United States
Environmental Protection
Agency
Air

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

EPA-454/R-99-036
January 1999

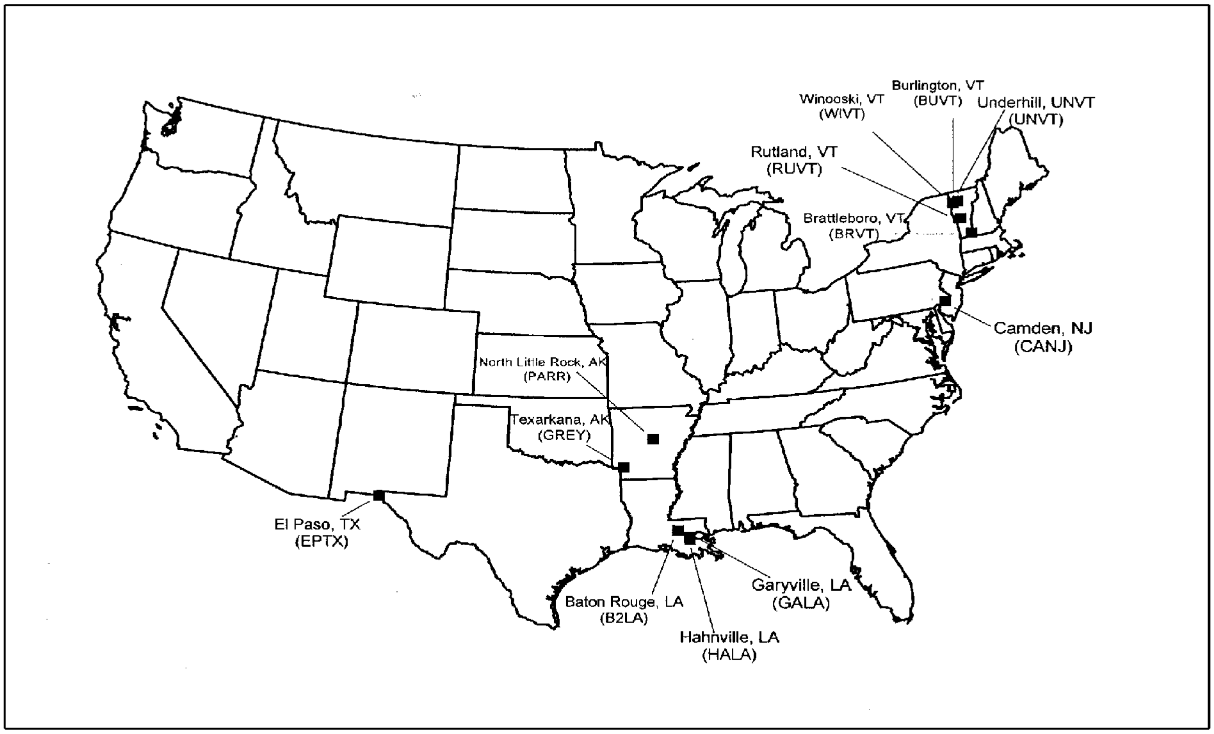
1997 URBAN AIR TOXICS MONITORING PROGRAM (UATMP)

1997 Urban Air Toxics Monitoring Program (UATMP)

Final Report
EPA Contract No. 68-D3-0095
Delivery Order 13

Prepared for:

Kathy Weant and Mike Jones
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711



January 1999

1997 Urban Air Toxics Monitoring Program (UATMP)

Final Report
EPA Contract No. 68-D3-0095
Delivery Order 13

Prepared for:

Kathy Weant and Mike Jones
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Prepared by:

Eastern Research Group, Inc.
110 Hartwell Avenue
Lexington, MA 02421

January 1999

DISCLAIMER

Through its Office of Air Quality Planning and Standards, the U.S. Environmental Protection Agency funded and managed the research described in this report under EPA Contract No. 68-D3-0095 to Eastern Research Group, Inc. This report has been subjected to the Agency's administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products in this report does not constitute endorsement or recommendation for their use.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Appendices

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF ABBREVIATIONS

AIRS	Aerometric Information and Retrieval System
AQS	Air Quality Subsystem (of the Aerometric Information and Retrieval System)
BTEX	benzene, toluene, ethylbenzene, and xylene (*o*-, *m*-, and *p*-xylene)
DNPH	2,4-dinitrophenylhydrazine
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ETBE	ethyl *tert*-butyl ether
FID	flame ionization detection
GC	gas chromatography
HPLC	high performance liquid chromatography
MSD	mass selective detection
MTBE	methyl *tert*-butyl ether
ND	nondetect
ppbv	parts per billion (by volume)
RPD	relative percent difference
TAME	*tert*-amyl methyl ether
TRI	Toxics Release Inventory
UATMP	Urban Air Toxics Monitoring Program
VOC	volatile organic compounds

Monitoring Stations

B2LA	Baton Rouge, Louisiana
BRVT	Brattleboro, Vermont
BUVT	Burlington, Vermont
CANJ	Camden, New Jersey
EPTX	El Paso, Texas
GALA	Garyville, Louisiana
GREY	Texarkana, Arkansas
HALA	Hahnville, Louisiana
PARR	North Little Rock, Arkansas
RUVT	Rutland, Vermont
UNVT	Underhill, Vermont
WIVT	Winooski, Vermont

ABOUT THIS REPORT

This report presents the results of ambient air monitoring conducted as part of the 1997 Urban Air Toxics Monitoring Program (UATMP)—a program designed to characterize the magnitude and composition of potentially toxic air pollution in, or near, urban locations. The 1997 UATMP included 12 monitoring stations that collected 24-hour air samples, typically on a biweekly basis. These samples were analyzed for concentrations of 47 volatile organic compounds (VOC) and 16 carbonyls. Overall, nearly 28,000 ambient air concentrations were measured during the 1997 UATMP. This summary report uses various graphical, numerical, and statistical analyses to put this vast amount of ambient air monitoring data into perspective.

The structure of this report differs significantly from that of earlier UATMP reports in one important regard: instead of commenting primarily on the *general* trends observed during the program, as was done previously, this report is divided into sections that review the *specific* air quality trends for individual monitoring stations. This revised structure allows for a much more thorough review and interpretation of site-specific trends, which may be of greater interest to the agencies that sponsor the monitoring stations. The structure does, however, lend to a certain amount of repetition, as air quality trends that are common to urban environments (e.g., the effects of mobile sources) are discussed in every site-specific section.

The content of this report has been expanded from previous reports, but includes certain elements that have been addressed previously. For example, each section of this report presents a succinct, yet thorough, overview of the monitoring data collected at a particular site. These data summaries intentionally follow the framework used in earlier reports to facilitate comparisons with historical data. Further, each section analyzes and interprets air quality trends for nine compounds (all nitriles and oxygenated compounds) that were not measured during previous UATMPs, including methyl *tert*-butyl ether—a compound that has received much attention lately due to its use as a fuel additive in many parts of the country. Finally, to assess annual variations in air quality, each section describes how levels of air pollution have changed since the 1994 UATMP. Each section concludes by highlighting the most notable trends for the particular monitoring station.

When reading this report, it is important to note that the 1997 UATMP characterized levels of air pollution near only a small subset of urban centers in the United States. Because emissions sources and meteorological conditions vary from city to city, data trends common to the 12 monitoring stations that participated in the 1997 program do not necessarily apply to other urban environments. Further, though the analyses in this report are extensive, they should not be viewed as a comprehensive evaluation of the ambient air monitoring data. To encourage future research, the complete 1997 UATMP monitoring data have been made publicly available in electronic format from the Environmental Protection Agency's Aerometric Information Retrieval System. The data are also included in the appendices to this report.

1.0 Introduction

This report summarizes ambient air monitoring data collected in or near 12 urban centers as part of the 1997 Urban Air Toxics Monitoring Program (UATMP). The U.S. Environmental Protection Agency (EPA) sponsors the UATMP to provide state and local environmental agencies with important information on the composition and magnitude of potentially toxic urban air pollution. Since 1987, UATMP air monitoring devices have collected over 10,000 ambient air samples, which were subsequently analyzed for concentrations of over 50 different organic compounds. Results from these previous monitoring efforts have provided invaluable insight into the many factors that affect air pollution in cities.

To supplement findings from previous UATMPs and other urban air monitoring efforts, this report includes detailed numerical and statistical analyses of the ambient air monitoring data collected during the 1997 program. So that new and historical data can easily be compared, the report presents descriptive summary statistics in a format identical to that of previous UATMP reports. To offer greater insight into the current data, however, much of the report focuses on topics that previous annual UATMP reports have not addressed in detail. Overall, there are three basic goals for this report:

- To provide thorough summaries of the data collected during the 1997 UATMP.
- To analyze and interpret data trends for a group of compounds—nine nitriles and oxygenated compounds—that analytical methods from previous UATMPs did not identify.
- To illustrate how ambient air concentrations of the most prevalent components of urban air pollution changed from one year to the next.

