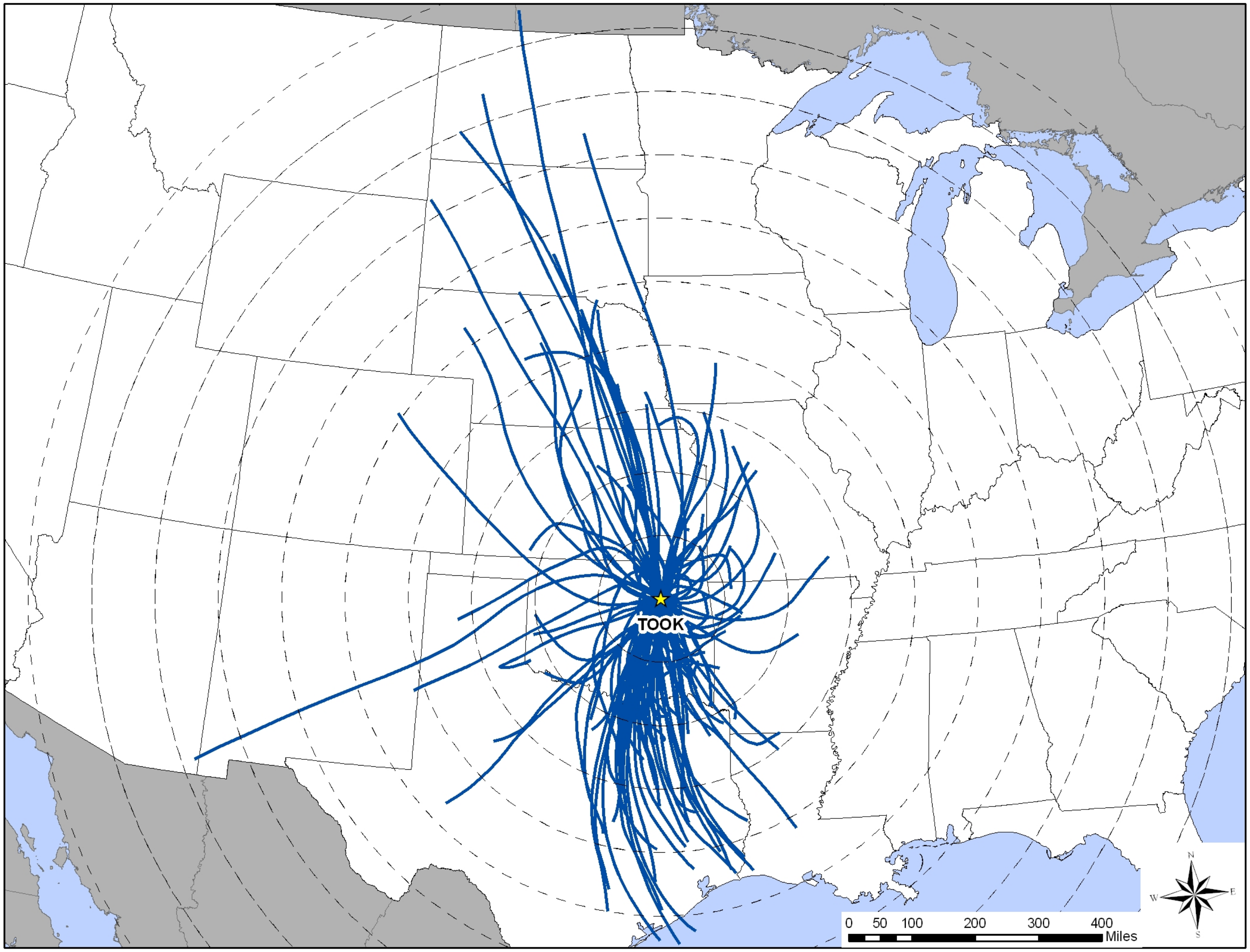


Figure 10. Composite Back Trajectory Map for TSOK

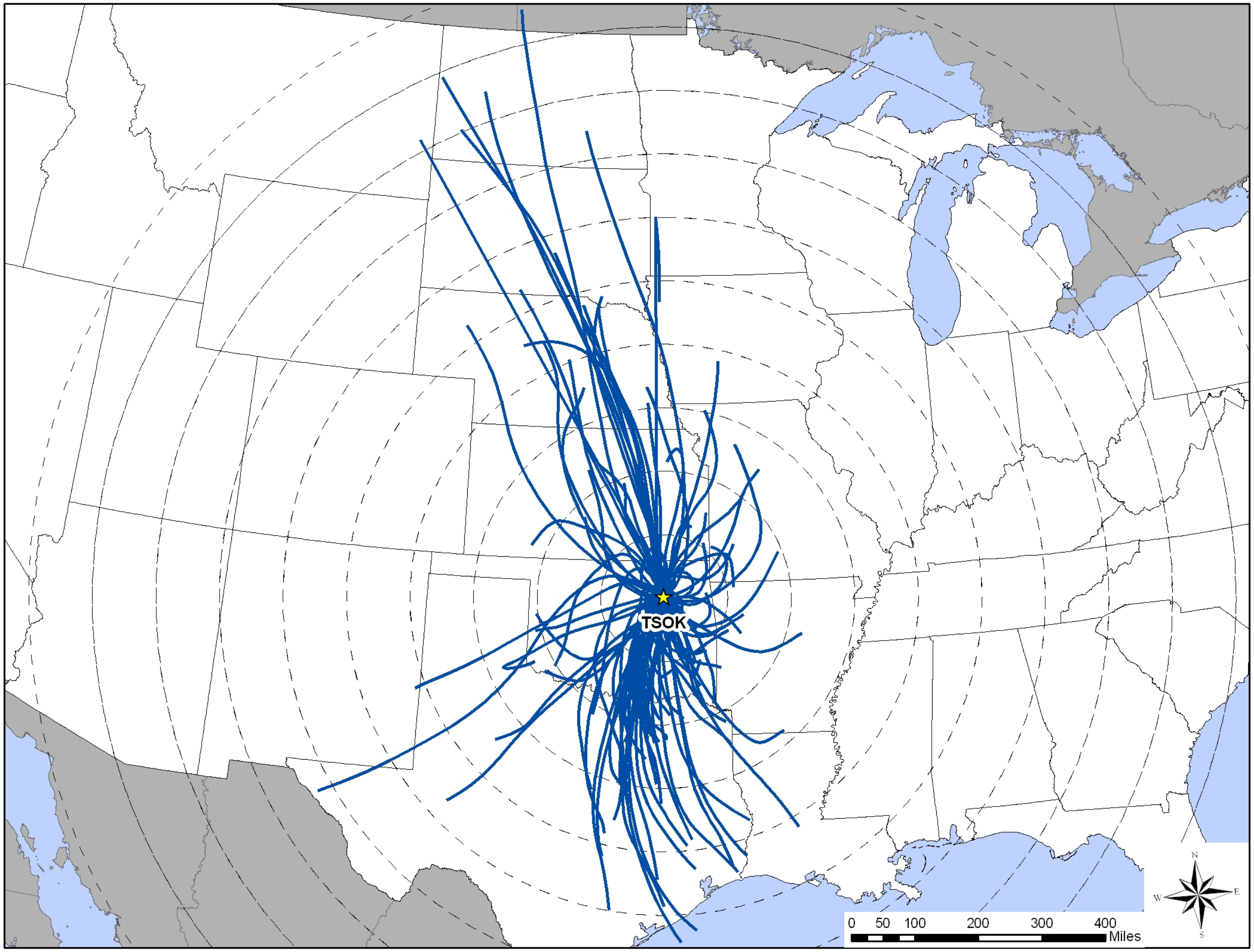
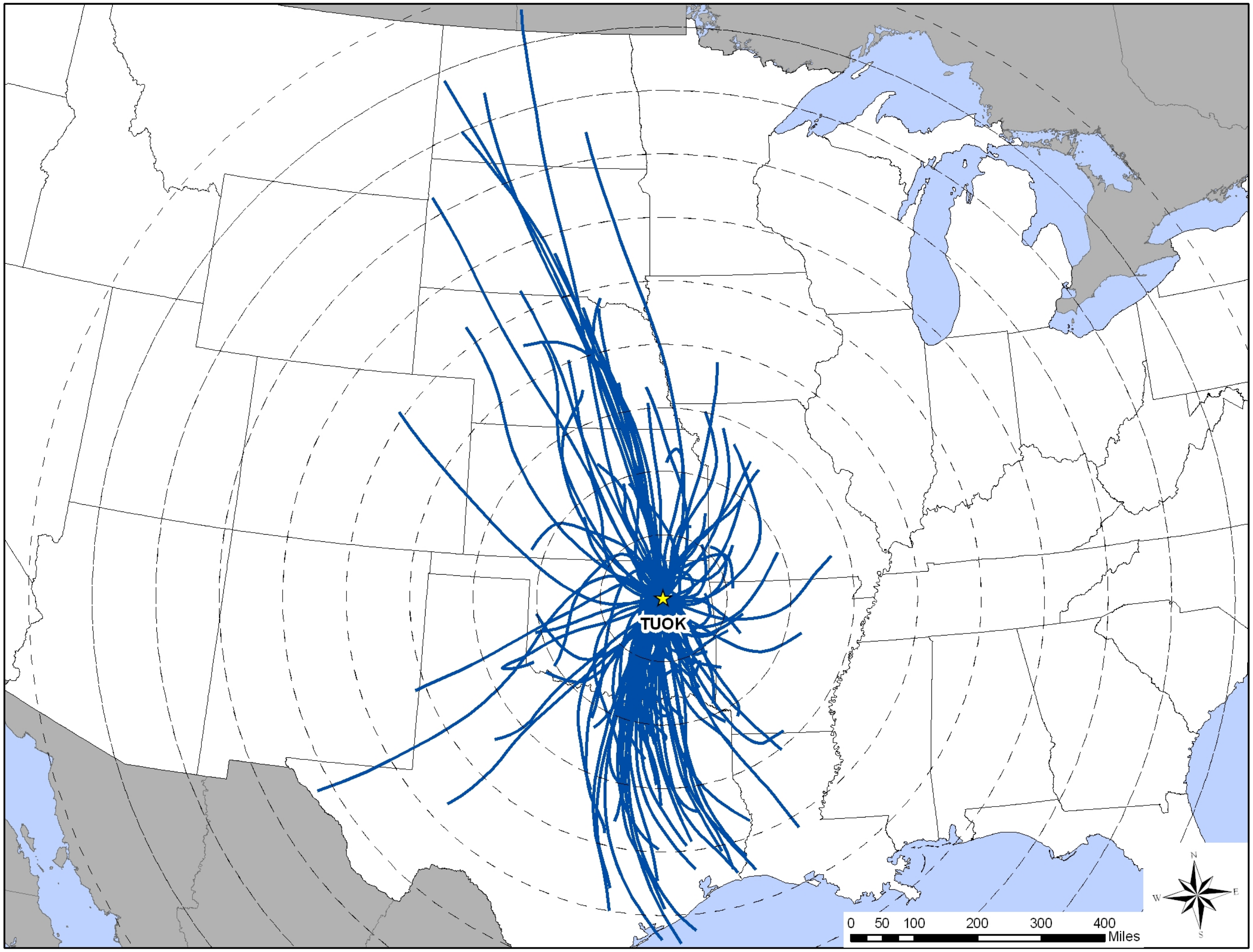


Figure 11. Composite Back Trajectory Map for TUOK



3.4 Wind Roses for Sampling Days

Wind roses were constructed for each site to help identify the predominant direction from which the wind blows. A wind rose shows the frequency of wind directions about a 16-point compass, and uses color or shading to represent wind speeds. Wind roses are constructed by uploading hourly surface wind data from the nearest weather station into a wind rose software program, WRPLOT (Lakes, 2007). A wind rose is often used in determining where to put an ambient monitoring site when trying to capture emissions from an upwind source. A wind rose may also be useful in determining whether high concentrations correlate with a specific wind direction. While the composite back trajectory maps show where a parcel of air originated from on a number of days, the wind rose shows the frequency at which wind speed and direction are measured near the monitoring site. In other words, the back trajectory map focuses on long range transport, while the wind rose captures day-to-day fluctuations at the surface. Both are used to identify potential meteorological influences on the monitoring sites.

Figures 12 through 15 are the wind roses for the monitoring sites on days that samples were collected. Similar to the composite back trajectory maps, the site-specific wind roses are also similar to each other due to the close proximity to one another. Southerly winds were the most prevalent on sample days during the 18-month period. Northerly winds were the second most commonly observed wind direction near the monitoring sites.

The frequency of calm winds varied by location. TSOK experienced calm winds the least (eight percent), followed by CNEP (16 percent). TOOK and TUOK experienced the highest percentage of calm winds at approximately 25 percent. Wind measurements for these two sites came from the same weather station, the Richard Lloyd Jones Jr Airport (WBAN 53908).

4.0 VOC Analytical Method

VOC sampling and analysis was performed in accordance with EPA Compendium Method TO-15 (EPA, 1999). Ambient air samples for VOC analysis were collected in passivated stainless steel canisters. The ERG laboratory distributed the prepared canisters (i.e., cleaned and evacuated) to the monitoring sites before each scheduled sample collection event, and site

Figure 12. Wind Rose for CNEP Sampling Days

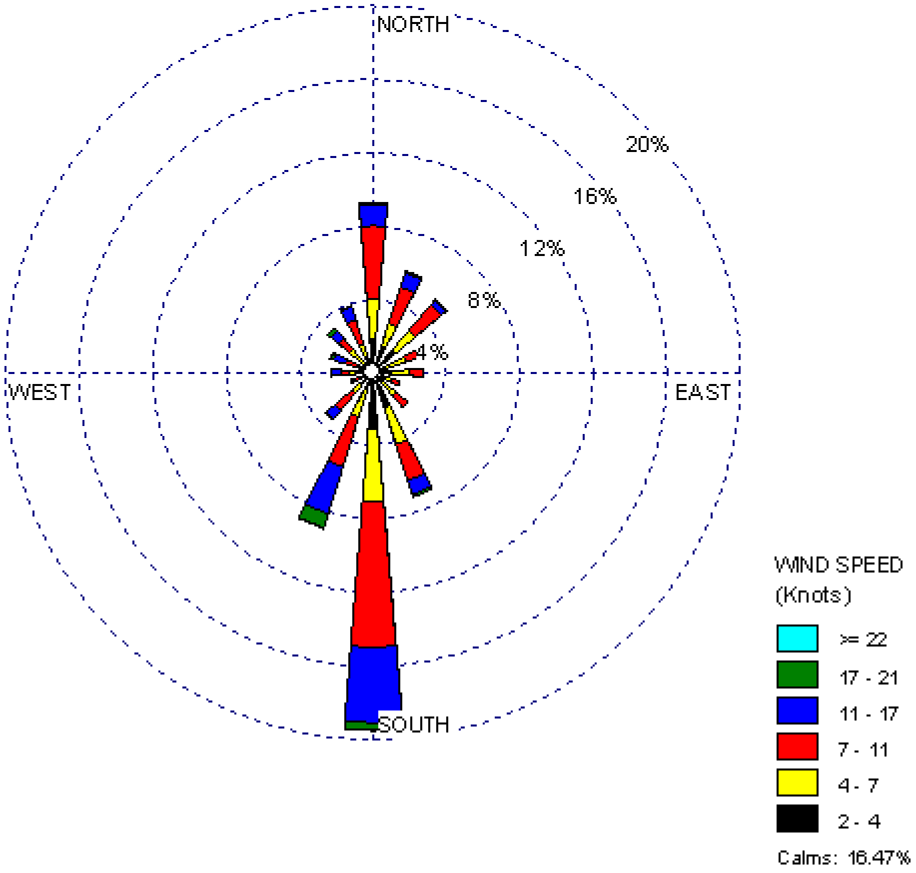


Figure 13. Wind Rose for TOOK Sampling Days

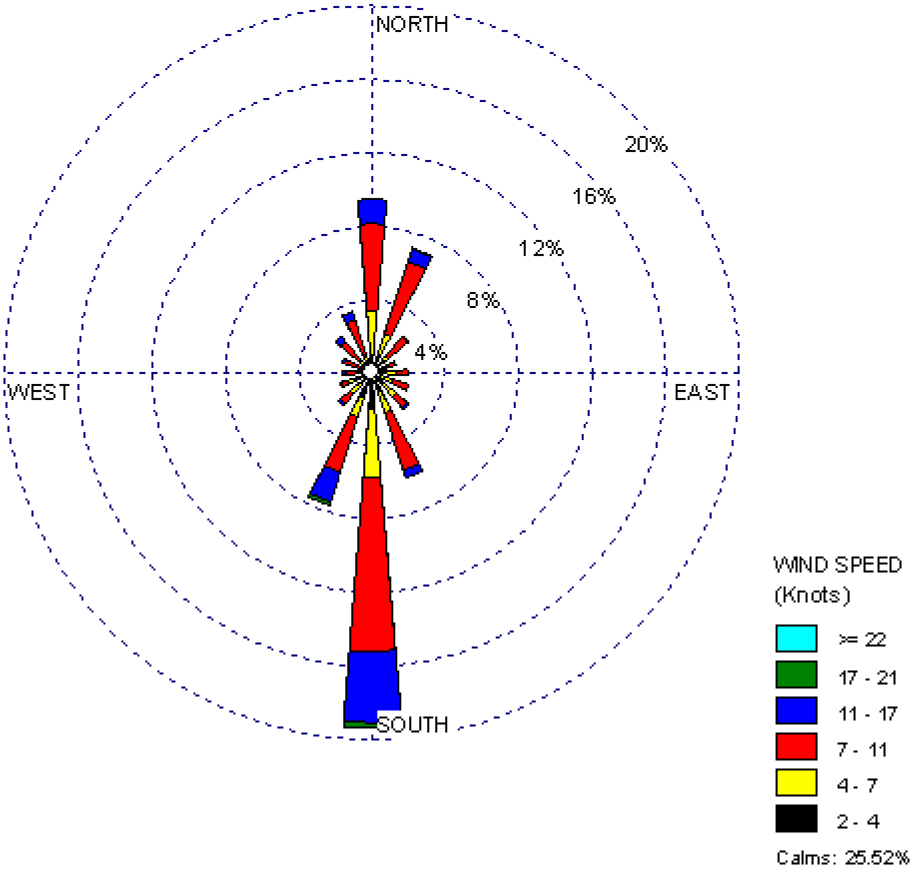


Figure 14. Wind Rose for TSOK Sampling Days

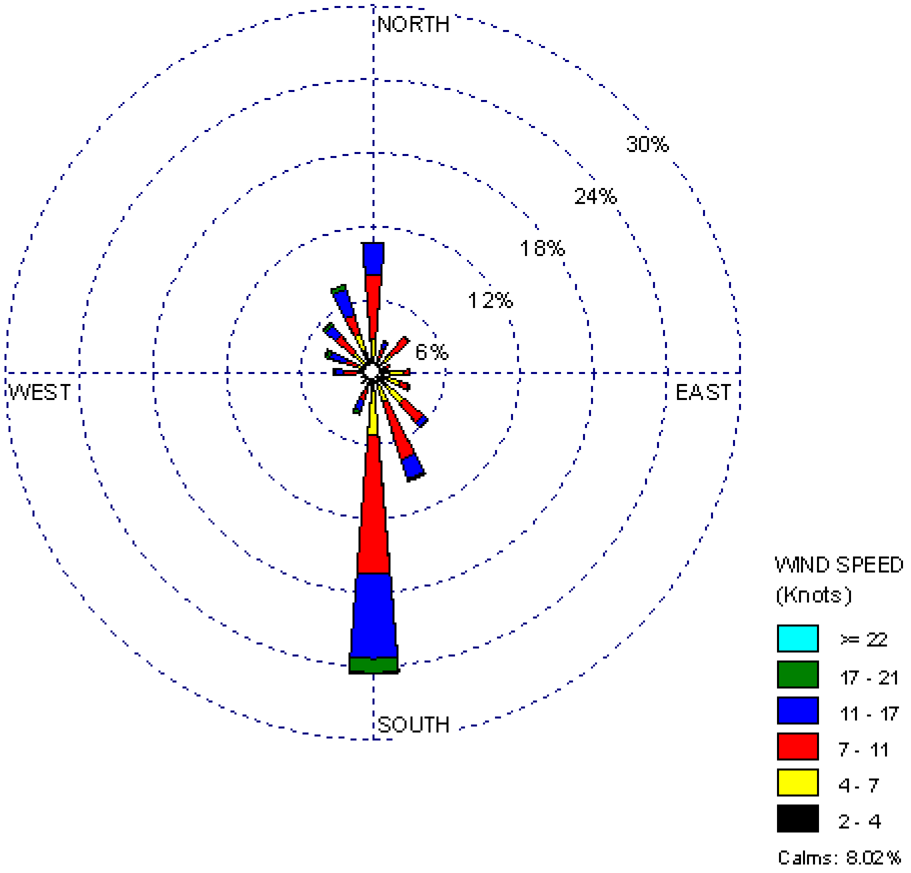
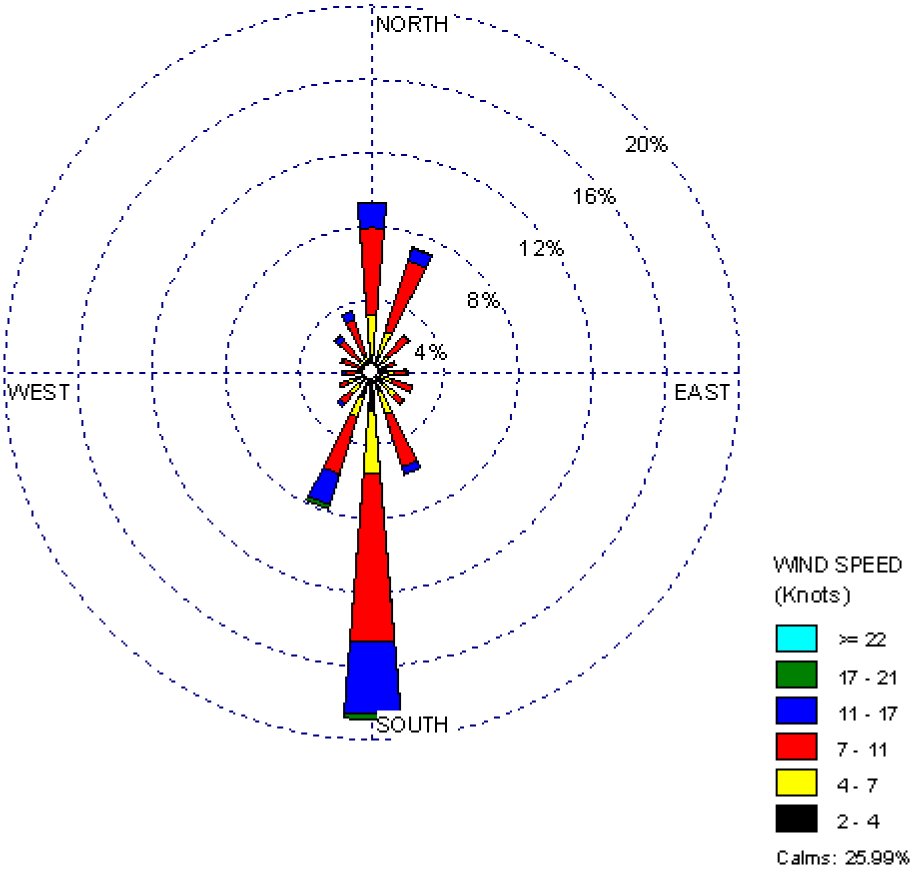


Figure 15. Wind Rose for TUOK Sampling Days



operators connected the canisters to air sampling equipment prior to each sampling day. Before use in the field, the passivated canisters had internal pressures much lower than atmospheric pressure. Using this pressure differential, ambient air naturally flowed into the canisters once they were opened. A mass flow controller on the sampling device inlet ensured that ambient air entered the canister at an integrated constant rate across the collection period. At the end of the 24-hour sampling period, a solenoid valve automatically stopped ambient air from flowing into the canister. Site operators recovered and returned the canisters to the ERG laboratory for analysis.

By analyzing each sample with gas chromatography incorporating mass spectrometry and flame ionization detection (GC/MS-FID), laboratory staff determined ambient air concentrations of 61 VOC. Because *m*-xylene and *p*-xylene elute from the gas chromatography (GC) column at the same time, the VOC analytical method reports only the sum of the concentrations for these compounds, and not the separate concentrations for each compound. Raw data are presented in Appendices A and B.

The detection limits of the analytical method must be considered carefully when interpreting the corresponding ambient air monitoring data. By definition, method detection limits (MDLs) represent the lowest concentrations at which laboratory equipment have been experimentally determined to reliably quantify concentrations of selected pollutants to a specific confidence level. If a chemical concentration in ambient air does not exceed the method sensitivity (as gauged by the detection limit), the analytical method might not differentiate the pollutant from other pollutants in the sample or from the random “noise” inherent in laboratory analyses. While quantification below the MDL is possible, the measurement reliability is lower. Therefore, when samples contain concentrations at levels below their respective detection limits, multiple analyses of the same sample may lead to a wide range of results, including highly variable concentrations or “non-detect” observations. Data analysts must exercise caution when interpreting monitoring data with many reported concentrations at levels near or below the corresponding detection limits. The method detection limits are presented in Appendix C.

Regarding samples of acetonitrile, laboratory analysts have indicated that the values may be artificially high (or nonexistent) due to site conditions and potential cross-contamination with concurrent sampling of carbonyl compounds using Method TO-11A. No contamination is expected for the CNEP dataset because CNEP did not sample carbonyls. However, the Tulsa sites sampled VOC and carbonyls concurrently, which may result in cross-contamination. Because the acetonitrile results are included in all subsequent data analyses, readers should use caution when interpreting calculations based on the Tulsa sites' acetonitrile data.

4.1 Analytical Completeness

Twenty-four hour integrated samples were collected at each monitoring site on a 1-in-6 day collection frequency and each sample collection began and ended at midnight, local standard time. The 1-in-6 day sampling schedule provides cost-effective approaches to data collection for trends characterization of toxic pollutants in ambient air and ensures that sampling days are evenly distributed among the seven days of the week to allow weekday/weekend comparison of air quality.

Completeness refers to the number of valid samples collected and analyzed compared to the number of total samples attempted. Monitoring programs that consistently generate valid results have higher completeness than programs that consistently invalidate samples. The completeness of an air monitoring program, therefore, can be a qualitative measure of the reliability of air sampling equipment and laboratory analytical equipment and a measure of the efficiency with which the program was managed. Appendix D identifies samples that were invalidated and lists the specific reasons why the samples were invalidated.

The data quality objective for completeness based on ERG's EPA-approved Quality Assurance Project Plan (QAPP), specifies that 85-100 percent of samples collected at a given monitoring site must be analyzed successfully to be considered sufficient for data trends analysis (ERG, 2006/2007). Ninety-one total samples were collected at the CNEP monitoring site, of which seven were invalidated, leaving a total of 84 valid samples. Completeness for CNEP is 92 percent.

5.0 Statistical Treatments

This section examines the various statistical tools employed to characterize the data collected during the 18-month period. The following paragraphs describe techniques used to prepare this large quantity of data for data analysis.

First, all duplicate and replicate (or collocated) measurements were averaged in order to calculate a single concentration for each pollutant for each sampling day at each site. Second, *m,p*-xylene and *o*-xylene concentrations were summed together and are henceforth referred to as "total xylenes," "xylenes (total)," or simply "xylenes" throughout the remainder of this report, with a few exceptions described below. This is referred to as the *preprocessed daily measurement.*

Table 4 presents the detection rate (percentage of pollutants detected in each sample) for each of the 91 samples collected during the 18-month period, based on the preprocessed daily measurement. The average detection rate was about 45 percent, and ranged from 32 to 54 percent.

Table 4. VOC Detection Rate for Samples Collected at CNEP

Date of Sample	# of Measured Detections	# of Non-Detects	Total Possible Detections	% Detected
9/26/2006	28	31	59	47.46
10/2/2006	27	32	59	45.76
10/10/2006	30	29	59	50.85
10/18/2006	28	31	59	47.46
10/20/2006	27	32	59	45.76
10/26/2006	23	36	59	38.98
11/1/2006	28	31	59	47.46
11/7/2006	25	34	59	42.37
11/13/2006	27	32	59	45.76
11/19/2006	30	29	59	50.85
11/25/2006	27	32	59	45.76
12/1/2006	INVALID			
12/7/2006	22	37	59	37.29
12/13/2006	25	34	59	42.37
12/19/2006	25	34	59	42.37
12/25/2006	INVALID			
12/31/2006	28	31	59	47.46

Table 4. VOC Detection Rate for Samples Collected at CNEP (Continued)

Date of Sample	# of Measured Detections	# of Non-Detects	Total Possible Detections	% Detected
1/6/2007	28	31	59	47.46
1/12/2007	29	30	59	49.15
1/18/2007	25	34	59	42.37
1/24/2007	27	32	59	45.76
1/30/2007	23	36	59	38.98
2/5/2007	27	32	59	45.76
2/11/2007	30	29	59	50.85
2/17/2007	23	36	59	38.98
2/23/2007	25	34	59	42.37
3/1/2007	25	34	59	42.37
3/7/2007	27	32	59	45.76
3/13/2007	26	33	59	44.07
3/19/2007	24	35	59	40.68
3/25/2007	29	30	59	49.15
3/31/2007	28	31	59	47.46
4/6/2007	28	31	59	47.46
4/12/2007	28	31	59	47.46
4/18/2007	INVALID			
4/24/2007	29	30	59	49.15
4/30/2007	30	29	59	50.85
5/6/2007	25	34	59	42.37
5/12/2007	29	30	59	49.15
5/18/2007	28	31	59	47.46
5/24/2007	25	34	59	42.37
5/30/2007	32	27	59	54.24
6/5/2007	32	27	59	54.24
6/11/2007	31	28	59	52.54
6/17/2007	30	29	59	50.85
6/23/2007	31	28	59	52.54
6/29/2007	INVALID			
7/5/2007	22	37	59	37.29
7/11/2007	32	27	59	54.24
7/17/2007	28	31	59	47.46
7/23/2007	30	29	59	50.85
7/29/2007	28	31	59	47.46
8/4/2007	29	30	59	49.15
8/10/2007	27	32	59	45.76
8/16/2007	25	34	59	42.37
8/22/2007	27	32	59	45.76
8/28/2007	29	30	59	49.15
9/3/2007	23	36	59	38.98
9/9/2007	24	35	59	40.68
9/15/2007	29	30	59	49.15

Table 4. VOC Detection Rate for Samples Collected at CNEP (Continued)

Date of Sample	# of Measured Detections	# of Non-Detects	Total Possible Detections	% Detected
9/21/2007	27	32	59	45.76
9/27/2007	29	30	59	49.15
10/3/2007	INVALID			
10/15/2007	27	32	59	45.76
10/21/2007	24	35	59	40.68
10/27/2007	23	36	59	38.98
11/2/2007	22	37	59	37.29
11/8/2007	19	40	59	32.20
11/14/2007	20	39	59	33.90
11/20/2007	28	31	59	47.46
11/26/2007	32	27	59	54.24
12/2/2007	30	29	59	50.85
12/8/2007	26	33	59	44.07
12/14/2007	27	32	59	45.76
12/20/2007	27	32	59	45.76
12/26/2007	INVALID			
1/1/2008	25	34	59	42.37
1/7/2008	23	36	59	38.98
1/13/2008	26	33	59	44.07
1/19/2008	25	34	59	42.37
1/25/2008	29	30	59	49.15
1/31/2008	30	29	59	50.85
2/6/2008	29	30	59	49.15
2/12/2008	29	30	59	49.15
2/18/2008	30	29	59	50.85
2/24/2008	INVALID			
3/1/2008	29	30	59	49.15
3/7/2008	21	38	59	35.59
3/13/2008	32	27	59	54.24
3/25/2008	27	32	59	45.76
3/31/2008	27	32	59	45.76

Table 5 presents basic central tendency (mean, median, mode, geometric mean) and data distribution statistics (frequency of detected measurements, ranges, quartiles, standard deviation, and coefficient of variation) performed on the CNEP dataset. In this table, the xylenes results are broken into *m,p*-xylene and *o*-xylene species.