Unlike previous UATMP annual reports, which focused on air quality trends that were apparently common to different urban environments, this report focuses on data trends at each of the 12 different air sampling locations. This site-specific approach allows for much more detailed analyses of the factors (e.g., motor vehicles sources, industrial sources, natural sources) that affect air quality differently from one urban center to the next. Though they are extensive, the analyses in this report should not be viewed as a comprehensive account of urban air pollution at every UATMP monitoring station. As a result, state and local environmental agencies are encouraged to perform additional analyses on the monitoring data so that the many factors that affect ambient air quality can be fully appreciated. To facilitate further analysis of the 1997 UATMP sampling results, appendices to this report present the entire set of ambient air monitoring data. These data also will be available in electronic format from the Air Quality Subsystem (AQS) of the Aerometric Information and Retrieval System (AIRS), an electronic database that EPA maintains.

This report is organized into 13 sections; Table 1-1 lists the contents of each section. Sections 2 and 3 present necessary background information on the air monitoring program and the data analysis methodology used to identify site-specific trends. Sections 4 through 11 then present detailed analyses of the data collected at the different monitoring stations that comprised the 1997 UATMP. Finally, Section 12 reviews the major findings of the report, identifying those air quality trends that appear to be common to different urban areas. Section 13 lists the references cited throughout this report.

As with previous UATMP annual reports, all figures and tables in this report appear at the ends of their respective sections (figures first, followed by tables).

Note: Each "year" of UATMP sampling begins in September and ends in August of the following calendar year. According to convention, the UATMP "program year" corresponds to the calendar year during which sampling begins. For this reason, the program that ran from September 1997 to August 1998 is called the "1997 UATMP," even though most of its samples were collected in 1998.

Table 1-1
Organization of the 1997 UATMP Report

Report Section	Section Title	Overview of Contents
2	The 1997 UATMP	This section provides background information on how the 1997 UATMP was implemented. Topics of discussion include sampling locations, sampling and analytical methods, sampling schedules, and measurement accuracy and precision.
3	Data Analysis Methodology	This section presents the data analysis methodology used in Sections 4 through 11 to interpret the UATMP air monitoring data.
4	Monitoring Results for Baton Rouge, LA (B2LA), Garyville, LA (GALA), and Hahnville, LA (HALA)	These sections summarize the 1997 UATMP monitoring data collected in the respective cities, analyze in detail ambient air concentrations of selected nitriles and oxygenated compounds (i.e., compounds that previous UATMPs did not measure), and examine how concentrations of certain compounds have changed since the 1994 UATMP.
5	Monitoring Results for Brattleboro, VT (BRVT)	
6	Monitoring Results for Burlington, VT (BUVT), Underhill, VT (UNVT), and Winooski, VT (WIVT)	
7	Monitoring Results for Camden, NJ (CANJ)	
8	Monitoring Results for El Paso, TX (EPTX)	
9	Monitoring Results for North Little Rock, AR (PARR)	
10	Monitoring Results for Rutland, VT (RUVT)	
11	Monitoring Results for Texarkana, AR (GREY)	
12	Conclusions and Recommendations	This section summarizes the most significant findings of the 1997 UATMP and makes several recommendations for future urban air monitoring applications.
13	References	This section lists the references cited throughout the report.

2.0 The 1997 UATMP

This section describes the monitoring locations, sampling and analytical methods, and sampling schedules used during the 1997 UATMP—all of which are important factors to consider when interpreting ambient air monitoring results. The 1997 program included 12 monitoring stations that collected 24-hour integrated air samples, according to site-specific schedules, from September 1997 to August 1998. During this period, nearly 1,000 ambient air samples were collected and over 27,000 ambient air concentrations were measured. The remainder of this section describes relevant features of the 1997 UATMP in greater detail, highlighting several areas in which the scope of the 1997 monitoring program differs from earlier UATMPs.

2.1 Monitoring Locations

The UATMP is an EPA-sponsored program in which state and local environmental agencies can voluntarily participate. EPA works with participating agencies to select appropriate monitoring locations and to train staff on how to collect ambient air samples and send them to the analytical laboratory. Both EPA and participating agencies contribute to the overall monitoring costs.

Figure 2-1 shows the locations of the 12 monitoring stations that participated in the 1997 program. Of these, 10 have participated in previous UATMPs; the North Little Rock, Arkansas, and Texarkana, Arkansas, stations are new to the program. Table 2-1 presents additional information on the 12 monitoring stations, including (1) their four-character UATMP site codes, which were used to track samples from the field to the laboratory, (2) their unique nine-digit AIRS site codes, which are used to index monitoring data in the AIRS database, and (3) their starting and ending sampling dates for the 1997 UATMP, which Section 2.3 describes further. As Figure 2-1 shows, the monitoring stations that participated in the 1997 program are located in five states (Arkansas, Louisiana, New Jersey, Texas, and Vermont) and therefore do not characterize all urban locations in the United States. Nonetheless, ambient air monitoring data from the 1997 UATMP provide useful insight into selected components of air pollution in the vicinity of the 12 monitoring locations, and certain data trends that were found to be common to these monitoring locations may represent air quality trends in urban centers across the United States.

The composition and magnitude of air pollution at any monitoring location depends largely on its proximity to various emissions sources, like heavily traveled roadways and industrial facilities. To put these emissions sources into perspective for the 1997 UATMP monitoring locations, Sections 4 through 11 include detailed site maps and emissions data for nearby sources. Not mentioned in the latter sections of the report is the fact that air sampling equipment at every monitoring location was installed in a small enclosure (usually a trailer or a shed) with air sampling probes protruding through the roof. Using this common setup, every air monitor sampled air at heights approximately 5 to 20 feet above local ground level.

2.2 Sampling and Analytical Methods

A monitoring program's sampling and analytical methods ultimately determine what compounds can be identified in air samples, and at what levels. During the 1997 UATMP, ambient air concentrations of 47 VOC were measured using the EPA-approved "Compendium Method TO-15" (USEPA, January 1997), and concentrations of 16 carbonyl compounds were measured using the EPA-approved "Compendium Method TO-11A" (USEPA, January 1997). Although both of these methods were also used during the 1996 UATMP, improved laboratory analytical techniques allowed VOC samples to be analyzed for nine compounds that could not be measured previously. Section 2.2.1 describes this improvement in greater detail.

The final report for the 1996 UATMP thoroughly describes the sampling and analytical methods for VOC and carbonyls (ERG, 1998), as do the original Compendium Method documents (USEPA, January 1997). Sections 2.2.1 and 2.2.2, therefore, only briefly highlight salient features of the VOC and carbonyl methods, respectively. These sections also include estimates of the precision and accuracy of these monitoring methods.

2.2.1 VOC Sampling and Analytical Method

Ambient air concentrations of 47 VOC were measured according to EPA's Compendium Method TO-15. This method specifies steps for collecting 24-hour integrated samples of ambient air in passivated stainless steel canisters, and analyzing them using a gas chromatography column with mass selective detection and flame ionization detection (GC/MSD-FID). Before the 1997 UATMP commenced, several improvements were made to the VOC laboratory analytical techniques. One specific improvement (removal of Nafion® dryers from the analytical apparatus) allowed for the analysis of nine nitriles and oxygenated compounds that previous UATMPs could not identify: acetonitrile, acrylonitrile, ethyl acrylate, ethyl *tert*-butyl ether, methyl ethyl ketone, methyl isobutyl ketone, methyl methacrylate, methyl *tert*-butyl ether, and *tert*-amyl methyl ether. Section 3.2 provides background information on these compounds, and Sections 4 through 11 describe their air quality trends.

The sensitivity of analytical methods, as indicated by their detection limits, is an important consideration for interpreting ambient air monitoring data. Table 2-2 lists the detection limits for the 47 VOC identified during the 1997 UATMP. Two sets are shown because the analytical laboratory revised its detection limits at the beginning of June, 1998. This revision was based on the results of annual testing on the sensitivity of the analytical method. During the 1997 program, the detection limit for almost every VOC was less than 0.5 parts per billion, by volume (ppbv), and many compounds had a detection limit less than 0.1 ppbv. Earlier UATMP reports have emphasized the importance of interpreting nondetect observations in proper context. For reference, the sidebar on the following page, "Appreciating Detection Limits," reviews the significance of detection limits and describes how this study considers nondetect observations when calculating summary statistics.