Table 5. Statistical Summaries of the VOC Concentrations for CNEP

Pollutant	# of Measured Detections[1]	Minimum (ppbv)	Maximum (ppbv)	Arithmetic Mean (ppbv)	Mode (ppbv)	Median (ppbv)	Geometric Mean (ppbv)	First Quartile (ppbv)	Third Quartile (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	75	0.04	0.98	0.15	0.06	0.13	0.13	0.08	0.19	0.12	0.78
Acetylene	84	0.09	2.15	0.54	0.59	0.40	0.42	0.25	0.66	0.41	0.77
Acrolein	84	0.08	1.86	0.67	0.57	0.58	0.57	0.45	0.82	0.36	0.54
Acrylonitrile	2	0.02	0.02	0.02	NA	0.02	0.02	0.02	0.02	0.001	0.09
tert-Amyl Methyl Ether	2	0.002	0.004	0.003	NA	0.003	0.003	0.003	0.004	0.001	0.37
Benzene	84	0.05	0.77	0.17	0.20	0.15	0.15	0.12	0.19	0.09	0.52
Bromochloromethane	1	0.004		NA							
Bromodichloromethane	0	NA									
Bromoform	0	NA									
Bromomethane	80	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.003	0.26
1,3-Butadiene	62	0.01	0.06	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.63
Carbon Tetrachloride	84	0.03	0.17	0.11	0.08	0.10	0.11	0.09	0.12	0.02	0.22
Carbon Disulfide	62	0.01	0.06	0.02	0.02	0.02	0.02	0.01	0.03	0.01	0.49
Chlorobenzene	3	0.003	0.004	0.003	0.003	0.004	0.003	0.003	0.007	<0.001	0.14
Chloroethane	75	0.01	0.04	0.02	0.02	0.02	0.02	0.01	0.03	0.01	0.37
Chloroform	76	0.01	0.04	0.02	0.02	0.02	0.02	0.01	0.02	0.004	0.26
Chloromethane	84	0.19	0.92	0.56	0.49	0.56	0.54	0.49	0.62	0.12	0.21
Chloromethylbenzene	0	NA									
Chloroprene	0	NA									
Dibromochloromethane	0	NA									
1,2-Dibromoethane	0	NA									
m-Dichlorobenzene	1	0.004		NA							
o-Dichlorobenzene	0	NA									
p-Dichlorobenzene	20	0.002	0.010	0.005	0.004	0.004	0.004	0.003	0.005	0.002	0.46
Dichlorodifluoromethane	84	0.15	0.74	0.51	0.51	0.50	0.50	0.47	0.55	0.08	0.15
1,1-Dichloroethane	0	NA									
1,2-Dichloroethane	2	0.02	0.03	0.02	NA	0.02	0.02	0.02	0.03	0.01	0.33
1,1-Dichloroethene	0	NA									
cis-1,2-Dichloroethylene	0	NA									
trans-1,2-Dichloroethylene	0	NA									

[1] Out of 84 samples

Table 5. Statistical Summaries of the VOC Concentrations for CNEP (Continued)

Pollutant	# of Measured Detections[1]	Minimum (ppbv)	Maximum (ppbv)	Arithmetic Mean (ppbv)	Mode (ppbv)	Median (ppbv)	Geometric Mean (ppbv)	First Quartile (ppbv)	Third Quartile (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Dichloromethane	84	0.01	0.40	0.06	0.05	0.06	0.06	0.05	0.07	0.04	0.66
1,2-Dichloropropane	1	0.01		NA							
cis-1,3-Dichloropropene	0	NA									
trans-1,3-Dichloropropene	0	NA									
Dichlorotetrafluoroethane	83	0.003	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.004	0.23
Ethyl Acrylate	0	NA									
Ethyl tert-Butyl Ether	0	NA									
Ethylbenzene	84	0.01	0.19	0.02	0.02	0.02	0.02	0.01	0.03	0.03	1.15
Hexachloro-1,3-butadiene	0	NA									
Methyl Ethyl Ketone	83	0.18	4.82	1.28	1.11	1.03	1.03	0.67	1.65	0.87	0.67
Methyl Isobutyl Ketone	81	0.02	0.44	0.09	0.05	0.07	0.07	0.04	0.11	0.08	0.88
Methyl Methacrylate	0	NA									
Methyl tert-Butyl Ether	2	0.002	0.006	0.004	NA	0.004	0.003	0.003	0.005	0.002	0.50
n-Octane	68	0.01	0.07	0.02	0.03	0.02	0.02	0.01	0.03	0.01	0.59
Propylene	84	0.08	1.24	0.30	0.18	0.24	0.25	0.16	0.37	0.20	0.66
Styrene	59	0.003	0.23	0.03	0.02	0.02	0.02	0.01	0.03	0.04	1.34
1,1,2,2-Tetrachloroethane	0	NA									
Tetrachloroethylene	55	0.004	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.003	0.34
Toluene	84	0.05	5.80	0.21	0.13	0.13	0.13	0.09	0.17	0.62	2.91
1,2,4-Trichlorobenzene	1	0.004		NA							
1,1,1-Trichloroethane	84	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.004	0.23
1,1,2-Trichloroethane	3	0.002	0.006	0.004	NA	0.004	0.004	0.003	0.005	0.002	0.41
Trichloroethylene	26	0.01	0.10	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.98
Trichlorofluoromethane	83	0.06	0.39	0.25	0.23	0.25	0.25	0.23	0.28	0.04	0.16
Trichlorotrifluoroethane	84	0.02	0.16	0.10	0.09	0.10	0.10	0.09	0.11	0.02	0.18
1,2,4-Trimethylbenzene	81	0.003	0.06	0.02	0.01	0.02	0.02	0.01	0.03	0.01	0.63
1,3,5-Trimethylbenzene	68	0.002	0.02	0.01	0.01	0.01	0.01	0.004	0.01	0.004	0.56
Vinyl chloride	23	0.003	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.002	0.39
m,p-Xylene	84	0.01	0.67	0.05	0.04	0.04	0.04	0.02	0.05	0.08	1.51
o-Xylene	84	0.01	0.17	0.02	0.02	0.02	0.02	0.01	0.03	0.02	0.97

[1] Out of 84 samples

Some pollutants are consistently detected while others are infrequently detected. Fourteen pollutants, such as benzene and toluene, were reported in every valid sample collected (84). Eighteen other pollutants, such as 1,1-dichloroethene and ethyl acrylate, were not detected in a single sample collected.

The minimum and maximum concentration measured for each target pollutant is also presented in Table 5. Some pollutants, such as toluene and methyl ethyl ketone, had a relatively large range of concentrations measured, as shown by the minimum and maximum concentrations, as well as the standard deviation. Other pollutants, such as dichloromethane and carbon tetrachloride, had smaller concentration ranges.

A multitude of observations can be made from the remaining statistical parameters in Table 5. In brief, the following pollutants had the three highest average concentrations, by mass, for CNEP:

- Methyl Ethyl Ketone – 1.28 ppbv
- Acrolein – 0.67 ppbv
- Chloromethane – 0.56 ppbv.

As a means of comparing the Tulsa sites' concentrations to CNEP's concentrations, Table 6 presents the average concentration for each VOC for each monitoring site. The average concentrations of some pollutants, such as acetonitrile, are very different between CNEP and the Tulsa sites, while the average concentrations of other pollutants, such as dichlorodifluoromethane and chloromethane, were very similar. Acetonitrile is higher at TOOK and TSOK than at TUOK, and all three average concentrations are higher than CNEP's average acetonitrile concentration.

Table 6. Comparison of VOC Average Concentrations Across Monitoring Sites

	Site			
Pollutant	**CNEP Average Concentration (ppbv)**	**TOOK Average Concentration (ppbv)**	**TSOK Average Concentration (ppbv)**	**TUOK Average Concentration (ppbv)**
Acetonitrile	0.15	9.29	9.19	2.04
Acetylene	0.54	0.75	0.70	0.81
Acrolein	0.67	0.35	0.38	0.40
Acrylonitrile	0.02	0.15	0.08	0.08
tert-Amyl Methyl Ether	0.003	ND	0.003	0.01
Benzene	0.17	0.62	0.30	0.38
Bromochloromethane	0.004	ND	ND	ND
Bromodichloromethane	ND	0.01	ND	0.01
Bromoform	ND	0.003	ND	ND
Bromomethane	0.01	0.01	0.01	0.01
1,3-Butadiene	0.01	0.04	0.03	0.04
Carbon Disulfide	0.02	0.04	0.04	0.38
Carbon Tetrachloride	0.11	0.09	0.09	0.09
Chlorobenzene	0.003	ND	ND	0.02
Chloroethane	0.02	0.03	0.04	0.03
Chloroform	0.02	0.02	0.02	0.02
Chloromethane	0.56	0.57	0.61	0.57
Chloromethylbenzene	ND	ND	ND	ND
Chloroprene	0.03	0.05	0.04	0.02
Dibromochloromethane	0.004	0.001	0.002	ND
1,2-Dibromoethane	ND	ND	ND	ND
m-Dichlorobenzene	0.004	0.01	0.01	0.003
o-Dichlorobenzene	ND	ND	0.01	0.02
p-Dichlorobenzene	0.005	0.02	0.02	0.02
Dichlorodifluoromethane	0.51	0.51	0.51	0.51
1,1-Dichloroethane	ND	0.01	ND	0.01
1,2-Dichloroethane	0.02	ND	0.01	0.01
1,1-Dichloroethene	ND	ND	ND	ND
cis-1,2-Dichloroethylene	ND	ND	ND	ND
trans-1,2-Dichloroethylene	ND	ND	0.01	0.003
Dichloromethane	0.06	0.10	0.10	0.11
1,2-Dichloropropane	0.01	ND	ND	ND
cis-1,3-Dichloropropene	ND	ND	ND	ND
trans-1,3-Dichloropropene	ND	ND	ND	0.00
Dichlorotetrafluoroethane	0.02	0.02	0.02	0.02
Ethyl Acrylate	ND	ND	ND	ND
Ethyl tert-Butyl Ether	ND	ND	ND	0.01
Ethylbenzene	0.02	0.13	0.10	0.09
Hexachloro-1,3-butadiene	ND	0.002	ND	ND
Methyl Ethyl Ketone	1.28	0.86	0.69	0.71

Table 6. Comparison of VOC Average Concentrations Across Monitoring Sites (Continued)

Pollutant	Site CNEP Average Concentration (ppbv)	TOOK Average Concentration (ppbv)	TSOK Average Concentration (ppbv)	TUOK Average Concentration (ppbv)
Methyl Isobutyl Ketone	0.09	0.06	0.07	0.06
Methyl Methacrylate	ND	0.01	0.06	0.07
Methyl tert-Butyl Ether	0.004	0.05	0.03	0.03
n-Octane	0.02	0.10	0.03	0.05
Propylene	0.30	0.77	0.38	0.53
Styrene	0.03	0.03	0.05	0.03
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND
Tetrachloroethylene	0.01	0.03	0.03	0.05
Toluene	0.21	1.38	1.04	1.02
1,2,4-Trichlorobenzene	0.004	0.01	0.01	0.02
1,1,1-Trichloroethane	0.02	0.02	0.02	0.02
1,1,2-Trichloroethane	0.004	0.01	0.01	0.01
Trichloroethylene	0.02	0.02	0.03	0.02
Trichlorofluoromethane	0.25	0.24	0.25	0.25
Trichlorotrifluoroethane	0.10	0.11	0.10	0.14
1,2,4-Trimethylbenzene	0.02	0.15	0.07	0.09
1,3,5-Trimethylbenzene	0.01	0.05	0.02	0.03
Vinyl chloride	0.01	0.01	0.01	0.01
m,p-Xylene	0.05	0.38	0.22	0.25
o-Xylene	0.02	0.14	0.09	0.10

6.0 Measurement Precision

Precision refers to the agreement between independent measurements performed according to identical protocols and procedures. Method precision, or s*ampling and analytical precision,* quantifies random errors associated with collecting ambient air samples and analyzing the samples in the laboratory. Precision is evaluated by comparing concentrations measured in duplicate or collocated samples collected from the same air parcel. A *duplicate* sample is a sample collected simultaneously with a primary sample using the same sampling system (i.e., two separate samples through the same sampling system at the same time). This simultaneous collection is typically achieved by teeing the line from the sampler to two canisters and doubling the flow rate applied to achieve integration over the 24-hour collection period. Analysis of duplicate samples provides information on the potential for variability (or precision) expected from a single collection system, but does not provide information on the variability expected between different collection systems (inter-system assessment).

During the sampling period, duplicate samples were collected at CNEP on approximately 10 percent of the scheduled sampling days. Most of these samples were analyzed in replicate. To calculate sampling and analytical precision, data analysts compare the concentrations of the two duplicates for each compound. This report uses Relative Percent Difference (RPD) to quantify random errors indicated by duplicate analyses of samples. The RPD expresses average concentration differences relative to the average concentrations measured during duplicate analyses. The RPD is calculated as follows:

$$\frac{X_1 - X_2}{\overline{X}} \times 100 = RPD$$

Where:

X_1 is the ambient air concentration of a given pollutant measured in one sample;
X_2 is the concentration of the same pollutant measured during duplicate analysis; and
$\overline{X}$ is the arithmetic mean of X_1 and X_2.

As this equation shows, duplicate analyses with low variability have lower RPDs (and better precision), and duplicate analyses with high variability have higher RPDs (and poorer precision).

Table 7 presents the RPDs for each duplicate sample collected. The pollutants shown in the table are limited to those with at least one measured detection for all duplicate samples. RPDs were calculated for every duplicate analysis performed over the period. In cases where pollutants were not detected during duplicate analyses, non-detects were replaced with 1/2 the MDL.

EPA recently revised the methodology for assessing method precision in “Revisions to Ambient Air Monitoring Regulations; Final Rule,” finalized October 17, 2006 (EPA, 2006b). The primary change includes the substitution of ½ MDLs for non-detects in calculating precision statistics where a concentration is reported for the primary sample but not the duplicate (or vice versa). In some cases, this substitution affected the calculated RPDs by causing those values to increase. The ½ MDL substitutions are denoted by an asterisk (*) in Table 7.

Table 7. Sampling and Analytical Precision by Sample

Pollutant	Primary Concentration (ppbv)	Duplicate Concentration (ppbv)	% RPD	Primary Concentration (ppbv)	Duplicate Concentration (ppbv)	% RPD
	10/2/2006			**11/7/2006**		
1,1,1-Trichloroethane	0.020	0.020	0.00	0.020	0.020	0.00
1,1,2-Trichloroethane	Not Detected			Not Detected		
1,2,4-Trimethylbenzene	0.020	0.030	**40.00**	0.020	0.020	0.00
1,3,5-Trimethylbenzene	0.010°	0.002*°	**133.33**	0.010°	0.010°	0.00
1,3-Butadiene	Not Detected			Not Detected		
Acetonitrile	0.270°	0.270°	0.00	0.090°	0.090°	0.00
Acetylene	0.160	0.150	6.45	0.560	0.570	1.77
Acrolein	1.870	1.640	13.11	0.660	0.540	20.00
Benzene	0.100	0.100	0.00	0.180	0.170	5.71
Bromomethane	0.010°	0.010°	0.00	0.010°	0.010°	0.00
Carbon Disulfide	0.030°	0.030°	0.00	Not Detected		
Carbon Tetrachloride	0.160	0.160	0.00	0.160	0.140	13.33
Chlorobenzene	Not Detected			Not Detected		
Chloroethane	0.040°	0.040°	0.00	0.020°	0.020°	0.00
Chloroform	0.010°	0.010°	0.00	0.020°	0.010°	**66.67**
Chloromethane	0.630	0.600	4.88	0.590	0.590	0.00
Dibromochloromethane	Not Detected			Not Detected		
Dichlorodifluoromethane	0.530	0.520	1.90	0.550	0.540	1.83
Dichloromethane	0.040°	0.040°	0.00	0.060°	0.070°	15.38
Dichlorotetrafluoroethane	0.020	0.010°	**66.67**	0.020	0.020	0.00
Ethylbenzene	0.010°	0.010°	0.00	0.020°	0.020°	0.00
m,p-Xylene	0.020°	0.030°	**40.00**	0.050	0.040°	22.22
Methyl Ethyl Ketone	3.640	3.780	3.77	1.160	1.180	1.71
Methyl Isobutyl Ketone	0.390	0.440	12.05	0.190	0.150	23.53
Methyl Methacrylate	Not Detected			Not Detected		
n-Octane	0.030°	0.020°	**40.00**	0.020°	0.020°	0.00
o-Dichlorobenzene	Not Detected			Not Detected		
o-Xylene	0.020°	0.010°	**66.67**	0.030	0.020°	**40.00**
p-Dichlorobenzene	Not Detected			Not Detected		
Propylene	1.250	1.290	3.15	0.350	0.400	13.33
Styrene	0.010°	0.010°	0.00	0.020°	0.020°	0.00
tert-Amyl Methyl Ether	Not Detected			Not Detected		
Tetrachloroethylene	Not Detected			Not Detected		
Toluene	0.060	0.050	18.18	0.140	0.150	6.90
Trichloroethylene	0.020°	0.005*°	**120.00**	Not Detected		
Trichlorofluoromethane	0.270	0.260	3.77	0.270	0.260	3.77
Trichlorotrifluoroethane	0.100	0.100	0.00	0.100	0.090	10.53
Vinyl chloride	Not Detected			Not Detected		
Average RPD	20.50			9.49		

° Concentration is less than 5 times the Method Detection Limit.
* Denotes ½ MDL substitution.

Table 7. Sampling and Analytical Precision by Sample (Continued)

Pollutant	Primary Concentration (ppbv)	Duplicate Concentration (ppbv)	% RPD	Primary Concentration (ppbv)	Duplicate Concentration (ppbv)	% RPD
	1/12/2007			**4/30/2007**		
1,1,1-Trichloroethane	0.010°	0.020°	**66.67**	0.017°	0.018°	5.71
1,1,2-Trichloroethane	Not Detected			Not Detected		
1,2,4-Trimethylbenzene	0.030°	0.020°	**40.00**	0.024°	0.024°	0.00
1,3,5-Trimethylbenzene	0.010°	0.010°	0.00	0.012°	0.012°	0.00
1,3-Butadiene	0.010°	0.020°	**66.67**	0.013°	0.012°	8.00
Acetonitrile	Not Detected			0.143	0.139	2.84
Acetylene	1.020	1.120	9.35	0.380	0.400	5.13
Acrolein	0.420	0.510	19.35	0.467	0.358	**26.42**
Benzene	0.320	0.210	**41.51**	0.167	0.186	10.76
Bromomethane	0.010°	0.010°	0.00	0.009°	0.013°	**36.36**
Carbon Disulfide	0.040°	0.040°	0.00	0.015°	0.013°	14.29
Carbon Tetrachloride	0.080	0.090	11.76	0.103	0.117	12.73
Chlorobenzene	Not Detected			Not Detected		
Chloroethane	0.010°	0.010°	0.00	0.025°	0.028°	11.32
Chloroform	0.020°	0.020°	0.00	0.016°	0.018°	11.76
Chloromethane	0.520	0.560	7.41	0.591	0.636	7.33
Dibromochloromethane	Not Detected			Not Detected		
Dichlorodifluoromethane	0.470	0.510	8.16	0.522	0.562	7.38
Dichloromethane	0.100	0.110	9.52	0.050	0.063	23.01
Dichlorotetrafluoroethane	0.010°	0.020°	**66.67**	0.018°	0.017°	5.71
Ethylbenzene	0.030°	0.030°	0.00	0.029°	0.039°	**29.41**
m,p-Xylene	0.060°	0.060°	0.00	0.058°	0.082°	**34.29**
Methyl Ethyl Ketone	0.610	1.060	**53.89**	1.160	0.814	**35.06**
Methyl Isobutyl Ketone	0.080°	0.130	**47.62**	0.083	0.072	14.19
Methyl Methacrylate	Not Detected			Not Detected		
n-Octane	0.030°	0.030°	0.00	0.024°	0.023°	4.26
o-Dichlorobenzene	Not Detected			Not Detected		
o-Xylene	0.030°	0.030°	0.00	0.028°	0.035°	22.22
p-Dichlorobenzene	Not Detected			0.004	0.003	**28.57**
Propylene	0.410	0.510	21.74	0.313	0.264	16.98
Styrene	0.020°	0.020°	0.00	0.019°	0.018°	5.41
tert-Amyl Methyl Ether	Not Detected			Not Detected		
Tetrachloroethylene	0.010°	0.010°	0.00	0.008°	0.011°	**31.58**
Toluene	0.150	0.150	0.00	0.170	0.253	**39.24**
Trichloroethylene	0.010°	0.010°	0.00	0.011°	0.012°	8.70
Trichlorofluoromethane	0.230	0.250	8.33	0.241	0.270	11.35
Trichlorotrifluoroethane	0.080°	0.090°	11.76	0.084°	0.092°	9.09
Vinyl chloride	0.012*°	0.010°	19.94	Not Detected		
Average RPD	17.01			15.46		

° Concentration is less than 5 times the Method Detection Limit.

* Denotes ½ MDL substitution.

Table 7. Sampling and Analytical Precision by Sample (Continued)

Pollutant	Primary Concentration (ppbv)	Duplicate Concentration (ppbv)	% RPD	Primary Concentration (ppbv)	Duplicate Concentration (ppbv)	% RPD
	7/11/2007			**8/4/2007**		
1,1,1-Trichloroethane	0.020°	0.021°	4.88	0.016°	0.016°	0.00
1,1,2-Trichloroethane	Not Detected			Not Detected		
1,2,4-Trimethylbenzene	0.031°	0.038°	20.29	0.038°	0.034°	11.11
1,3,5-Trimethylbenzene	0.013°	0.014°	7.41	0.018°	0.016°	11.76
1,3-Butadiene	0.013°	0.013°	0.00	0.007°	0.009°	**25.00**
Acetonitrile	0.158	0.159	0.63	0.213	0.231	8.11
Acetylene	0.293	0.273	7.07	0.249	0.266	6.60
Acrolein	0.618	0.694	11.59	0.822	0.801	2.59
Benzene	0.127	0.146	13.92	0.176	0.158	10.78
Bromomethane	0.020°	0.020°	0.00	0.018°	0.016°	11.76
Carbon Disulfide	0.036°	0.039°	8.00	0.026°	0.024°	8.00
Carbon Tetrachloride	0.130	0.133	2.28	0.105	0.112	6.45
Chlorobenzene	Not Detected			Not Detected		
Chloroethane	0.031°	0.034°	9.23	0.027°	0.030°	10.53
Chloroform	Not Detected			Not Detected		
Chloromethane	0.656	0.647	1.38	0.598	0.627	4.73
Dibromochloromethane	Not Detected			Not Detected		
Dichlorodifluoromethane	0.576	0.570	1.05	0.523	0.548	4.67
Dichloromethane	0.075°	0.070°	6.90	0.058°	0.067°	14.40
Dichlorotetrafluoroethane	0.022°	0.023°	4.44	0.015°	0.017°	12.50
Ethylbenzene	0.033°	0.035°	5.88	0.028°	0.028°	0.00
m,p-Xylene	0.082°	0.094°	13.64	0.043°	0.042°	2.35
Methyl Ethyl Ketone	1.190	2.050	**53.09**	2.000	1.410	**34.60**
Methyl Isobutyl Ketone	0.081	0.117	**36.36**	0.110	0.093	16.75
Methyl Methacrylate	Not Detected			Not Detected		
n-Octane	0.013°	0.014°	7.41	0.013°	0.011°	16.67
o-Dichlorobenzene	Not Detected			Not Detected		
o-Xylene	0.036°	0.044°	20.00	0.021°	0.022°	4.65
p-Dichlorobenzene	0.007	0.008	13.33	0.007*	0.003	**85.44**
Propylene	0.189°	0.302	**46.03**	0.298	0.208	**35.57**
Styrene	0.020°	0.022°	9.52	0.020°	0.012°	**50.00**
tert-Amyl Methyl Ether	0.004	0.005*	**27.97**	Not Detected		
Tetrachloroethylene	0.011°	0.011°	0.00	0.006°	0.008°	**28.57**
Toluene	0.234	0.250	6.61	0.166	0.172	3.55
Trichloroethylene	0.018°	0.011°	**48.28**	Not Detected		
Trichlorofluoromethane	0.281	0.268	4.74	0.252	0.269	6.53
Trichlorotrifluoroethane	0.094°	0.098°	4.17	0.082°	0.088°	7.06
Vinyl chloride	0.008°	0.008°	0.00	Not Detected		
Average RPD	12.38			15.20		

° Concentration is less than 5 times the Method Detection Limit.

* Denotes ½ MDL substitution.

Table 7. Sampling and Analytical Precision by Sample (Continued)

Pollutant	**Primary Concentration (ppbv)**	**Duplicate Concentration (ppbv)**	**% RPD**	**Primary Concentration (ppbv)**	**Duplicate Concentration (ppbv)**	**% RPD**
	1/19/2008			**3/1/2008**		
1,1,1-Trichloroethane	0.018°	0.021°	15.38	0.018°	0.019°	5.41
1,1,2-Trichloroethane	Not Detected			0.002°	0.004*°	0.002
1,2,4-Trimethylbenzene	0.005°	0.003°	**50.00**	0.011°	0.010°	9.52
1,3,5-Trimethylbenzene	Not Detected			0.003°	0.003°	0.00
1,3-Butadiene	0.008°	0.008°	0.00	0.020°	0.021°	4.88
Acetonitrile	0.074°	0.056°	**27.69**	0.103°	0.129	22.41
Acetylene	0.490	0.478	2.48	0.512	0.496	3.17
Acrolein	0.626	0.306	**68.67**	0.413	0.431	4.27
Benzene	0.182	0.170	6.82	0.161	0.175	8.33
Bromomethane	0.010°	0.015°	**40.00**	0.010°	0.009°	10.53
Carbon Disulfide	0.017°	0.018°	5.71	0.011°	0.014°	24.00
Carbon Tetrachloride	0.138	0.162	16.00	0.100	0.114	13.08
Chlorobenzene	Not Detected			Not Detected		
Chloroethane	0.009°	0.013°	**36.36**	0.024	0.023	4.26
Chloroform	0.016°	0.021°	**27.03**	0.018°	0.018°	0.00
Chloromethane	0.605	0.641	5.78	0.441	0.475	7.42
Dibromochloromethane	Not Detected			Not Detected		
Dichlorodifluoromethane	0.544	0.596	9.12	0.472	0.510	7.74
Dichloromethane	0.088°	0.101	13.76	0.063°	0.054°	15.38
Dichlorotetrafluoroethane	0.018	0.022	20.00	0.016	0.015°	6.45
Ethylbenzene	0.010°	0.011°	9.52	0.015°	0.015°	0.00
m,p-Xylene	0.019°	0.007°	**92.31**	0.035°	0.032°	8.96
Methyl Ethyl Ketone	0.866	0.314	**93.56**	0.449	0.506	11.94
Methyl Isobutyl Ketone	0.043°	0.008*°	**137.77**	0.045°	0.041°	9.30
Methyl Methacrylate	Not Detected			Not Detected		
n-Octane	Not Detected			0.012°	0.012°	0.00
o-Dichlorobenzene	Not Detected			Not Detected		
o-Xylene	0.010°	0.007°	**35.29**	0.016°	0.015°	6.45
p-Dichlorobenzene	Not Detected			0.005°	0.004°	22.22
Propylene	0.209	0.191	0.193	0.191	0.193	1.04
Styrene	0.010*	0.002°	**134.99**	Not Detected		
tert-Amyl Methyl Ether	Not Detected			Not Detected		
Tetrachloroethylene	Not Detected			0.008°	0.008°	0.00
Toluene	0.060°	0.103°	0.102	0.103°	0.102°	0.98
Trichloroethylene	Not Detected			Not Detected		
Trichlorofluoromethane	0.283	0.316	11.02	0.247	0.260	5.13
Trichlorotrifluoroethane	0.102	0.117	13.70	0.101	0.111	9.43
Vinyl chloride	Not Detected			Not Detected		
Average RPD	**36.21**			9.48		

° Concentration is less than 5 times the Method Detection Limit.

* Denotes ½ MDL substitution.