Another important consideration for interpreting ambient air monitoring data is the precision and accuracy with which concentrations are measured. Air monitoring programs typically collect duplicate samples and analyze them in replicate to quantify the precision of air quality measurements. During the 1997 UATMP, 37 duplicate VOC samples were collected, all

Appreciating Detection Limits

The detection limit of an analytical method must be carefully considered when interpreting ambient air monitoring data. By definition, the detection limit is the lowest level at which laboratory equipment can *reliably* quantify concentrations of selected compounds 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 compound from other compounds in the sample or from the random “noise” inherent in laboratory analyses. 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 “nondetect” observations. Because analytical methods do not quantify concentrations at levels below the detection limits accurately or precisely, data analysts must exercise caution when interpreting monitoring data with many concentrations at levels near or below the corresponding detection limits.

Two important assumptions were made regarding detection limits when processing the raw UATMP monitoring data for this report. First, the analytical equipment used in the UATMP can measure concentrations of compounds at levels below those compounds’ detection limits. Such measurements are considered to be valid results in the air monitoring database, even though they may have poor measurement precision. Second, nondetect observations are assigned a concentration equal to one-half their corresponding detection limit. This approach has been followed in earlier UATMPs and is a recommended approach for conducting risk assessments with environmental monitoring data (USEPA, 1989).

of which were analyzed in replicate. Comparison of concentrations from replicate analyses characterizes *analytical precision* (how precisely the laboratory analyzes environmental samples), and comparison of concentrations from duplicate samples characterizes *sampling and analytical precision* (how precisely field sampling techniques and laboratory analytical techniques measure concentrations). This report uses the relative percent difference (RPD) and the average concentration difference to quantify precision. Previous UATMP reports have defined these parameters and explained their significance. For reference, the sidebar on the following page, “Estimating Measurement Precision,” provides this background information.

Table 2-3 summarizes how precisely the laboratory conducted replicate analyses of air samples during the 1997 UATMP. According to the precision figures, every VOC that was detected in replicate analyses was measured with an RPD of 43.5 percent or lower—a precision

Estimating Measurement Precision

This report uses two parameters to quantify how precisely concentrations were measured during the 1997 UATMP. An absolute indicator of precision, the *average concentration difference* simply quantifies how multiple measurements by the same procedures differ. Applied to this monitoring program, average concentration differences were calculated for each compound (1) for concentrations measured during replicate analyses and (2) for concentrations measured from duplicate samples. When interpreting ambient air monitoring data for specific compounds, the average concentration difference should be compared to summary statistics like the arithmetic mean. If a compound's average concentration difference exceeds or nearly equals the arithmetic mean value, the analytical method may not be capable of precisely characterizing the average concentration. Data interpretations for such compounds should be made with caution.

As a relative indicator of precision, the *relative percent difference* (RPD) expresses average concentration differences relative to the magnitude of the concentration observed. The RPD is calculated using the following equation:

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

Where X_1 is the ambient air concentration of a given compound measured in one sample; X_2 is the concentration of the same compound measured during replicate analysis or in a duplicate sample; and X is the arithmetic mean of X_1 and X_2. By this equation, compounds with relatively low measurement variability will have lower RPDs (and better precision), and compounds with relatively high measurement variability will have higher RPDs (and poorer precision). The UATMP data quality objectives indicate that concentrations should be measured to within 100 percent of their actual ambient levels in order to provide data sufficient for evaluating the nature and magnitude of urban air pollution (USEPA, 1988).

level well within the UATMP data quality objectives (USEPA, 1988). The average concentration difference data in Table 2-3 indicate that, with some exceptions, laboratory analytical precision was excellent, at a level of ±0.10 ppbv or better. The average concentration differences for acetylene (0.26 ppbv), propylene (0.12 ppbv), and toluene (0.18 ppbv) were all slightly higher than this threshold. However, since these compounds were consistently detected at levels greater than 1.0 ppbv (see Sections 4 through 11), the higher concentration difference for these compounds is not expected to influence their summary statistics. Of the 47 VOC, acetonitrile had the highest average concentration difference (7.75 ppbv). The notably high variability for this compound resulted almost entirely from the fact that replicate analyses of samples collected at the Baton Rouge monitoring station consistently had concentration differences greater than 10.0 ppbv. As Section 4 notes, ambient air concentrations of acetonitrile at Baton Rouge were often greater than 100.0 ppbv. Therefore, the average concentration difference for this compound is actually quite small in comparison to the magnitude of concentrations measured. The relatively low RPD for acetonitrile (4.2 percent) confirms that the laboratory measured concentrations of this compound precisely, even though the average concentration differences for samples from one monitoring station were relatively high.

The sampling and analytical precision data in Table 2-4, which characterize measurement variability between duplicate samples, corroborate the findings presented for analytical precision: every compound had an RPD of 39.7 percent or lower; most compounds had average concentration differences of ±0.10 ppbv or better; acetonitrile, acetylene, methyl ethyl ketone, and toluene had higher average concentration differences, but had excellent RPD figures (21.1 percent or lower); and the higher average concentration difference for acetonitrile (6.33 ppbv) resulted almost entirely from the elevated concentrations observed at Baton Rouge.

Overall, replicate analyses of duplicate samples collected during the 1997 UATMP showed that the VOC sampling and analytical method consistently measured concentrations within acceptable levels of precision. Because EPA did not provide external audit samples during the 1997 UATMP, the accuracy of the VOC data cannot be quantified. However, given that the program uses an EPA-approved sampling and analytical method and that field sampling staff and laboratory analysts strictly follow quality control and quality assurance guidelines, the monitoring data are believed to be highly accurate.

2.2.2 Carbonyl Sampling and Analytical Method

Following the specifications of EPA Compendium Method TO-11A (USEPA, 1984), concentrations of 16 carbonyl compounds were measured by passing ambient air over silica gel cartridges coated with 2,4-dinitrophenylhydrazine (DNPH), a compound known to react reversibly with selected aldehydes and ketones. For chemical analysis, the sampling cartridges are eluted with acetonitrile, which liberates the hydrazones (DNPH-carbonyl derivatives) from the sampling matrix. This solution is then analyzed by high-performance liquid chromatography (HPLC) with ultraviolet detection. The carbonyl compounds identified by this method have not changed over the last 3 UATMPs.

Table 2-5 lists the detection limits for the 16 carbonyls identified during the 1997 UATMP. The annual determination of method detection limits was performed near the end of the monitoring program (i.e., August 17, 1998). As Table 2-5 shows, detection limits for carbonyls were all less than 0.025 ppbv. The sidebar "Appreciating Detection Limits" explains the significance of detection limits for ambient air monitoring programs.

To quantify the precision of the laboratory analytical method, 82 carbonyl samples were analyzed in replicate during the 1997 UATMP. As Table 2-6 shows, ambient air concentrations of every carbonyl measured during these replicate analyses were, on average, different by no more than ±0.054 ppbv. Moreover, many compounds had average concentration differences less than ±0.01 ppbv, indicating extremely low measurement variability. Every carbonyl compound had an RPD of 19.8 percent or lower—a precision level well within the data quality objectives of the UATMP and the Compendium Method.

Table 2-7 summarizes data on sampling and analytical precision, which are based on the results from 41 duplicate samples. As the table shows, average concentration differences for sampling and analytical precision ranged from ±0.002 ppbv (for crotonaldehyde) to ±0.355 ppbv (for formaldehyde). Though the concentration difference for formaldehyde is higher than that for the other carbonyls, the RPD for formaldehyde (10.8 percent) suggests that measurement variability generally accounts for only one-tenth of the actual measured concentrations. As expected, RPDs for sampling and analytical precision varied from one compound to the next; however, every carbonyl had an RPD less than 25 percent—a level well below the UATMP data quality objectives.

To assess the accuracy of the carbonyl analytical method, three external audit samples (prepared and supplied by the State of Indiana) were analyzed during the 1997 UATMP. These samples contained varying levels of the three carbonyls that are most prevalent in urban ambient air: acetaldehyde, acetone, and formaldehyde. Results from the three carbonyl audits showed that the laboratory analyzed concentrations of acetaldehyde at levels within 7.0 percent of the actual values, concentrations of acetone at levels within 12.0 percent of the actual values, and concentrations of formaldehyde within 6.0 percent of the actual values. These percent differences are all notably lower than the minimum performance limits specified in the carbonyl audit protocol. (The performance limits range from 16 to 29 percent, depending on the compound being analyzed.)

Overall, results from replicate analyses, duplicate samples, and audit samples all indicate that the carbonyl monitoring data collected during the 1997 UATMP are highly precise and accurate.

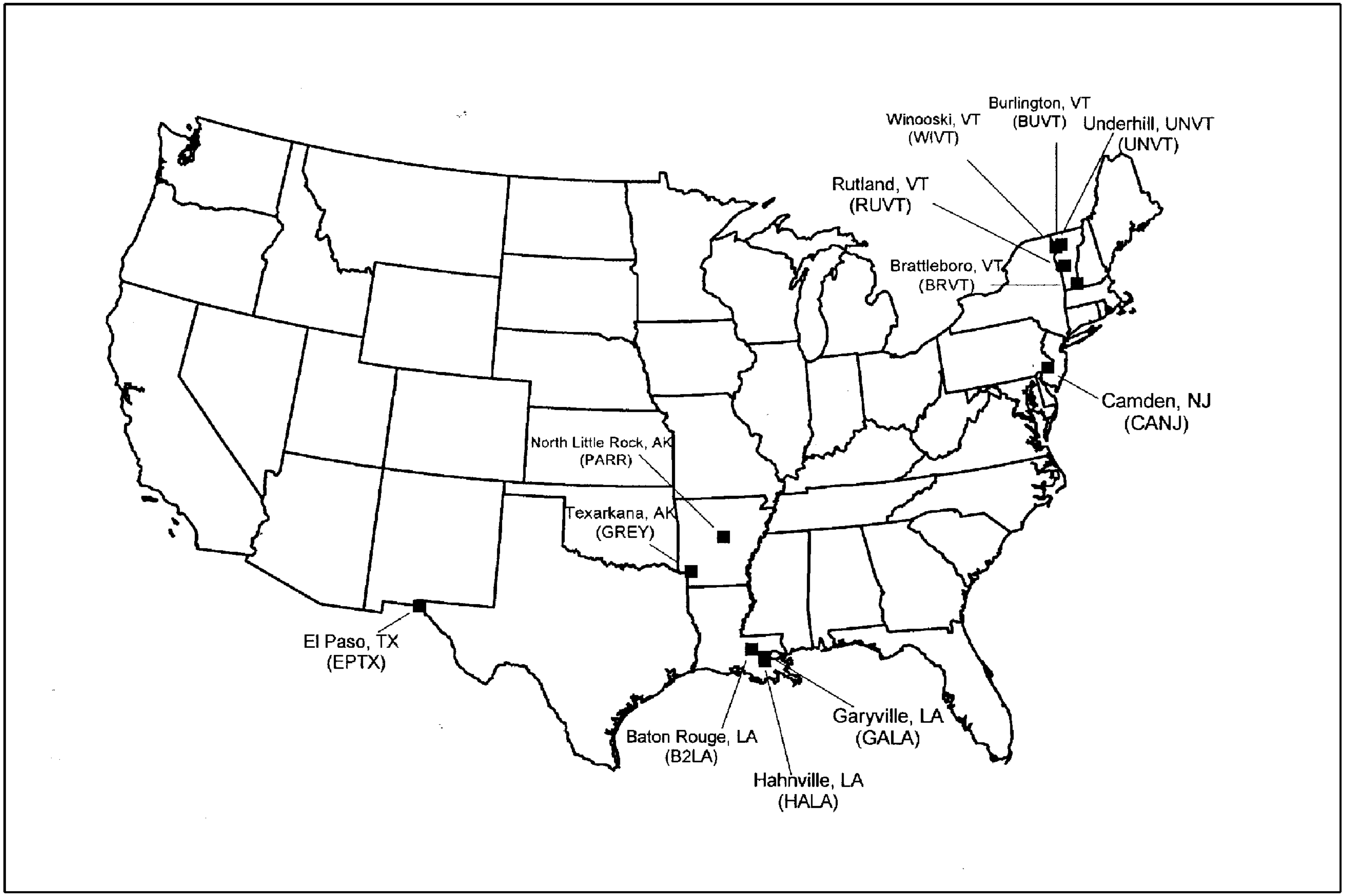
2.3 Sampling Schedules

Table 2-1 lists the dates on which sampling began and ended at each monitoring location during the 1997 program. Most stations operated for 12 months and collected samples from September 1997 to August 1998. As exceptions, the monitoring station in Winooski, Vermont (WIVT), was dismantled after December 1997 and, therefore, collected samples for only 4 months; and the monitoring stations in North Little Rock, Arkansas (PARR), and Texarkana, Arkansas (GREY), did not start sampling until February 1998 and, therefore, collected samples for only 7 months. Later sections of this report explain why summary statistics for these three stations (WIVT, PARR, GREY) may be biased by the fact that they did not collect samples for an entire year.

Regardless of the starting and ending dates for sampling, every station collected 24-hour integrated samples on each scheduled sampling date. Sample collection at every station began and ended at midnight, local time. With one exception, monitoring stations collected samples once every 12 days—a monitoring frequency that ensures samples are collected on different days of the week and that allows for characterizing annual-average trends in a cost-effective manner. The monitoring stations in Arkansas, however, sampled air more frequently, generally once every 6 days. When monitors failed to collect valid samples on scheduled sampling days, site operators sometimes rescheduled samples for other days. This practice explains why some stations did not always adhere to the 12-day sampling schedule.

As part of the sampling schedule, site operators collected duplicate samples on roughly 10 percent of the sampling days. As noted earlier, these duplicate samples were analyzed in replicate to characterize the precision of the sampling and analytical methods.

Figure 2-1
Locations of the 1997 UATMP Monitoring Stations



Note: The four-letter codes shown here were used primarily to track ambient air samples during their transfer from the monitoring stations to the analytical laboratory.

Table 2-1
Background Information for the 1997 UATMP Monitoring Stations

1997 UATMP Site Code	AIRS Site Code	Location	Sampling Schedule	
			Starting Date	Ending Date
B2LA	22-033-0009	Baton Rouge, LA	September 19, 1997	August 19, 1998
BRVT	50-025-0004	Brattleboro, VT	September 7, 1997	August 21, 1998
BUVT	50-007-0003	Burlington, VT	September 7, 1997	August 21, 1998
CANJ	34-007-0003	Camden, NJ	September 7, 1997	August 15, 1998
EPTX	48-141-0027	El Paso, TX	September 13, 1997	August 27, 1998
GALA	22-095-0002	Garyville, LA	September 7, 1997	August 27, 1998
GREY	05-091-0096	Texarkana, AR	February 4, 1998	August 28, 1998
HALA	22-089-0003	Hahnville, LA	September 7, 1997	August 27, 1998
PARR	05-119-0007	North Little Rock, AR	February 4, 1998	August 27, 1998
RUVT	50-021-0002	Rutland, VT	September 19, 1997	August 27, 1998
UNVT	50-007-0007	Underhill, VT	September 7, 1997	August 21, 1998
WIVT	50-007-0010	Winooski, VT	September 7, 1997	December 24, 1997

Table 2-2
VOC Detection Limits

Compound	Detection Limit (ppbv)	
	September 1997–May 1998	June 1998–August 1998
Acetonitrile	0.57	0.21
Acetylene	0.10	0.07
Acrylonitrile	0.21	0.06
Benzene	0.07	0.06
Bromochloromethane	0.09	0.04
Bromodichloromethane	0.05	0.05
Bromoform	0.15	0.12
Bromomethane	0.14	0.04
1,3-Butadiene	0.09	0.05
Carbon tetrachloride	0.05	0.09
Chlorobenzene	0.07	0.04
Chloroethane	0.06	0.06
Chloroform	0.06	0.04
Chloromethane	0.13	0.06
Chloroprene	0.10	0.03
Dibromochloromethane	0.15	0.04
m-Dichlorobenzene	0.15	0.09
o-Dichlorobenzene	0.16	0.10
p-Dichlorobenzene	0.13	0.08
1,1-Dichloroethane	0.10	0.03
1,2-Dichloroethane	0.06	0.08
trans-1,2-Dichloroethylene	0.12	0.05
1,2-Dichloropropane	0.04	0.09
cis-1,3-Dichloropropylene	0.06	0.03
trans-1,3-Dichloropropylene	0.11	0.03
Ethyl acrylate	0.10	0.04
Ethylbenzene	0.12	0.10
Ethyl *tert*-butyl ether	0.07	0.05
Methylene chloride	0.09	0.10
Methyl ethyl ketone	0.17	0.03
Methyl isobutyl ketone	0.07	0.07
Methyl methacrylate	0.07	0.06
Methyl *tert*-butyl ether	0.06	0.03
n-Octane	0.21	0.09

Note: Section 2.2 describes the significance of detection limits and why they changed during the 1997 UATMP.