Table 7. Sampling and Analytical Precision by Sample (Continued)

Pollutant	Primary Concentration (ppbv)	Duplicate Concentration (ppbv)	% RPD
	3/13/2008		
1,1,1-Trichloroethane	0.016°	0.015°	6.45
1,1,2-Trichloroethane	0.004°	0.004*°	5.06
1,2,4-Trimethylbenzene	0.069°	0.023°	**100.00**
1,3,5-Trimethylbenzene	0.015°	0.007°	**72.73**
1,3-Butadiene	0.096	0.028	**109.68**
Acetonitrile	0.133	0.130	2.28
Acetylene	0.983	0.536	**58.85**
Acrolein	0.547	0.502	8.58
Benzene	1.190	0.387	**101.84**
Bromomethane	0.012°	0.011°	8.70
Carbon Disulfide	0.014°	0.016°	13.33
Carbon Tetrachloride	0.108	0.108	0.00
Chlorobenzene	Not Detected		
Chloroethane	0.026	0.028	7.41
Chloroform	0.016°	0.014°	13.33
Chloromethane	0.598	0.590	1.35
Dibromochloromethane	Not Detected		
Dichlorodifluoromethane	0.466	0.474	1.70
Dichloromethane	0.063°	0.066°	4.65
Dichlorotetrafluoroethane	0.016	0.013°	20.69
Ethylbenzene	0.318	0.078	**121.21**
m,p-Xylene	0.490	0.117	**122.90**
Methyl Ethyl Ketone	0.772	1.300	**50.97**
Methyl Isobutyl Ketone	0.042°	0.066°	**44.44**
Methyl Methacrylate	Not Detected		
n-Octane	0.033	0.016°	**69.39**
o-Dichlorobenzene	Not Detected		
o-Xylene	0.192	0.053	**113.47**
p-Dichlorobenzene	0.004°	0.002°	**66.67**
Propylene	1.120	0.562	**66.35**
Styrene	0.009°	0.009°	0.00
tert-Amyl Methyl Ether	Not Detected		
Tetrachloroethylene	0.008°	0.006°	**28.57**
Toluene	1.400	0.340	**121.84**
Trichloroethylene	0.007°	0.002*°	**119.95**
Trichlorofluoromethane	0.228	0.228	0.00
Trichlorotrifluoroethane	0.080	0.079	1.26
Vinyl chloride	0.005°	0.004°	22.22
Average RPD	**45.03**		

° Concentration is less than 5 times the Method Detection Limit.

* Denotes ½ MDL substitution.

RPDs exceeding the desired 25 percent control limit are bolded in Table 7. In addition, the average RPD per sample is presented at the bottom of Table 7. Of the nine valid samples, two (1/19/2008 and 3/13/2008) did not meet the 25 percent control limit. Duplicate analysis could not be performed on 4/18/2007, 6/29/2007, 12/26/2007, and 2/24/2008 because one or both of the samples were invalid.

The majority of the RPDs outside of the accepted critera are also less than five times the method detection limit. The confidence level of the results decreases as the concentration approaches the detection limit. If duplicate pairs are detected at a level less than 5 times the detection limit, the higher RPDs do not signify as much as they would if the detection limits were above 5 times the MDL. Concentrations that are less than five times the MDL are identified in Table 7.

7.0 BTEX Concentration Profiles

Mobile source emissions from motor vehicles contribute significantly to air pollution in urban environments. “Mobile sources” refer to emitters of air pollutants that move, or can be moved, from place to place and include both on-road and non-road emissions (EPA, 2008). Pollutants found in motor vehicle exhaust generally result from incomplete combustion of vehicle fuels. Although modern vehicles and, more recently, vehicle fuels have been engineered to minimize air emissions, all motor vehicles with internal combustion engines emit a wide range of chemical pollutants.

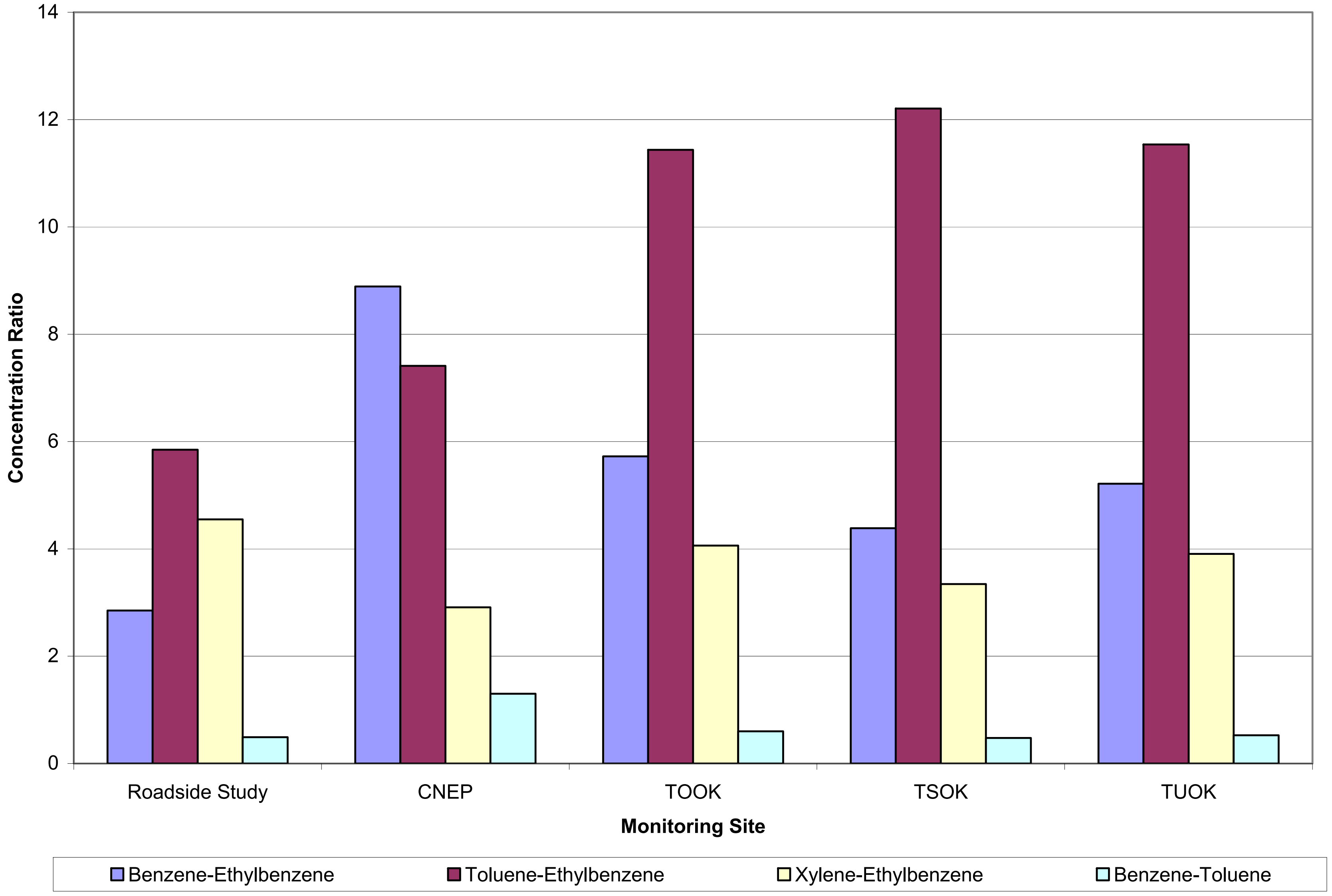
The *magnitude* of emissions from motor vehicles generally depends on the volume of traffic in urban areas, but the *composition* of these emissions depends more on vehicle design. Because the distribution of vehicle designs (i.e., the relative number of motor vehicles of different styles) is probably quite similar from one urban area to the next, the composition of air pollution resulting from motor vehicle emissions is not expected to exhibit significant spatial variations. In support of this hypothesis, previous air monitoring studies have observed relatively constant composition of ambient air samples collected along heavily traveled urban roadways (Conner et al., 1995). Roadside studies have found particularly consistent proportions of four hydrocarbons (benzene, toluene, ethylbenzene, and the xylene isomers - the “BTEX” compounds) both in motor vehicle exhaust and in ambient air near roadways.

To examine the impact of motor vehicle emissions on air quality near the Oklahoma monitoring sites, Figure 16 compares average concentration ratios for the BTEX compounds measured during the 18-month period to the ratios reported in the roadside study. This comparison provides a qualitative depiction of how greatly motor vehicle emissions affect air quality near the monitoring sites: the more similar the concentration ratios at a particular monitoring site are to those of the roadside study, the more likely that motor vehicle emissions impact ambient levels of hydrocarbons at that location.

Figure 16 shows that the concentration ratios for BTEX compounds measured at CNEP do not resemble those from the roadside study. Unlike the roadside study, the benzene-ethylbenzene ratio is the highest of the four ratios and more than twice the value of the roadside study’s benzene-ethylbenzene ratio. The toluene-ethylbenzene ratio for CNEP is the next highest ratio, followed by xylenes-ethylbenzene and benzene-toluene. The differences indicate that other emission sources are also influencing the concentrations of the BTEX compounds near this site.

The ratios for the Tulsa monitoring sites bear some resemblance to the ratios reported in the roadside study. For these three monitoring sites, the toluene-ethylbenzene ratio is the largest of the ratios, similar to the roadside study. But each site’s toluene-ethylbenzene ratio is nearly twice the value of the roadside study’s toluene-ethylbenzene ratio. The benzene-toluene ratio is the smallest of the four ratios for the Tulsa sites, as well as CNEP. These observations suggest that emissions from motor vehicles have an impact on the levels of hydrocarbons in the air near these sites, although they are not the only contributing factor.

Figure 16. BTEX Concentration Profiles



8.0 Pollutants of Interest

A practical approach to making an assessment on a large number of measurements is to screen the data by focusing on a subset of pollutants based on the end-use of the dataset. For example, if evaluating the influence of VOCs to the production of ozone, then focusing on pollutants with the highest mass concentrations and/or greatest reactivity would be an acceptable method for ozone evaluation screening. In this report, CNEP is interested in the ambient air quality as a result of industrial sources affecting the tribal community. Thus, risk-based calculations were used to screen for “pollutants of interest”. EPA defines risk as “the probability that damage to life, health, and/or the environment will occur as a result of a given hazard (such as exposure to a toxic chemical)” (EPA, 2006c). EPA has published a guidance document outlining a risk screening approach that utilizes a risk-based methodology for performing an initial screen of ambient air toxics monitoring data sets (EPA, 2006d). This screening process provides a risk-based methodology for analysts and interested parties to identify which pollutants may pose a risk in their area. Not all VOC have screening values; those that do are also typically referred to as Hazardous Air Pollutants (HAPs), as they are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects.

Preprocessed daily measurements of the target pollutants were compared to these risk screening values in order to identify pollutants of interest across the program. The following risk screening process was completed to identify these pollutants:

1. Each 24-hour speciated measurement was compared against the screening value. Concentrations that were greater than the screening value are described as “failing the screen.”

2. The number of failed screens was summed for each applicable pollutant.

3. The percent contribution of the number of failed screens to the total number of failed screens was calculated for each applicable pollutant.

4. The pollutants contributing to the top 95 percent of the total failed screens were identified as pollutants of interest.

Table 8 presents the pollutants that failed at least one screen at the monitoring sites and highlights each site's pollutants of interest based on this risk screening approach (shaded). CNEP's pollutants of interest are acrolein, benzene, carbon tetrachloride, and 1,3-butadiene. These four pollutants were also pollutants of interest for the three Tulsa sites. In addition, tetrachloroethylene and *p*-dichlorobenzene were also pollutants of interest for all three Tulsa sites. Acetonitrile was also a pollutant of interest for TSOK and TUOK. Although not a pollutant of interest for TOOK, acetonitrile did fail screens for this site. Three pollutants, acrolein, benzene, and carbon tetrachloride, failed 100 percent of the screens for each of the monitoring sites.

Table 8. Comparison of Measured Concentrations and EPA Screening Values for the Oklahoma Monitoring Sites

Pollutant	# of Failed Screens	# of Measured Detections	% of Screens Failed	% of Total Failures	Cumulative % Contribution
Cherokee Heights, Oklahoma (CNEP)					
Acrolein	84	84	100.00	29.68	29.68
Benzene	84	84	100.00	29.68	59.36
Carbon Tetrachloride	84	84	100.00	29.68	89.05
1,3-Butadiene	26	62	41.94	9.19	98.23
Acrylonitrile	2	2	100.00	0.71	98.94
1,2-Dichloroethane	2	2	100.00	0.71	99.65
Trichloroethylene	1	26	3.85	0.35	100.00
Total	283	344	82.27		
Tulsa, Oklahoma, Site #1 (TOOK)					
Acrolein	90	90	100.00	20.32	20.32
Carbon Tetrachloride	90	90	100.00	20.32	40.63
Benzene	90	90	100.00	20.32	60.95
1,3-Butadiene	85	89	95.51	19.19	80.14
p-Dichlorobenzene	42	89	47.19	9.48	89.62
Tetrachloroethylene	32	86	37.21	7.22	96.84
Acetonitrile	7	90	7.78	1.58	98.42
Xylenes	4	90	4.44	0.90	99.32
Acrylonitrile	2	2	100.00	0.45	99.77
Dichloromethane	1	89	1.12	0.23	100.00
Total	443	805	55.03		

Table 8. Comparison of Measured Concentrations and EPA Screening Values for the Oklahoma Monitoring Sites (Continued)

Pollutant	# of Failed Screens	# of Measured Detections	% of Screens Failed	% of Total Failures	Cumulative % Contribution
Tulsa, Oklahoma, Site #2 (TSOK)					
Benzene	86	86	100.00	19.42	19.42
Acrolein	86	86	100.00	19.42	38.48
Carbon Tetrachloride	85	85	100.00	19.02	57.49
1,3-Butadiene	78	85	91.76	17.45	74.94
p-Dichlorobenzene	41	84	48.81	9.17	84.12
Acetonitrile	29	84	34.52	6.49	90.60
Tetrachloroethylene	29	77	37.66	6.49	97.09
Acrylonitrile	9	10	90.00	2.01	99.11
1,2-Dichloroethane	2	2	100.00	0.45	99.55
Trichloroethylene	1	51	1.96	0.22	99.78
1,1,2-Trichloroethane	1	3	33.33	0.22	100.00
Total	418	569	73.46		
Tulsa, Oklahoma, Site #3 (TUOK)					
Acrolein	88	88	100.00	18.67	18.67
Benzene	88	88	100.00	18.67	37.37
Carbon Tetrachloride	88	88	100.00	18.67	56.05
1,3-Butadiene	83	87	95.40	17.62	73.67
Tetrachloroethylene	56	86	65.12	11.89	85.56
p-Dichlorobenzene	42	87	48.28	8.92	94.48
Acetonitrile	12	88	13.64	2.55	97.03
Acrylonitrile	7	7	100.00	1.49	98.51
Carbon Disulfide	5	64	7.81	1.06	99.58
Xylenes	1	88	1.14	0.21	99.79
Trichloroethylene	1	44	2.27	0.21	100.00
Total	459	727	63.14		

9.0 Pearson Correlations

Concentrations in ambient air can be significantly influenced by meteorological conditions. The following three subsections describe select meteorological parameters and how each may affect air quality. Pearson correlation coefficients were calculated between concentration data for the site-specific pollutants of interest and these meteorological parameters: average maximum daily temperature; average daily temperature; average daily dew point temperature; average daily wet bulb temperature; average daily relative humidity; average daily sea level pressure; and average scalar wind speed.

Pearson correlation coefficients are used to measure the degree of correlation between two variables. By definition, Pearson correlation coefficients always lie between -1 and +1. Three qualification statements apply:

- A correlation coefficient of -1 indicates a perfectly “negative” relationship, indicating that increases in the magnitude of one variable are associated with proportionate decreases in the magnitude of the other variable, and vice versa.
- A correlation coefficient of +1 indicates a perfectly “positive” relationship, indicating that the magnitudes of two variables both increase and both decrease proportionately.
- Data that are completely uncorrelated have Pearson correlation coefficients of 0.

Therefore, the sign (positive or negative) and magnitude of the Pearson correlation coefficient indicate the direction and strength, respectively, of data correlations. In this report, correlation coefficients greater than 0.50 or less than -0.50 are classified as strong, while correlation coefficients less than 0.50 and greater than -0.50 are classified as weak.

When calculating correlations, several measures were taken to identify spurious correlations and to avoid introducing bias to the correlations:

- Data correlations were calculated only for the site-specific pollutants of interest identified in Section 8.0.
- Correlations were calculated from the preprocessed daily measurements, in which each pollutant has just one numerical concentration for each successful sampling date. Non-detects were not included in this analysis.

The number of observations used in a calculation is an important factor to consider when analyzing the correlations. A correlation using few observations may skew the correlation, making the degree of correlation appear higher than it may actually be. In this report, five data points must be available to present a correlation. Table 9 presents the resulting correlations, which are discussed in the following sections.

Table 9. Pearson Correlations Between Selected Meteorological Parameters and Pollutants of Interest for the Oklahoma Monitoring Sites

Pollutant	# of Measured Detections	Maximum Temperature	Temperature	Dew Point Temperature	Wet Bulb Temperature	Relative Humidity	Sea Level Pressure	Scalar Wind Speed
Cherokee Heights, Oklahoma (CNEP)								
1,3-Butadiene	62	-0.23	-0.25	-0.23	-0.13	0.07	NA	-0.10
Acrolein	84	0.13	0.16	0.13	0.04	-0.12	NA	0.03
Benzene	84	-0.20	-0.25	-0.23	-0.09	0.10	NA	-0.08
Carbon Tetrachloride	84	0.10	0.10	0.09	0.18	0.12	NA	0.17
Tulsa, Oklahoma, Site #1 (TOOK)								
1,3-Butadiene	89	-0.11	-0.22	-0.20	-0.22	0.05	0.18	-0.51
Acrolein	90	0.39	0.40	0.39	0.40	0.03	-0.17	-0.08
Benzene	90	0.28	0.15	0.13	0.13	-0.01	0.01	-0.51
Carbon Tetrachloride	90	0.32	0.36	0.34	0.35	0.02	-0.10	0.13
p-Dichlorobenzene	89	0.24	0.23	0.19	0.21	-0.09	-0.08	-0.01
Tetrachloroethylene	86	0.06	0.02	0.02	0.02	0.04	-0.06	-0.05
Tulsa, Oklahoma, Site #2 (TSOK)								
1,3-Butadiene	85	0.04	-0.01	-0.03	-0.03	-0.07	0.16	-0.54
Acetonitrile	84	-0.22	-0.25	-0.30	-0.28	-0.19	0.16	0.17
Acrolein	86	0.21	0.22	0.20	0.21	-0.04	0.03	-0.06
Benzene	86	0.22	0.18	0.15	0.16	-0.06	0.03	-0.53
Carbon Tetrachloride	85	0.36	0.38	0.38	0.38	0.02	-0.28	0.01
p-Dichlorobenzene	84	0.36	0.36	0.35	0.36	0.00	-0.05	-0.14
Tetrachloroethylene	77	0.21	0.18	0.19	0.19	0.07	-0.09	-0.31
Tulsa, Oklahoma, Site #3 (TUOK)								
1,3-Butadiene	87	-0.15	-0.22	-0.18	-0.21	0.11	0.26	-0.49
Acetonitrile	88	-0.21	-0.19	-0.17	-0.18	0.01	0.16	0.06
Acrolein	88	0.43	0.45	0.43	0.44	0.06	-0.20	-0.12
Benzene	88	0.12	0.06	0.09	0.07	0.17	0.05	-0.54
Carbon Tetrachloride	88	0.36	0.37	0.37	0.37	0.12	-0.23	-0.03
p-Dichlorobenzene	87	0.00	0.04	0.09	0.06	0.18	-0.07	-0.07
Tetrachloroethylene	86	0.39	0.35	0.34	0.34	0.08	-0.07	-0.30

NA= Sea level pressure was not recorded at the Claremore Regional Airport

9.1 Maximum and Average Temperature

Temperature is often a factor associated with high ambient air concentrations for some pollutants, such as ozone. Higher temperatures help speed up the kinetic process as pollutants react with each other. Pearson correlations were calculated between the site-specific pollutants of interest and average maximum daily temperature and average daily temperature. Table 9 shows that the site-specific pollutants of interest had fairly weak correlations with maximum temperature and average temperature. The strongest correlation was calculated between acrolein and average temperature for TUOK (0.45). However, with a few exceptions the correlations were mostly positive.

9.2 Moisture

Correlations were calculated for three moisture parameters and the site-specific pollutants of interest. The *dew point temperature* is the temperature to which moist air must be cooled to reach saturation with respect to water. The *wet bulb temperature* is the temperature to which moist air must be cooled by evaporating water into it at constant pressure until saturation is reached. The *relative humidity* is the ratio of the mixing ratio to its saturation value at the same temperature and pressure (Rogers and Yau, 1989). All three of these parameters provide an indication of how much moisture is presently in the air. Higher dew point and wet bulb temperatures indicate increasing amounts of moisture in the air, while relative humidity is expressed as a percentage with 100 percent indicating saturation. It should be noted that a high dew point and wet bulb temperature do not necessarily equate to a relative humidity near 100 percent, nor does a relative humidity near 100 percent equate to a relatively high dew point or wet bulb temperature.

The three moisture parameters had weak correlations with the site-specific pollutants of interest, as shown in Table 9. The strongest correlation was calculated between acrolein and average wet bulb temperature for TUOK (0.44).

9.3 Wind and Pressure

Wind is an important component affecting air quality. Surface wind observations include two primary components: wind speed and wind direction. *Wind speed*, by itself, is a scalar value and is usually measured in miles per hour or knots (1 knot = 0.5 meters per second = 1.15 miles per hour). *Wind direction* describes where the wind is coming from, and is measured in degrees where 0/360° is from the north, 90° is from the east, 180° is from the south, and 270° is from the west. Wind speed and direction together represent a vector quantity, but in some cases wind speed can be quantified separately (the scalar value).

The scalar wind speed had stronger correlations with some of the pollutants of interest than the other meteorological parameters, as shown in Table 9. Benzene and 1,3-butadiene had strong negative correlations with wind speed for all three Tulsa sites. This indicates that as wind speeds decrease, concentrations of these pollutants increase. The correlations for CNEP did not reflect this tendency. However, most of the correlations between wind speed and the pollutants of interest were negative, somewhat supporting this inverse correlation.

Wind is created through changes in pressure. The magnitude of the pressure difference (or pressure gradient) over an area is directly proportional to the magnitude of the wind speed. The direction of the wind flow is governed by the direction of the pressure gradient. Sea level pressure is the local station pressure corrected for elevation, in effect bringing all geographic locations down to sea-level, thus making different topographical areas comparable. Overall, sea level pressure correlated weakly with ambient concentrations at the Tulsa sites. Sea level pressure was not recorded at the Claremore Regional Airport.

10.0 Concentration Averages and Risk Assessments

This section presents various concentration averages used to characterize pollution levels at the monitoring sites. These averages are based on various time periods, such as seasons. The averages presented are provided for the pollutants of interest for each site. The various time-period averages were then compared to various health benchmarks and used as surrogates to approximate chronic risk.

10.1 Concentration Averages

Three types of concentration averages were calculated for the pollutants of interest: daily, seasonal, and period. The *daily* average of a particular pollutant is simply the average concentration of all measured detections. If there were at least seven measured detections within each season, then a *seasonal* average was calculated. The seasonal average includes ½ MDLs substituted for all non-detects. A seasonal average was not calculated for pollutants with less than seven measured detections in a respective season. The winter season included concentrations from January, February, and March; spring season included April, May, and June; summer included July, August, and September; autumn included October, November, and December. Because more than one year of sampling was conducted at the monitoring sites, the seasonal averages are calculated from data from multiple years within that season. Finally, the *period* average is the average concentration of all measured detections and ½ MDLs substituted for non-detects over the entire period. The resulting daily average concentrations may therefore be inherently higher than the period average concentrations where ½ MDLs replacing non-detects are incorporated into the average.

Daily, seasonal, and period averages are presented in Table 10. Also included is the 95 percent confidence interval for each average. Please note that the averages presented in Table 10 are in units of µg/m^3. The averages were calculated this way in order to compare to various health benchmarks described in subsequent sections.

Table 10. Daily, Seasonal, and Period Average Concentrations for the Pollutants of Interest for the Oklahoma Monitoring Sites

Pollutant	# of Measured Detections	# of Samples	Daily Average (µg/m^3)	Winter Average (µg/m^3)	Spring Average (µg/m^3)	Summer Average (µg/m^3)	Autumn Average (µg/m^3)	Period Average (µg/m^3)
Cherokee Heights, Oklahoma - CNEP								
1,3-Butadiene	62	84	0.03 ± <0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± <0.01	0.03 ± 0.01	0.03 ± <0.01
Acrolein	84	84	1.53 ± 0.18	1.27 ± 0.17	1.88 ± 0.38	1.52 ± 0.47	1.67 ± 0.38	1.53 ± 0.18
Benzene	84	84	0.53 ± 0.06	0.58 ± 0.15	0.45 ± 0.08	0.42 ± 0.05	0.58 ± 0.06	0.53 ± 0.06
Carbon Tetrachloride	84	84	0.68 ± 0.03	0.65 ± 0.06	0.66 ± 0.04	0.67 ± 0.08	0.73 ± 0.05	0.68 ± 0.03

Table 10. Daily, Seasonal, and Period Average Concentrations for the Pollutants of Interest for the Oklahoma Monitoring Sites (Continued)

Pollutant	# of Measured Detections	# of Samples	Daily Average (µg/m^3)	Winter Average (µg/m^3)	Spring Average (µg/m^3)	Summer Average (µg/m^3)	Autumn Average (µg/m^3)	Period Average (µg/m^3)
Tulsa, Oklahoma Site #1 - TOOK								
1,3-Butadiene	89	90	0.09 ± 0.01	0.08 ± 0.02	0.07 ± 0.01	0.07 ± 0.01	0.10 ± 0.03	0.08 ± 0.01
Acrolein	90	90	0.80 ± 0.11	0.77 ± 0.27	0.88 ± 0.11	0.99 ± 0.26	0.66 ± 0.12	0.80 ± 0.11
Benzene	90	90	1.99 ± 0.26	1.55 ± 0.35	1.88 ± 0.42	2.23 ± 0.35	2.38 ± 0.62	1.99 ± 0.26
Carbon Tetrachloride	90	90	0.56 ± 0.03	0.51 ± 0.05	0.63 ± 0.05	0.61 ± 0.04	0.55 ± 0.05	0.56 ± 0.03
p-Dichlorobenzene	89	90	0.12 ± 0.02	0.10 ± 0.04	0.19 ± 0.04	0.11 ± 0.02	0.09 ± 0.02	0.12 ± 0.02
Tetrachloroethylene	86	90	0.22 ± 0.05	0.22 ± 0.11	0.19 ± 0.05	0.17 ± 0.05	0.25 ± 0.09	0.21 ± 0.05
Tulsa, Oklahoma Site #2 - TSOK								
1,3-Butadiene	85	86	0.07 ± 0.01	0.06 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	0.08 ± 0.02	0.07 ± 0.01
Acetonitrile	84	86	16.93 ± 5.39	26.83 ± 11.14	1.42 ± 0.34	2.06 ± 0.19	22.56 ± 9.27	16.54 ± 5.29
Acrolein	86	86	0.87 ± 0.17	0.79 ± 0.26	0.86 ± 0.13	0.96 ± 0.36	0.91 ± 0.42	0.87 ± 0.17
Benzene	86	86	0.97 ± 0.09	0.81 ± 0.15	1.10 ± 0.19	1.10 ± 0.22	0.99 ± 0.15	0.97 ± 0.09
Carbon Tetrachloride	85	86	0.58 ± 0.03	0.51 ± 0.06	0.63 ± 0.05	0.63 ± 0.06	0.59 ± 0.07	0.58 ± 0.03
p-Dichlorobenzene	84	86	0.10 ± 0.01	0.06 ± 0.01	0.19 ± 0.04	0.11 ± 0.02	0.08 ± 0.02	0.10 ± 0.01
Tetrachloroethylene	77	86	0.17 ± 0.04	0.12 ± 0.05	0.24 ± 0.13	0.16 ± 0.04	0.15 ± 0.03	0.16 ± 0.03
Tulsa, Oklahoma Site #3 - TUOK								
1,3-Butadiene	87	88	0.10 ± 0.01	0.09 ± 0.02	0.10 ± 0.03	0.08 ± 0.02	0.11 ± 0.03	0.09 ± 0.01
Acetonitrile	88	88	3.76 ± 1.92	5.71 ± 5.41	3.00 ± 1.14	1.86 ± 1.19	3.15 ± 1.07	3.76 ± 1.92
Acrolein	88	88	0.93 ± 0.14	0.75 ± 0.15	0.89 ± 0.15	1.63 ± 0.58	0.72 ± 0.12	0.93 ± 0.14
Benzene	88	88	1.22 ± 0.11	1.06 ± 0.20	1.45 ± 0.27	1.33 ± 0.21	1.19 ± 0.20	1.22 ± 0.11
Carbon Tetrachloride	88	88	0.57 ± 0.03	0.52 ± 0.06	0.65 ± 0.03	0.60 ± 0.06	0.56 ± 0.06	0.57 ± 0.03
p-Dichlorobenzene	87	88	0.12 ± 0.02	0.10 ± 0.03	0.17 ± 0.03	0.12 ± 0.02	0.10 ± 0.04	0.12 ± 0.02
Tetrachloroethylene	86	88	0.34 ± 0.07	0.21 ± 0.07	0.38 ± 0.10	0.60 ± 0.28	0.29 ± 0.09	0.34 ± 0.07

Concentrations of 1,3-butadiene did not vary much from season to season at the monitoring sites. CNEP had the lowest daily average 1,3-butadiene concentration of all the sites, although the 1,3-butadiene concentrations did not vary significantly among the Tulsa sites.

Among the Oklahoma sites, CNEP had the highest daily average concentration of acrolein (1.53 ± 0.18 $\mu g/m^3$). With the exception of summer, CNEP's seasonal acrolein averages were also higher than the other sites. TUOK's average summer concentration of acrolein (1.63 ± 0.58 $\mu g/m^3$) was higher than CNEP's (1.52 ± 0.47 $\mu g/m^3$), although not significantly so. However, TUOK's average summer acrolein concentration was significantly higher compared to TUOK's other seasonal acrolein averages.

CNEP had the lowest daily average concentration of benzene among the four monitoring sites. Among the Tulsa sites, TOOK had the highest daily average concentration of benzene. Concentrations of benzene are not significantly different from season to season at the monitoring sites, when the confidence interval is considered.

Concentrations of carbon tetrachloride did not vary much from season to season or across monitoring sites, although the CNEP averages were just slightly higher than the averages for the Tulsa sites. The carbon tetrachloride concentration averages support the accepted belief that this compound is a background pollutant, and not the result of direct emission sources.

Concentrations of *p*-dichlorobenzene did not vary much from season to season or across the Tulsa monitoring sites, although the spring averages tended to be somewhat higher than the other seasons. The daily and period average concentrations of tetrachloroethylene were slightly higher at TUOK than the other two Tulsa sites. These compounds were not pollutants of interest for CNEP.