Table 2-2 (Continued)
VOC Detection Limits

Compound	Detection Limit (ppbv)	
	September 1997–May 1998	June 1998–August 1998
Propylene	0.10	0.03
Styrene	0.10	0.11
Tert-Amyl methyl ether	0.07	0.06
1,1,2,2-Tetrachloroethane	0.17	0.05
Tetrachloroethylene	0.22	0.10
Toluene	0.21	0.10
1,1,1-Trichloroethane	0.05	0.06
1,1,2-Trichloroethane	0.11	0.03
Trichloroethylene	0.04	0.06
Vinyl chloride	0.06	0.07
m,*p*-Xylene	0.23	0.08
o-Xylene	0.10	0.03

Notes: Section 2.2 describes the significance of detection limits and why they changed during the 1997 UATMP. Because *m*-xylene and *p*-xylene elute from the GC column at the same time, the VOC analytical method can only report the sum of *m*-xylene and *p*-xylene concentrations and not concentrations of the individual compounds.

VOC Analytical Precision
(Based on Replicate Analysis of 74 Valid Samples)

	Observations	Average RPD in Replicate Analyses (%)	Difference in Replicate Analyses (ppbv)
	16	4.2	
Acetylene	**74**		**0.26**
Acrylonitrile		19.3	0.06
	72	**10.0**	
Bromochloromethane	0		NA
Bromodichloromethane		NA	NA
	0	NA	
Bromomethane	4		0.01
1,3-Butadiene		19.1	0.03
	71	**17.1**	
Chlorobenzene	0		NA
Chloroethane		NA	NA
	5	25.4	
Chloromethane	**74**		**0.06**
Chloroprene		1.8	0.03
	0	NA	
m-Dichlorobenzene		NA	NA
-Dichlorobenzene	0		NA
p	12	43.5	
1,1-Dichloroethane	0		NA
1,2-Dichloroethane		8.3	0.02
-1,2-Dichloroethylene	0		NA
1,2-Dichloropropane		NA	NA
-1,3-Dichloropropylene	0		NA

NA = Not applicable. Precision cannot be evaluated for compounds not detected in any of the replicate analyses.

Compounds detected in more than half of the samples at most of the UATMP monitoring stations are shown in boldface. As Section 2.2.1 describes, these compounds generally had better precision than those less prevalent

Section 2.2.1 explains why a relatively high concentration difference was observed for acetonitrile.

Table 2-3 (Continued)

(Based on Replicate Analysis of 74 Valid Samples)

Compound	Number of	Average RPD in	Average Concentration Difference in Replicate Analyses (ppbv)
-1,3-Dichloropropylene	0		NA
Ethyl acrylate		NA	NA
	70	**12.3**	
Ethyl *tert*	0	NA	
Methylene chloride	**63**		**0.05**
Methyl ethyl ketone		**15.8**	**0.10**
	0	NA	
Methyl methacrylate	3		0.01
Methyl -butyl ether	39		0.10
***n*-Octane**	**63**	**19.9**	**0.03**
Propylene	**74**	**11.5**	**0.12**
Styrene	**55**	**20.9**	**0.02**
Tert-amyl methyl ether	10	39.6	0.09
1,1,2,2-Tetrachloroethane	0	NA	NA
Tetrachloroethylene	**31**	**30.5**	**0.02**
Toluene	**73**	**10.5**	**0.18**
1,1,1-Trichloroethane	**65**	**21.6**	**0.03**
1,1,2-Trichloroethane	0	NA	NA
Trichloroethylene	10	42.7	0.03
Vinyl chloride	5	4.3	0.01
***m,p*-Xylene**	**69**	**11.3**	**0.09**
***o*-Xylene**	**72**	**12.0**	**0.04**

Notes: NA = Not applicable. Precision cannot be evaluated for compounds not detected in any of the replicate analyses.

"Number of observations" equals the number of replicate analyses in which the compound was detected.

Compounds detected in more than half of the samples at most of the UATMP monitoring stations are shown in boldface. As Section 2.2.1 describes, these compounds generally had better precision than those less prevalent in ambient air (i.e., the compounds in plain font).

Table 2-4
VOC Sampling and Analytical Precision
(Based on Duplicate Analysis of 37 Valid Samples)

Compound	Number of Observations	Average RPD in Duplicate Analyses (%)	Average Concentration Difference in Duplicate Analyses (ppbv)
Acetonitrile	7	12.9	6.33
Acetylene	**37**	**8.1**	**0.14**
Acrylonitrile	3	18.3	0.07
Benzene	**37**	**7.0**	**0.04**
Bromochloromethane	0	NA	NA
Bromodichloromethane	0	NA	NA
Bromoform	0	NA	NA
Bromomethane	2	29.4	0.03
1,3-Butadiene	20	11.6	0.02
Carbon tetrachloride	**36**	**15.6**	**0.02**
Chlorobenzene	0	NA	NA
Chloroethane	0	NA	NA
Chloroform	2	17.0	0.02
Chloromethane	**37**	**13.1**	**0.08**
Chloroprene	1	4.7	0.07
Dibromochloromethane	0	NA	NA
m-Dichlorobenzene	0	NA	NA
o-Dichlorobenzene	0	NA	NA
p-Dichlorobenzene	4	19.0	0.03
1,1-Dichloroethane	0	NA	NA
1,2-Dichloroethane	1	22.7	0.04
trans-1,2-Dichloroethylene	0	NA	NA
1,2-Dichloropropane	0	NA	NA
cis-1,3-Dichloropropylene	0	NA	NA

Notes: NA = Not applicable. Precision cannot be evaluated for compounds not detected in any of the duplicate samples.

"Number of observations" equals the number of duplicate samples in which the compound was detected.

Compounds detected in more than half of the samples at most of the UATMP monitoring stations are shown in boldface. As Section 2.2.1 describes, these compounds generally had better precision than those less prevalent in ambient air (i.e., the compounds in plain font).

Section 2.2.1 explains why a relatively high concentration difference was observed for acetonitrile.

Table 2-4 (Continued)
VOC Sampling and Analytical Precision
(Based on Replicate Analysis of 37 Valid Samples)

Compound	Number of Observations	Average RPD in Duplicate Analyses (%)	Average Concentration Difference in Duplicate Analyses (ppbv)
trans-1,3-Dichloropropylene	0	NA	NA
Ethyl acrylate	0	NA	NA
Ethylbenzene	**37**	**12.2**	**0.03**
Ethyl *tert*-butyl ether	0	NA	NA
Methylene chloride	**32**	**30.9**	**0.10**
Methyl ethyl ketone	**36**	**21.1**	**0.13**
Methyl isobutyl ketone	0	NA	NA
Methyl methacrylate	1	30.1	0.04
Methyl *tert*-butyl ether	19	11.7	0.18
***n*-Octane**	**31**	**16.2**	**0.02**
Propylene	**37**	**8.8**	**0.07**
Styrene	**29**	**17.3**	**0.03**
Tert-Amyl methyl ether	5	33.9	0.16
1,1,2,2-Tetrachloroethane	0	NA	NA
Tetrachloroethylene	**17**	**27.7**	**0.01**
Toluene	**37**	**12.8**	**0.13**
1,1,1-Trichloroethane	**35**	**14.1**	**0.02**
1,1,2-Trichloroethane	0	NA	NA
Trichloroethylene	5	39.7	0.03
Vinyl chloride	2	8.4	0.01
***m,p*-Xylene**	**37**	**12.3**	**0.07**
***o*-Xylene**	**37**	**13.1**	**0.04**

Notes: NA = Not applicable. Precision cannot be evaluated for compounds not detected in any of the duplicate samples.

"Number of observations" equals the number of duplicate samples in which the compound was detected.

Compounds detected in more than half of the samples at most of the UATMP monitoring stations are shown in boldface. As Section 2.2.1 describes, these compounds generally had better precision than those less prevalent in ambient air (i.e., the compounds in plain font).

Table 2-5
Carbonyl Detection Limits

Compound	Estimated Detection Limit (ppbv)	
	September 1, 1997–August 16, 1998	August 17, 1998–September 1, 1998
Acetaldehyde	0.004	0.009
Acetone	0.003	0.002
Acrolein	0.005	0.008
Benzaldehyde	0.002	0.008
Butyr/Isobutyraldehyde	0.005	0.009
Crotonaldehyde	0.004	0.009
2,5-Dimethylbenzaldehyde	0.005	0.007
Formaldehyde	0.003	0.004
Hexanaldehyde	0.004	0.011
Isovaleraldehyde	0.010	0.009
Propionaldehyde	0.002	0.008
Tolualdehydes	0.009	0.023
Valeraldehyde	0.006	0.011

Notes: The carbonyl detection limits are based on a sample volume of 1,000 liters of ambient air.

Section 2.2 describes the significance of detection limits and why they changed during the 1997 UATMP.

Because butyraldehyde and isobutyraldehyde elute from the HPLC column at the same time, the carbonyl analytical method can only report the sum of concentrations for these two compounds and not concentrations of the individual compounds. For the same reason, the analytical method reports only the sum of concentrations for the three tolualdehyde isomers, as opposed to reporting separate concentrations for the three individual compounds.

Table 2-6
Carbonyl Analytical Precision
(Based on Replicate Analysis of 82 Valid Samples)

Compound	Number of Observations	Average RPD in Replicate Analyses (%)	Average Concentration Difference in Replicate Analyses (ppbv)
Acetaldehyde	**82**	**1.8**	**0.023**
Acetone	**82**	**2.2**	**0.020**
Acrolein	**81**	**11.2**	**0.004**
Benzaldehyde	**74**	**12.0**	**0.005**
Butyr/Isobutyraldehyde	**82**	**5.7**	**0.010**
Crotonaldehyde	28	9.0	0.003
2,5-Dimethylbenzaldehyde	19	18.1	0.002
Formaldehyde	**82**	**1.8**	**0.054**
Hexanaldehyde	**82**	**9.9**	**0.008**
Isovaleraldehyde	45	16.0	0.003
Propionaldehyde	**81**	**4.4**	**0.007**
Tolualdehydes	74	19.8	0.010
Valeraldehyde	**82**	**8.3**	**0.006**

Notes: "Number of observations" equals the number of replicate analyses in which the compound was detected.
Compounds detected in more than half of the samples at most of the UATMP monitoring stations are shown in boldface. These compounds generally had better precision than those less prevalent in ambient air (i.e., the compounds in plain font).
Section 2.2.2 describes the significance of the analytical precision data shown in the table.

Table 2-7
Carbonyl Sampling and Analytical Precision
(Based on Duplicate Analysis of 41 Valid Samples)

Compound	Number of Observations	Average RPD in Duplicate Analyses (%)	Average Concentration Difference in Duplicate Analyses (ppbv)
Acetaldehyde	**41**	**12.6**	**0.144**
Acetone	**41**	**15.6**	**0.167**
Acrolein	**40**	**14.7**	**0.006**
Benzaldehyde	**37**	**13.1**	**0.006**
Butyr/Isobutyraldehyde	**41**	**17.7**	**0.028**
Crotonaldehyde	13	10.4	0.002
2,5-Dimethylbenzaldehyde	9	18.1	0.003
Formaldehyde	**41**	**10.8**	**0.355**
Hexanaldehyde	**41**	**11.4**	**0.022**
Isovaleraldehyde	21	15.7	0.003
Propionaldehyde	**40**	**9.2**	**0.016**
Tolualdehydes	34	24.2	0.013
Valeraldehyde	**41**	**14.2**	**0.011**

Notes: “Number of observations” equals the number of duplicate analyses in which the compound was detected.
Compounds detected in more than half of the samples at most of the UATMP monitoring stations are shown in boldface. These compounds generally had better precision than those less prevalent in ambient air (i.e., the compounds in plain font).
Section 2.2.2 describes the significance of the analytical and sampling precision data shown in the table.

3.0 Data Analysis Methodology

This section presents the methodology used in this report to summarize and interpret the 1997 UATMP ambient air monitoring data. This methodology includes both data analyses that have been used in previous UATMP reports (e.g., data summary parameters) and data analyses that have not been used previously (e.g., analyses of concentrations of nitriles and oxygenated compounds and of annual variations). In general, this methodology consists of three categories of analyses for identifying notable data trends and patterns:

- *Data summary parameters*, to provide a succinct overview of the monitoring data (see Section 3.1)
- *Analyses of concentrations of nitriles and oxygenated compounds*, to identify significant spatial variations, statistical correlations, and emissions sources for nine nitriles and oxygenated compounds—a group of compounds that the VOC analytical method used in previous UATMPs could not identify (see Section 3.2)
- *Annual variations*, to examine how concentrations of selected compounds have changed at every station since the 1994 UATMP (see Section 3.3)

The remainder of this section describes these three categories of the data analysis methodology. Sections 4 through 11 then use this methodology to thoroughly characterize the UATMP ambient air monitoring data at the different stations that participated in the 1997 program.

3.1 Data Summary Parameters

Since previous UATMP reports describe in detail the four parameters that have been used to summarize this program’s monitoring data, the following discussion only briefly reviews how these parameters efficiently characterize the results of extensive ambient air monitoring studies. The four summary parameters—prevalence, concentration range, central tendency, and variability—are used to provide a complete but succinct overview of the nearly 27,000 ambient air concentrations that were measured during the 1997 UATMP. Sections 4 through 11 present these summary parameters in a series of tables, one for VOC and one for carbonyls, for each monitoring location. Brief definitions and descriptions of these summary parameters follow:

- *Prevalence* of air monitoring data refers to the frequency with which compounds, or groups of compounds, are detected; it is typically expressed as a percentage (e.g., a compound detected in 15 of 20 samples has a prevalence of 75 percent). Compounds that are never detected have a prevalence of 0 percent, and those that are always detected have a prevalence of 100 percent. Because sampling and analytical methods cannot reliably quantify concentrations of compounds at levels near their detection limits, summary statistics for compounds with low prevalence values should be interpreted with caution. It should be noted that compounds with a prevalence of zero may still be present in ambient air, but at levels below the sensitivity of the corresponding sampling and analytical methods.

- The *concentration range* of ambient air monitoring data refers to the span of measured concentrations, from lowest to highest. Because the UATMP only measures 24-hour average concentrations on a biweekly schedule, the lowest and highest concentrations may not represent the actual minimum and maximum concentrations observed during the year; ambient air concentrations of VOC and carbonyls likely rose to higher levels and fell to lower levels on days when samples were not collected.

- The *central tendency* of air monitoring data gives a sense of the long-term average ambient air concentrations. This report uses medians, arithmetic means, and geometric means to characterize the central tendencies of concentration distributions. Previous UATMP reports have explained the differences between these measures of central tendency. All three central tendency parameters are presented in this report to allow readers to compare UATMP monitoring results with those from other monitoring studies that may use different data summary parameters. For insight into how central tendency concentrations varied among the UATMP monitoring stations, Figures 3-1 and 3-2 present geometric mean concentrations for selected VOC and carbonyls, respectively. Data analyses in Sections 4 through 11 explain the trends indicated in these figures.

- *Variability* in ambient air monitoring data indicates the extent to which concentrations of certain compounds fluctuate with respect to their central tendency. This report characterizes data variability using standard deviations and coefficients of variation. The standard deviation is a commonly used statistical parameter that provides an absolute indicator of variability, and the coefficient of variation (calculated by dividing the standard deviation by the arithmetic mean) offers a relative indicator of variability. The coefficient of variation is better suited for comparing variability across data distributions for different sites and compounds.

All data summary parameters presented in this report were calculated from a database of processed 1997 UATMP ambient air monitoring data. This database was generated by manipulating the raw monitoring data to assign all nondetect observations a concentration equal to one-half the corresponding detection limit; after this, the results of all duplicate sampling events and replicate laboratory analyses were averaged so that only one concentration was considered for each compound for each sampling date. These data processing steps are identical to those described in the 1995 and 1996 UATMP final reports.

3.2 Analyses of Concentrations of Nitriles and Oxygenated Compounds

As Section 2.2.1 described, the VOC analytical method used during the 1997 UATMP could identify nine compounds—all nitriles or oxygenated compounds—that were not identified during earlier UATMPs. To provide participating agencies insight into the likely sources of these compounds, Sections 4 through 11 include detailed analyses of the airborne levels observed during the 1997 program. Conclusions drawn in these sections are generally consistent with current knowledge of how these compounds affect ambient air quality:

- *Acetonitrile* is used as a solvent in a variety of industrial applications, but recent studies have found that its largest use is as a solvent for selected oil refining unit operations (Kirk Othmer, 1985). The compound is also used for making resins and has been detected in motor vehicle exhaust. Acetonitrile is fairly unreactive with other airborne pollutants: estimates of its half-life in air (a parameter commonly used to gauge photochemical reactivity) range from 535 to 860 days (Howard, 1989). Therefore, the compound may transport long distances from its point of origin. Acetonitrile was detected in approximately one-fourth of the samples collected during the 1997 UATMP.

- *Acrylonitrile* is used as a reagent in many different chemical and materials production processes, but its largest industrial use is for the manufacture of acrylic fibers (Kirk Othmer, 1985). The compound has been found at trace levels in cigarette smoke and motor vehicle exhaust. Acrylonitrile is much more reactive in air than acetonitrile: on sunny days, the compound has an estimated half-life of 3.5

days (Howard, 1989). During the 1997 UATMP, acrylonitrile was detected less often than acetonitrile and was never detected at four of the monitoring stations.