TSOK's average acetonitrile concentrations vary significantly across the seasons, with the highest concentrations measured in winter and fall. The same is not true for TUOK. Although the winter average appears higher than the other seasonal averages, the large confidence interval indicates that this seasonal average is influenced by outliers. This compound was not a pollutant of interest for CNEP or TOOK.

10.2 Health Benchmark Evaluations

The following evaluations were conducted to compare the ambient monitoring time-period averages to established health benchmarks for each monitoring site.

10.2.1 Health Benchmark Evaluation Using MRLs

In addition to the risk screening approach described in Section 8.0, time-period averages were used as surrogates to compare acute, intermediate, and chronic minimal risk level (MRL) health benchmarks, as published by the Agency for Toxic Substances and Disease Registry (ATSDR) (ATSDR, 2007a). An MRL is a concentration of a hazardous substance that is "without appreciable risk of adverse noncancer health effects over a specified duration of exposure" (ATSDR, 2007b). MRLs are also intended to be used as screening tools, similar to the risk screening approach from Section 8.0.

ATSDR defines MRLs for three durations of exposure: acute, intermediate, and chronic exposure. Acute risk results from exposures of 1 to 14 days; intermediate risk results from exposures of 15 to 364 days; and chronic risk results from exposures of one year or greater. For this health benchmark evaluation, the preprocessed daily measurements were compared to the acute MRLs; seasonal averages were compared to the intermediate-term MRLs; and period averages were compared to the chronic MRLs. The results of this comparison are presented in Table 11. Where a seasonal or period average exceeds the applicable MRL, the concentration is bolded.

No acute MRLs were exceeded by any VOC measurement taken at the Oklahoma monitoring sites. The same is true for the chronic MRLs. Only the seasonal averages of acrolein exceeded an intermediate MRL benchmark, as shown in Table 11. The intermediate MRL benchmark is considerably lower than the acute MRL benchmark (0.09 $\mu g/m^3$ vs. 7 $\mu g/m^3$). ATSDR recently published an updated acute MRL for acrolein, increasing its value from 0.11

Table 11. MRL Comparison Summary for the Oklahoma Monitoring Sites

Site	Method	Pollutant	ATSDR Acute MRL (µg/m^3)	# of Exceedances/ # of Measured Detections	ATSDR Intermediate MRL (µg/m^3)	Winter Average (µg/m^3)	Spring Average (µg/m^3)	Summer Average (µg/m^3)	Autumn Average (µg/m^3)	ATSDR Chronic MRL (µg/m^3)	Period Average (µg/m^3)
CNEP	TO-15	Acrolein	7.00	0/84	0.09	**1.27 ± 0.17**	**1.88 ± 0.38**	**1.52 ± 0.47**	**1.67 ± 0.38**	NA	1.53 ± 0.18
TOOK	TO-15	Acrolein	7.00	0/90	0.09	**0.77 ± 0.27**	**0.88 ± 0.11**	**0.99 ± 0.26**	**0.66 ± 0.12**	NA	0.80 ± 0.11
TSOK	TO-15	Acrolein	7.00	0/86	0.09	**0.79 ± 0.26**	**0.86 ± 0.13**	**0.96 ± 0.36**	**0.91 ± 0.42**	NA	0.87 ± 0.17
TUOK	TO-15	Acrolein	7.00	0/88	0.09	**0.75 ± 0.15**	**0.89 ± 0.15**	**1.63 ± 0.58**	**0.72 ± 0.12**	NA	0.93 ± 0.14

NA = Not available due to short sampling duration.

BOLD = exceedance of intermediate MRL

$\mu g/m^3$ to 7 $\mu g/m^3$ due to a higher lowest-observed-adverse-effect level (LOAEL) and different endpoints (Arbogast, 2008). As a result, few exceedances of the acute MRL were expected using the updated benchmark.

10.2.2 Cancer and Noncancer Surrogate Risk Approximations

In February 2006, the EPA released the results of its national-scale air toxics assessment, NATA, for base year 1999 (EPA, 2007c). NATA uses the NEI for HAP as its starting point, but also incorporates ambient monitoring data, geographic information, and chemical/physical transformation information to model ambient concentrations at the census tract level. Cancer and noncancer risk factors are then applied to the modeled concentrations to yield census tract-level cancer and noncancer risk values.

Cancer risk is defined as the likelihood of developing cancer as a result of exposure over a 70-year period, and is presented as the number of people at risk for cancer per million people (EPA, 2006c). The cancer risks presented in this report estimate the cancer risk due to exposure at the period average-level over a 70-year period, not the risk resulting from exposure over the time period covered in this report. A cancer risk greater than 1.0 in-a-million is considered significant. Noncancer risk is presented as the Noncancer Hazard Quotient (HQ). Noncancer health effects include conditions such as asthma. An HQ less than 1.0 indicates no chance of developing noncancer effects through lifetime exposure, while an HQ greater than one indicates that developing a noncancerous health effect is possible (EPA, 2006c). The NATA is a useful resource that helps federal and state/local/tribal agencies identify potential areas of air quality concern.

The NATA risk factors applied to calculate cancer and noncancer risks are typically cancer unit risk estimates (UREs) and noncancer reference concentrations (RfCs), which are developed by EPA. However, UREs and RfCs are not available for all pollutants. In the absence of EPA values, risk factors developed by agencies with credible methods and that are similar in scope and definition were used (EPA, 2005).

National pollutant drivers are those that affect more than 25 million people, whereas regional driver pollutants affect more than 10 million people, as defined by NATA. Several of the site-specific pollutants of interest are HAP that were identified as NATA risk driver pollutants (EPA, 2006e):

- acrolein (national noncancer);
- benzene (national cancer);
- 1,3-butadiene (regional cancer and noncancer);
- carbon tetrachloride (regional cancer);
- tetrachloroethylene (regional cancer).

Chronic cancer and noncancer risk estimates were retrieved from the 1999 NATA for each site's respective census tract (e.g., the CNEP monitoring site is in census tract 40097040400). Using the cancer URE and noncancer RfC factors, modeled census-tract concentrations were back-calculated for any pollutants that failed at least one screen for CNEP and the Tulsa monitoring sites. NATA-modeled concentrations are assumed to be the average concentration that a person breathed for an entire year. Data from EPA's 1999 NATA are presented in Table 12.

As a means of comparison to the NATA cancer and noncancer risk data, cancer URE and noncancer RfC factors can be applied to the period average to approximate surrogate chronic risk estimates based on ambient monitoring. While these approximations do not incorporate human activity patterns and therefore do not reflect true human inhalation exposure, they may allow analysts to further refine their focus. Although EPA cautions users of NATA from making comparisons across different base years, it is useful to see if the concentration profiles are similar.

Table 12. Theoretical Cancer and Noncancer Risk Summary for the Monitoring Sites in Oklahoma

Pollutant	Cancer URE ($\mu g/m^3$)	Noncancer RfC (mg/m^3)	1999 NATA			2006 - 2008 Monitoring Period		
			Modeled Concentration ($\mu g/m^3$)	Cancer Risk (in-a-million)	Noncancer HQ	Period Average ($\mu g/m^3$)	Cancer Risk Approximation (in-a-million)	Noncancer Risk Approximation (HQ)
Cherokee Heights, Oklahoma (CNEP) - Census Tract ID 40097040400								
Acrolein	NR	0.00002	0.02	NR	0.94	1.53 ± 0.18	NR	76.67
Acrylonitrile	0.000068	0.002	<0.01	<0.01	<0.01	0.03 ± <0.01	2.18	0.02
Benzene	0.000007	0.03	0.43	3.36	0.01	0.54 ± 0.06	3.69	0.02
1,3-Butadiene	0.00003	0.002	0.01	0.30	0.01	0.03 ± <0.01	0.84	0.01
Carbon Tetrachloride	0.000015	0.04	0.21	3.19	0.01	0.68 ± 0.03	10.23	0.02
1,2-Dichloroethane	0.000026	2.4	0.01	0.32	<0.01	0.04 ± <0.01	1.02	<0.01
Trichloroethylene	0.000002	0.6	0.04	0.10	<0.01	0.06 ± 0.01	0.11	<0.01

BOLD indicates a pollutant of interest
NR = A risk factor is not available and therefore, no risk calculation can be made.

Table 12. Theoretical Cancer and Noncancer Risk Summary for the Monitoring Sites in Oklahoma (Continued)

Pollutant	Cancer URE ($\mu g/m^3$)	Noncancer RfC (mg/m^3)	1999 NATA			2006 - 2008 Monitoring Period		
			Modeled Concentration ($\mu g/m^3$)	Cancer Risk (in-a-million)	Noncancer HQ	Period Average ($\mu g/m^3$)	Cancer Risk Approximation (in-a-million)	Noncancer Risk Approximation (HQ)
Tulsa, Oklahoma (Site #1 - TOOK) - Census Tract ID 40143004600								
Acetonitrile	NR	0.06	<0.01	NR	<0.01	17.12 ± 13.76	NR	0.29
Acrolein	NR	0.00002	0.13	NR	6.59	0.80 ± 0.11	NR	39.77
Acrylonitrile	0.000068	0.002	<0.01	0.01	<0.01	0.04 ± 0.01	2.55	0.02
Benzene	0.000007	0.03	3.89	30.34	0.12	1.99 ± 0.26	13.96	0.07
1,3-Butadiene	0.00003	0.002	0.24	7.34	0.12	0.08 ± 0.01	2.53	0.04
Carbon Tetrachloride	0.000015	0.04	0.21	3.20	0.01	0.56 ± 0.03	8.43	0.01
***p*-Dichlorobenzene**	0.000011	0.8	0.03	0.35	<0.01	0.12 ± 0.02	1.27	<0.01
Dichloromethane	4.7E-07	1	0.31	0.15	<0.01	0.36 ± 0.09	0.17	<0.01
Tetrachloroethylene	0.000005	0.27	0.17	0.99	<0.01	0.21 ± 0.05	1.06	<0.01
Xylenes	NR	0.1	5.78	NR	0.06	3.96 ± 0.60	NR	0.04

BOLD indicates a pollutant of interest
NR = A risk factor is not available and therefore, no risk calculation can be made.

Table 12. Theoretical Cancer and Noncancer Risk Summary for the Monitoring Sites in Oklahoma (Continued)

			1999 NATA			2006 - 2008 Monitoring Period		
Pollutant	**Cancer URE ($\mu g/m^3$)**	**Noncancer RfC (mg/m^3)**	**Modeled Concentration ($\mu g/m^3$)**	**Cancer Risk (in-a-million)**	**Noncancer HQ**	**Period Average ($\mu g/m^3$)**	**Cancer Risk Approximation (in-a-million)**	**Noncancer Risk Approximation (HQ)**
Tulsa, Oklahoma (Site #2 - TSOK) - Census Tract ID 40143001000								
Acetonitrile	NR	0.06	<0.01	NR	<0.01	16.54 ± 5.29	NR	0.28
Acrolein	NR	0.00002	0.11	NR	5.51	0.87 ± 0.17	NR	43.49
Acrylonitrile	0.000068	0.002	<0.01	0.01	<0.01	0.05 ± 0.01	3.16	0.02
Benzene	0.000007	0.03	1.66	12.94	0.05	0.97 ± 0.09	6.77	0.03
1,3-Butadiene	0.00003	0.002	0.15	4.48	0.07	0.07 ± 0.01	2.08	0.03
Carbon Tetrachloride	0.000015	0.04	0.21	3.16	0.01	0.58 ± 0.03	8.65	0.01
***p*-Dichlorobenzene**	0.000011	0.8	0.03	0.30	<0.01	0.10 ± 0.01	1.10	<0.01
1,2-Dichloroethane	0.000026	2.4	0.03	0.85	<0.01	0.04 ± <0.01	1.00	<0.01
Tetrachloroethylene	0.000005	0.27	0.18	1.05	<0.01	0.16 ± 0.03	0.80	<0.01
1,1,2-Trichloroethane	0.000016	0.4	<0.01	<0.01	<0.01	0.04 ± <0.01	0.64	<0.01
Trichloroethylene	0.000002	0.6	0.08	0.17	<0.01	0.12 ± 0.03	0.25	<0.01

BOLD indicates a pollutant of interest
NR = A risk factor is not available and therefore, no risk calculation can be made.

Table 12. Theoretical Cancer and Noncancer Risk Summary for the Monitoring Sites in Oklahoma (Continued)

			1999 NATA			2006 - 2008 Monitoring Period		
Pollutant	**Cancer URE ($\mu g/m^3$)**	**Noncancer RfC (mg/m^3)**	**Modeled Concentration ($\mu g/m^3$)**	**Cancer Risk (in-a-million)**	**Noncancer HQ**	**Period Average ($\mu g/m^3$)**	**Cancer Risk Approximation (in-a-million)**	**Noncancer Risk Approximation (HQ)**
Tulsa, Oklahoma (Site #3 - TUOK) - Census Tract ID 40143003200								
Acetonitrile	NR	0.06	<0.01	NR	<0.01	3.76 ± 1.92	NR	0.06
Acrolein	NR	0.00002	0.11	NR	5.43	0.93 ± 0.14	NR	46.26
Acrylonitrile	0.000068	0.002	<0.01	0.02	<0.01	0.04 ± 0.01	2.91	0.02
Benzene	0.000007	0.03	1.79	13.94	0.05	1.22 ± 0.11	8.52	0.04
1,3-Butadiene	0.00003	0.002	0.18	5.27	0.08	0.09 ± 0.01	2.85	0.05
Carbon Disulfide	NR	0.7	0.04	NR	<0.01	0.86 ± 0.69	NR	<0.01
Carbon Tetrachloride	0.000015	0.04	0.21	3.13	0.01	0.57 ± 0.03	8.55	0.01
***p*-Dichlorobenzene**	0.000011	0.8	0.03	0.32	<0.01	0.12 ± 0.02	1.28	<0.01
Tetrachloroethylene	0.000005	0.27	0.21	1.26	<0.01	0.34 ± 0.07	1.68	<0.01
Trichloroethylene	0.000002	0.6	0.10	0.19	<0.01	0.08 ± 0.02	0.17	<0.01
Xylenes	NR	0.1	1.82	NR	0.02	2.61 ± 0.40	NR	0.03

BOLD indicates a pollutant of interest
NR = A risk factor is not available and therefore, no risk calculation can be made.

Cancer UREs and/or noncancer RfCs, site-specific period averages, and corresponding period average-based surrogate chronic risk approximations are presented in Table 12. The pollutants of interest for each site are bolded. Table 12 shows that some of the modeled concentrations from NATA were very similar to the period averages, such as benzene for CNEP (0.43 µg/m^3 from NATA and 0.54 µg/m^3 for the period average), while others were very different, such as acrolein for CNEP (0.02 µg/m^3 from NATA and 1.54 µg/m^3 for the period average).

Acrolein, carbon tetrachloride, and benzene had the highest period averages for CNEP while benzene, carbon tetrachloride, and trichloroethylene had the highest NATA-modeled concentrations of the pollutants of interest. The NATA-modeled noncancer HQ was less than 1.0 for all of the pollutants that failed screens at CNEP. Acrolein's period average-based chronic noncancer HQ approximation (76.98) was the only approximation greater than 1.0.

Acetonitrile, xylenes, and benzene had the highest period averages for TOOK and TUOK while xylenes and benzene had the highest NATA modeled concentrations. Acrolein was the only pollutant with a period average-based chronic noncancer HQ approximation greater than 1.0 for TOOK and TUOK (39.77 and 46.6, respectively). Acetonitrile, benzene, and acrolein had the highest period averages for TSOK while benzene, carbon tetrachloride, and tetrachloroethylene had the highest NATA modeled concentrations.