- *Ethyl acrylate*, an ester of acrylic acid, is predominantly used in industry for manufacturing polymers. The compound reacts quickly in ambient air: estimates of its half-life range from 2.37 to 22.7 hours (Howard, 1989). Ethyl acrylate was not detected in any of the samples collected during the 1997 UATMP.

- *Ethyl tert-butyl ether*, also called ETBE, is an ether that is used as an oxygenated fuel additive in some parts of the country (see sidebar at the bottom of the page, "Oxygenated Additives to Motor Vehicle Fuels"); however, other oxygenated additives (e.g., methyl *tert*-butyl ether and ethanol) are used far more often than ethyl *tert*-butyl ether. The compound is also used as a solvent for various industrial and medical applications. Ethyl *tert*-butyl ether was detected in only one VOC air sample collected during the 1997 UATMP.

Oxygenated Additives to Motor Vehicle Fuels

Many oxygenated compounds, when added to gasoline, have been found to help motor vehicle fuels burn more efficiently, thus reducing certain types of air pollution. Because many parts of the country have unhealthy levels of air pollution, EPA established two programs that require motor vehicles in these areas to use only oxygenated fuels.

EPA's *wintertime program* for oxygenated fuels applies to parts of the country that have potentially unhealthy levels of carbon monoxide in ambient air. Since 1992, motor vehicles in these areas have been required to use fuels that contain at least 2.7 percent oxygen, but only during the winter months (when concentrations of carbon monoxide are known to be highest). Some areas that are part of this program, including the El Paso metropolitan area, use motor vehicle fuels with ethanol additives to meet the oxygenation requirement. EPTX is the only 1997 UATMP monitoring station that is in an area that is part of EPA's wintertime program.

EPA's *year-round program* for oxygenated fuels applies to the ten parts of the country that have the worst ozone problems. Since 1995, EPA has required that all motor vehicles in these areas use fuels that contain at least 2 percent oxygen all year round. In these areas, many different oxygenated compounds are added to the fuels (including ethyl *tert*-butyl ether and *tert*-amyl methyl ether), but methyl *tert*-butyl ether has been used most widely. Of the 1997 UATMP monitoring stations, only the Camden, New Jersey, station is located in an area that is part of EPA's year-round program.

Source: USEPA, 1998a.

- *Methyl ethyl ketone* is used widely in industry as a solvent for paints, coating operations, and materials processing. It is also known to form in the air from photochemical reactions involving olefins and has been detected in emissions from combustion processes and motor vehicles. Methyl ethyl ketone reacts with other air pollution components to form acetaldehyde; its estimated half-life in air is 2.3 days (Howard, 1989). Of all the nitriles and oxygenated compounds, methyl ethyl ketone was detected most frequently during the 1997 UATMP. At nine monitoring stations, the compound was detected in more than 90 percent of the air samples.

- *Methyl isobutyl ketone*, like methyl ethyl ketone, is used in many different industries as a solvent and has been detected in motor vehicle exhaust. The compound participates in many different photochemical reactions and its half-life in ambient air is approximately 15 hours (Howard, 1989). Methyl isobutyl ketone was not detected at seven of the UATMP monitoring stations during the 1997 program; at the remaining stations, it was detected in fewer than 20 percent of the samples.

- *Methyl methacrylate* is used for various industrial processes, but primarily in the manufacture of resins and plastics. In fact, facilities that make methacrylic polymers (and copolymers) use approximately 75 percent of the methyl methacrylate that is used in the entire United States. Since the compound is not known to occur naturally and it has an estimated half-life of only 2.7 hours, airborne methyl methacrylate is expected to be found only near industrial facilities that emit the compound to the air. Methyl methacrylate was rarely detected during the 1997 UATMP: it was never detected at eight of the monitoring stations and was detected in fewer than 20 percent of the samples at the other stations.

- *Methyl tert-butyl ether*, commonly referred to as MTBE, is a synthetic chemical that has been used previously for various industrial applications, but is now predominantly used as an additive to gasoline (see sidebar on the previous page). In fact, gasoline sold in many parts of the country now contains up to 15 percent methyl *tert*-butyl ether. In these areas, motor vehicle exhaust and emissions from gasoline stations are expected to contain methyl *tert*-butyl ether. The compound's half-life in ambient air is estimated to be between 10 and 30 hours (Mackay et al., 1992). During the 1997 UATMP, methyl *tert*-butyl ether was detected in at least 90 percent of the samples at four stations, and far less frequently at the other stations.

- *Tert-amyl methyl ether*, also called TAME, has a very similar chemical structure to methyl-*tert* butyl ether and has many industrial uses. *Tert*-Amyl methyl ether has also been used as an additive to motor vehicle fuels, though not nearly as commonly as methyl *tert*-butyl ether. Data on the half-life of *tert*-amyl methyl ether in ambient air were not readily available in the scientific literature. With one exception (see Section 7), the compound was rarely, if ever, detected in the ambient air at the UATMP monitoring stations.

To identify trends and patterns among the ambient air monitoring data for nitriles and oxygenated compounds, Sections 4 through 11 use various numerical, statistical, and graphical techniques to highlight how levels of these compounds varied from one monitoring location to the next. Previous UATMP reports have used similar techniques to identify air quality trends that may not be apparent from a cursory inspection of the air monitoring data.

For additional insight into the sources of nitriles and oxygenated compounds in urban ambient air, Sections 4 through 11 summarize industrial emissions data that facilities within 10 miles of each monitoring station reported to the federal Toxics Release Inventory (TRI). As the

---

Toxics Release Inventory

Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) requires selected industrial facilities to disclose information characterizing environmental releases of, and waste management practices for, over 600 different "hazardous" chemicals. The TRI reporting requirements for reporting year 1995—the most recent year for which data were publicly available at the writing of this report—applied to facilities that:

- Have at least 10 full-time employees.
- Fall into Standard Industrial Classification (SIC) codes 20 through 39 (these include most industrial manufacturing facilities).
- Manufacture, process, or otherwise use hazardous chemicals in quantities exceeding established thresholds over the course of a calendar year.

Facilities meeting these criteria must submit to EPA either (1) "Form R" reports that specify the quantities of hazardous chemical released to the environment or transferred to offsite locations or (2) "Form A" reports that certify that chemical releases and waste management quantities total no more than 500 pounds. Every year, nearly 80,000 "Form R" and "Form A" reports are submitted to EPA and loaded into the TRI database. This report considers TRI emissions data almost exclusively from reporting year 1995. Emissions data from 1996 and 1997 are not yet publicly available on compact disk—the data release format that allows for the most sophisticated queries of emissions data.

Source: USEPA, 1997b.

---

sidebar on the previous page explains, the TRI contains extensive emissions data for a wide range of industries and provides an excellent reference for evaluating how industrial emissions might impact ambient air concentrations of selected pollutants in different parts of the country. The accuracy of TRI data is not known, but is certainly dependent upon the accuracy of emissions estimates provided by industrial facilities. Sections 4 through 11 summarize the 1995 TRI data for the nine nitriles and oxygenated compounds except for ethyl *tert*-butyl ether and *tert*-amyl methyl ether, which were not part of the TRI reporting requirements. These sections also note important limitations associated with TRI data (e.g., the accuracy not being known, the fact that not every industry is required to report, and the fact that small businesses do not have to report).

It should be noted that the TRI data presented in this report characterize environmental releases during 1995 and the ambient air monitoring data characterize air quality in 1997 and 1998. Despite the differing time frames, the 1995 TRI data are expected to be reasonably representative of more recent emissions trends. Though there are undoubtedly many exceptions, most facilities listed in the 1995 TRI database (especially those that manufactured listed chemicals) probably continue to use many of the same chemicals that they used in 1995. Since the exact relationship between emissions in 1995 and emissions in 1997 is not known, this report uses the 1995 TRI data only as an indicator of the extent to which industrial emissions in particular locations may affect air quality. Analyses of comprehensive local emissions inventories, if available, may provide participating agencies greater insight into how industrial sources affect air quality at the UATMP monitoring stations.

3.3 Annual Variations

When assessing trends in air pollution, data analysts typically try to answer one basic question: Are levels of air pollution in a given area increasing or decreasing over the long term? To help answer this question, Sections 4 through 11 assess how annual average concentrations of the most prevalent VOC and carbonyls have changed from one UATMP year to the next. These analyses of annual variations only consider ambient air monitoring data collected during the current UATMP procurement, which spanned program years 1994 to 1997. As Table 3-1 shows, every monitoring station that participated in the 1997 UATMP, except the monitoring stations in Arkansas, has also been part of earlier programs during this procurement. (Note: Sections 9 and 11 include more detailed analyses of the current ambient air monitoring data for the two stations in Arkansas.) Though some stations have participated in the UATMP prior to program year 1994, data from these earlier programs are not considered in this report because important features of the current monitoring program, such as detection limits, laboratory analytical equipment, and field sampling equipment, may differ from similar features of previous UATMP procurements.