10.2.3 Risk-Based Emissions Assessment

A pollutant emitted in high quantities does not necessarily present a higher risk to human health than a pollutant emitted in very low quantities. The more toxic the pollutant, the more risk associated with its emissions in ambient air. This section presents a summary of toxicity-weighted, county-level emissions based on an EPA-approved approach (EPA, 2007a). The toxicity-weighted emissions approach consists of the following steps:

1. Obtain HAP emissions data for all anthropogenic sectors from the NEI. For point sources, sum the process-level emissions to the county-level.

2. Apply the mass extraction speciation profiles to extract metal and cyanide mass. The only exception is for two chromium species: chromium and chromium compounds.
3. For chromium and chromium compounds, trivalent chromium (non-toxic) must be separated from hexavalent chromium (toxic). To do this, apply the chromium speciation profile to extract the hexavalent chromium mass by industry group.
4. Apply weight to the emissions derived from the steps above based on their toxicity.
    a. To apply weight based on cancer toxicity, multiply the emissions of each pollutant by its cancer URE.
    b. To apply weight based on noncancer toxicity, divide the emissions of each pollutant by its noncancer RfC.

The 10 pollutants with the highest total mass emissions and the associated toxicity-weighted emissions are presented in Tables 13 (cancer) and 14 (noncancer). While the absolute magnitude of the pollutant-specific toxicity-weighted emissions is not meaningful, the relevant magnitude of toxicity-weighted emissions is useful in identifying the order of potential priority for air quality managers. Higher values suggest greater priority; however, even the highest values may not reflect potential cancer effects greater than a level of concern (1 in-a-million) or potential noncancer effects above levels of concern (e.g., HQ = 1). The pollutants exhibiting the 10 highest period average-based surrogate chronic cancer and noncancer approximations are also presented in Tables 13 and 14. The results of this data analysis may help state, local, and tribal agencies better understand which pollutants emitted, from a toxicity basis, are of the greatest concern.

As shown in Table 13, benzene ranked highest in mass emissions for Tulsa and Mayes Counties, and ranked highest in cancer toxicity weighting for the Tulsa sites. The highest ranked pollutant by cancer toxicity weighting for Mayes County (CNEP) is arsenic, followed by hexavalent chromium and benzene. By comparison, carbon tetrachloride, benzene, and acrylonitrile had the highest period average-based chronic cancer risk approximation for all monitoring sites.

Table 13. Top 10 Emissions, Toxicity-Weighted Emissions, and Cancer Risk Approximations for Pollutants with Cancer UREs for the Monitoring Sites in Oklahoma

Top 10 Total Emissions for Pollutants with Cancer Risk Factors (County-Level)		Top 10 Cancer Toxicity-Weighted Emissions (County-Level)		Top 10 Period Average-Based Chronic Cancer Risk Approximations (Site-Specific)	
Pollutant	**Emissions (tpy)**	**Pollutant**	**Cancer Toxicity Weighted Emissions**	**Pollutant**	**Cancer Risk Approximation (in-a-million)**
Cherokee Heights, Oklahoma (CNEP) – Mayes County					
Benzene	70.47	Arsenic	3.87E-03	Carbon Tetrachloride	10.23
Formaldehyde	59.29	Hexavalent Chromium	7.45E-04	Benzene	3.69
Acetaldehyde	10.22	Benzene	5.50E-04	Acrylonitrile	2.18
1,3-Butadiene	5.69	Cadmium	1.94E-04	1,2-Dichloroethane	1.01
Naphthalene	5.36	Naphthalene	1.82E-04	1,3-Butadiene	0.84
Dichloromethane	3.47	1,3-Butadiene	1.71E-04	Trichloroethylene	0.11
Polycyclic Organic Matter as 7-PAH	2.17	Polycyclic Organic Matter as 7-PAH	1.53E-04		
Trichloroethylene	1.86	Lead	1.07E-04		
Benzyl Chloride	1.40	Nickel	9.65E-05		
Tetrachloroethylene	1.24	Benzyl Chloride	6.86E-05		
Tulsa, Oklahoma, Site #1 (TOOK) – Tulsa County					
Benzene	656.52	Benzene	5.12E-03	Benzene	13.96
Formaldehyde	230.68	Lead	2.71E-03	Carbon Tetrachloride	8.43
Tetrachloroethylene	95.57	1,3-Butadiene	2.24E-03	Acrylonitrile	2.55
Acetaldehyde	81.21	Hexavalent Chromium	1.45E-03	1,3-Butadiene	2.53
1,3-Butadiene	74.76	Naphthalene	6.67E-04	*p*-Dichlorobenzene	1.27
Dichloromethane	24.20	Tetrachloroethylene	5.64E-04	Tetrachloroethylene	1.06
Trichloroethylene	22.32	Polycyclic Organic Matter as 15-PAH	1.83E-04	Dichloromethane	0.17
Naphthalene	19.63	Acetaldehyde	1.79E-04		
p-Dichlorobenzene	12.22	Polycyclic Organic Matter as 7-PAH	1.68E-04		
Polycyclic Organic Matter as 15-PAH	3.33	*p*-Dichlorobenzene	1.34E-04		

Table 13. Top 10 Emissions, Toxicity-Weighted Emissions, and Cancer Risk Approximations for Pollutants with Cancer UREs for the Monitoring Sites in Oklahoma (Continued)

Top 10 Total Emissions for Pollutants with Cancer Risk Factors (County-Level)		Top 10 Cancer Toxicity-Weighted Emissions (County-Level)		Top 10 Period Average-Based Chronic Cancer Risk Approximations (Site-Specific)	
Pollutant	**Emissions (tpy)**	**Pollutant**	**Cancer Toxicity Weighted Emissions**	**Pollutant**	**Cancer Risk Approximation (in-a-million)**
Tulsa, Oklahoma, Site #2 – (TSOK) – Tulsa County					
Benzene	656.52	Benzene	5.12E-03	Carbon Tetrachloride	8.65
Formaldehyde	230.68	Lead	2.71E-03	Benzene	6.77
Tetrachloroethylene	95.57	1,3-Butadiene	2.24E-03	Acrylonitrile	3.16
Acetaldehyde	81.21	Hexavalent Chromium	1.45E-03	1,3-Butadiene	2.08
1,3-Butadiene	74.76	Naphthalene	6.67E-04	*p*-Dichlorobenzene	1.10
Dichloromethane	24.20	Tetrachloroethylene	5.64E-04	1,2-Dichloroethane	1.00
Trichloroethylene	22.32	Polycyclic Organic Matter as 15-PAH	1.83E-04	Tetrachloroethylene	0.80
Naphthalene	19.63	Acetaldehyde	1.79E-04	1,1,2-Trichloroethane	0.64
p-Dichlorobenzene	12.22	Polycyclic Organic Matter as 7-PAH	1.68E-04	Trichloroethylene	0.25
Polycyclic Organic Matter as 15-PAH	3.33	*p*-Dichlorobenzene	1.34E-04		
Tulsa, Oklahoma, Site #3 (TUOK) – Tulsa County					
Benzene	656.52	Benzene	5.12E-03	Carbon Tetrachloride	8.55
Formaldehyde	230.68	Lead	2.71E-03	Benzene	8.52
Tetrachloroethylene	95.57	1,3-Butadiene	2.24E-03	Acrylonitrile	2.91
Acetaldehyde	81.21	Hexavalent Chromium	1.45E-03	1,3-Butadiene	2.85
1,3-Butadiene	74.76	Naphthalene	6.67E-04	Tetrachloroethylene	1.68
Dichloromethane	24.20	Tetrachloroethylene	5.64E-04	*p*-Dichlorobenzene	1.28
Trichloroethylene	22.32	Polycyclic Organic Matter as 15-PAH	1.83E-04	Trichloroethylene	0.17
Naphthalene	19.63	Acetaldehyde	1.79E-04		
p-Dichlorobenzene	12.22	Polycyclic Organic Matter as 7-PAH	1.68E-04		
Polycyclic Organic Matter as 15-PAH	3.33	*p*-Dichlorobenzene	1.34E-04		

Table 14. Top 10 Emissions, Toxicity-Weighted Emissions, and Noncancer Risk Approximations for Pollutants with Noncancer RfCs for the Monitoring Sites in Oklahoma

Top 10 Total Emissions for Pollutants with Noncancer Risk Factors (County-Level)		Top 10 Noncancer Toxicity-Weighted Emissions (County-Level)		Top 10 Period Average-Based Chronic Noncancer Risk Approximations (Site-Specific)	
Pollutant	**Emissions (tpy)**	**Pollutant**	**Noncancer Toxicity Weighted Emissions**	**Pollutant**	**Noncancer Risk Approximation (HQ)**
Cherokee Nation, Oklahoma (CNEP) – Mayes County					
Toluene	140.89	Acrolein	88,332.62	Acrolein	76.67
Xylenes	91.15	Arsenic	30,003.79	Benzene	0.02
Benzene	70.47	Manganese	20,653.19	Carbon Tetrachloride	0.02
Hydrochloric Acid	61.46	Nickel	9,274.52	Acrylonitrile	0.02
Formaldehyde	59.29	Formaldehyde	6,050.05	1,3-Butadiene	0.01
Methanol	58.86	Cadmium	5,391.68	Trichloroethylene	<0.01
Ethylene Glycol	25.78	Cyanide	3,097.21	1,2-Dichloroethane	<0.01
Methyl Ethyl Ketone	24.77	Hydrochloric Acid	3,072.88		
Hexane	22.47	1,3-Butadiene	2,845.14		
Ethylbenzene	21.85	Mercury	2,650.60		
Tulsa, Oklahoma, Site #1 (TOOK) – Tulsa County					
Toluene	1,693.16	Acrolein	666,521.43	Acrolein	39.77
Xylenes	1,071.67	Manganese	44,619.69	Acetonitrile	0.29
Benzene	656.52	1,3-Butadiene	37,378.71	Benzene	0.07
Methanol	315.45	Formaldehyde	23,538.94	1,3-Butadiene	0.04
Hexane	285.46	Benzene	21,883.97	Xylenes	0.04
Ethylbenzene	259.65	Xylenes	10,716.70	Acrylonitrile	0.02
Methyl Ethyl Ketone	237.23	Nickel	10,459.51	Carbon Tetrachloride	0.01
Formaldehyde	230.68	Acetaldehyde	9,023.31	Tetrachloroethylene	<0.01
Methyl Isobutyl Ketone	132.45	Cyanide	7,120.19	Dichloromethane	<0.01
Tetrachloroethylene	95.57	Naphthalene	6,543.01	*p*-Dichlorobenzene	<0.01

Table 14. Top 10 Emissions, Toxicity-Weighted Emissions, and Noncancer Risk Approximations for Pollutants with Noncancer RfCs for the Monitoring Sites in Oklahoma (Continued)

Top 10 Total Emissions for Pollutants with Noncancer Risk Factors (County-Level)		Top 10 Noncancer Toxicity-Weighted Emissions (County-Level)		Top 10 Period Average-Based Chronic Noncancer Risk Approximations (Site-Specific)	
Pollutant	**Emissions (tpy)**	**Pollutant**	**Noncancer Toxicity Weighted Emissions**	**Pollutant**	**Noncancer Risk Approximation (HQ)**
Tulsa, Oklahoma, Site #2 (TSOK) – Tulsa County					
Toluene	1,693.16	Acrolein	666,521.43	Acrolein	43.49
Xylenes	1,071.67	Manganese	44,619.69	Acetonitrile	0.28
Benzene	656.52	1,3-Butadiene	37,378.71	1,3-Butadiene	0.03
Methanol	315.45	Formaldehyde	23,538.94	Benzene	0.03
Hexane	285.46	Benzene	21,883.97	Acrylonitrile	0.02
Ethylbenzene	259.65	Xylenes	10,716.70	Carbon Tetrachloride	0.01
Methyl Ethyl Ketone	237.23	Nickel	10,459.51	Tetrachloroethylene	<0.01
Formaldehyde	230.68	Acetaldehyde	9,023.31	Trichloroethylene	<0.01
Methyl Isobutyl Ketone	132.45	Cyanide	7,120.19	*p*-Dichlorobenzene	<0.01
Tetrachloroethylene	95.57	Naphthalene	6,543.01	1,1,2-Trichloroethane	<0.01
Tulsa, Oklahoma, Site #3 (TUOK) – Tulsa County					
Toluene	1,693.16	Acrolein	666,521.43	Acrolein	46.26
Xylenes	1,071.67	Manganese	44,619.69	Acetonitrile	0.06
Benzene	656.52	1,3-Butadiene	37,378.71	1,3-Butadiene	0.05
Methanol	315.45	Formaldehyde	23,538.94	Benzene	0.04
Hexane	285.46	Benzene	21,883.97	Xylenes	0.03
Ethylbenzene	259.65	Xylenes	10,716.70	Acrylonitrile	0.02
Methyl Ethyl Ketone	237.23	Nickel	10,459.51	Carbon Tetrachloride	0.01
Formaldehyde	230.68	Acetaldehyde	9,023.31	Tetrachloroethylene	<0.01
Methyl Isobutyl Ketone	132.45	Cyanide	7,120.19	Carbon Disulfide	<0.01
Tetrachloroethylene	95.57	Naphthalene	6,543.01	*p*-Dichlorobenzene	<0.01

As shown in Table 14, toluene and xylenes had the highest mass emissions in both Tulsa and Mayes Counties for pollutants with noncancer risk factors. However, acrolein had the highest toxicity-weighted emissions for both counties. Acrolein was not identified as one of the 10 pollutants with the highest mass emissions for the noncancer pollutants. Acrolein also had the highest period average-based chronic noncancer risk approximation for all four monitoring sites.

11.0 Summary of the 2006-2008 Monitoring Data

Results from several of the treatments described above include the following:

- *The pollutants of interest common to all four sites were acrolein, benzene, 1,3-butadiene, and carbon tetrachloride. Tetrachloroethylene and p-dichlorobenzene were also pollutants of interest for the three Tulsa sites. Acetonitrile was a pollutant of interest for TSOK and TUOK.*

- *Of the site-specific pollutants of interest, acrolein had the highest daily average for CNEP; benzene had the highest daily average for TOOK; and acetonitrile had the highest daily average for TSOK and TUOK.*

- *Seasonal averages of acrolein were consistently higher than the intermediate health benchmark risk factor for all four sites.*

- *For CNEP, carbon tetrachloride had the highest period average-based chronic cancer risk approximation, while acrolein exhibited the highest period average-based noncancer risk approximation.*

- *Arsenic, hexavalent chromium, and benzene have the highest toxicity-weighted emissions for a cancer-causing pollutant in Mayes County. Benzene, lead, and 1,3-butadiene have the highest toxicity-weighted emissions for a cancer-causing pollutant in Tulsa County.*

- *Acrolein had the highest highest toxicity-weighted emissions among the noncancer pollutants for all four sites.*

12.0 Recommendations

Based on the toxicity-weighted emissions analysis, metals such as lead, cadmium, arsenic, and manganese are toxic pollutants affecting the Cherokee Heights area. Monitoring for metals may help verify their presence in ambient air and assess their impact.

In addition, laboratory analysts have detected large concentrations of acetaldehyde in canister samples. Because this method is not validated for the analysis of acetaldehyde, known concentrations could not be supplied. It is recommended that carbonyl monitoring following Compendium Method TO-11A would allow accurate determinations of acetaldehyde in the ambient air around the CNEP site.

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