Each year, the UATMP final report estimates annual average concentrations of selected pollutants based on the results of around 30 sampling events. Because sampling for this program does not occur daily, the annual average concentrations presented in UATMP reports should only be viewed as estimates of the true annual average levels. Therefore, changes in *estimated* annual average concentrations from one year to the next do not necessarily imply that *actual* levels of air pollution have changed over the same time frame. To assess the statistical significance of annual variations, this report uses the 95-percent confidence interval of estimated annual average concentrations to determine whether the UATMP monitoring data indicate notable long-term changes in air quality. As opposed to using point-estimates of annual average concentrations, confidence intervals indicate a range of annual average concentrations in which one can be reasonably certain that the actual annual average concentration lies.[1] Sections 4 through 11 (excluding the two monitoring stations in Arkansas) present a series of figures—one for each compound—that indicate how the 95-percent confidence interval of the annual average concentration changed from the 1994 UATMP to the 1997 UATMP. It can be inferred that two

---

[1] Technically, 95-percent confidence intervals have a slightly different statistical meaning. If one were to compute 95-percent confidence intervals for 100 different samples of a population, 95 of the intervals would contain the actual population average. Applied to the UATMP, this means that if 95-percent confidence intervals were calculated for 100 different ambient air monitoring programs (of similar scope) that were conducted at a particular monitoring station in the same year, 95 out of the 100 confidence intervals would include the actual annual average concentration. By inference, one can be 95-percent certain that the 95-percent confidence interval of a specific monitoring program (e.g., the 1997 UATMP) includes the actual annual average concentration.

different annual average concentrations with overlapping confidence intervals may not be statistically different; similarly, two different annual average concentrations with confidence intervals that do not overlap are likely statistically different.[2]

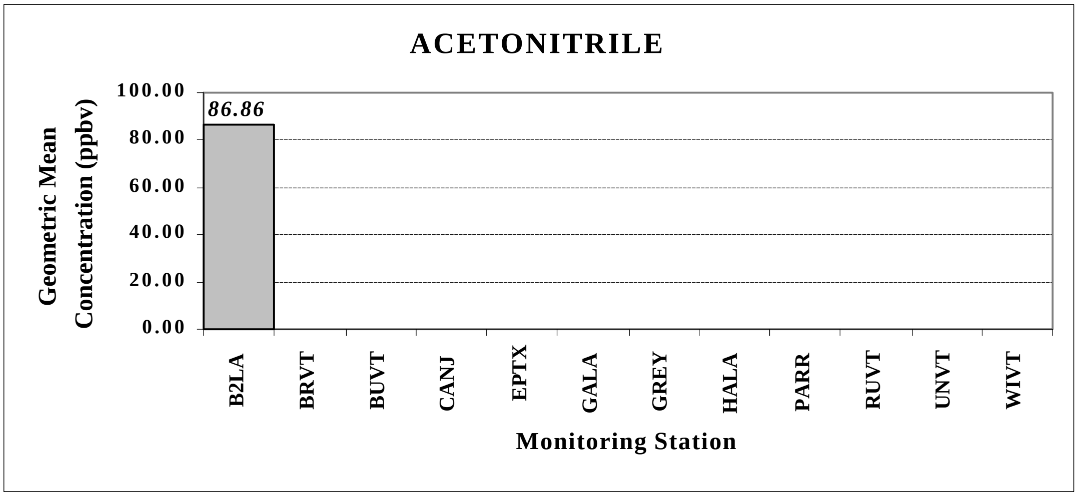
Though the annual variations presented in Sections 4 through 11 may suggest notable trends, it is important to interpret all apparent trends in proper context. For instance, many different factors may cause statistically significant changes in air quality over a 3-year period: environmental regulations may require decreased emissions from certain industrial sources, traffic patterns and the composition of motor vehicle fuels may change from one year to the next, and certain meteorological conditions that affect photochemical reactivity and atmospheric transport are known to exhibit annual fluctuations. Though this report attempts to explain likely causes of annual variations in air quality, participating agencies should research the apparent causes of such variations in greater detail.

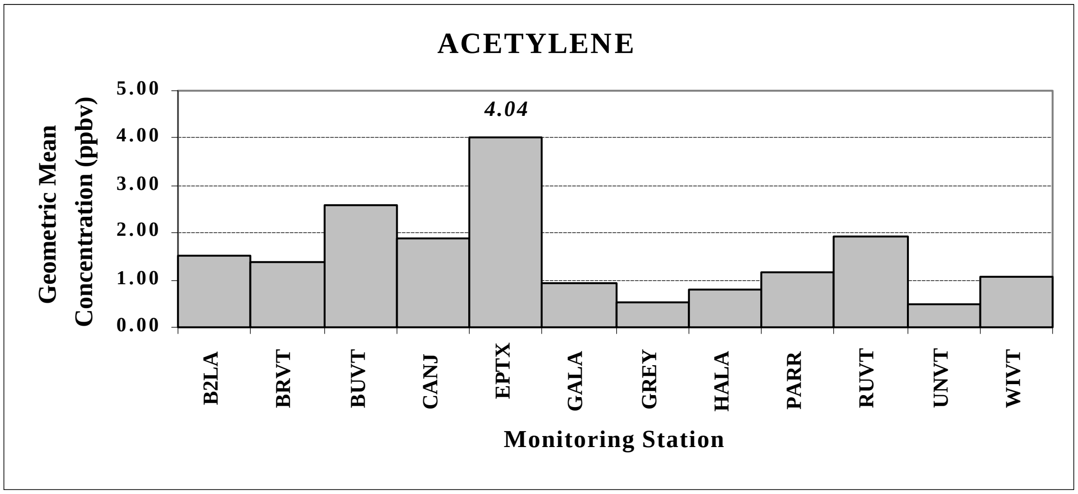
Another important consideration for evaluating annual trends is the fact that statistically significant changes in air quality, even those over 3-year periods, are not necessarily representative of trends over longer time frames. For instance, for pollutants emitted primarily by industrial sources at discrete locations in urban areas, ambient air concentrations are typically a function of prevailing wind patterns and other meteorological conditions. For such pollutants, a statistically significant decrease in concentrations may only reflect fluctuating meteorology, and such a trend would not be expected to persist over the longer term (assuming the industrial emissions do not change). Thus, participating agencies should carefully consider the many different factors that affect air quality (e.g., pollution control regulations, reformulated gasoline policies, meteorological conditions) when interpreting the annual variations presented in Sections 4 through 11.

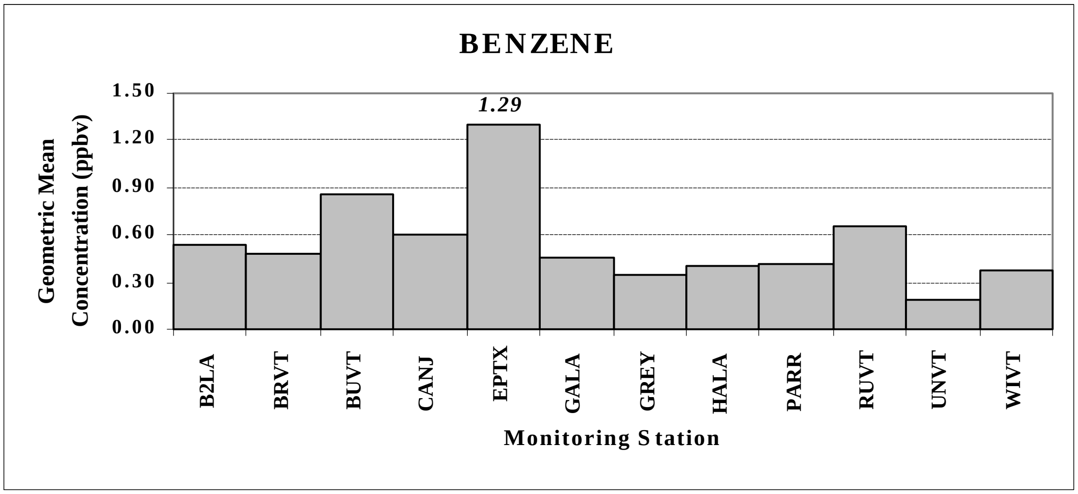
---

[2] Though comparing 95-percent confidence intervals of average concentrations from one year to the next is useful for illustrating air quality trends, this approach does not necessarily identify all situations where the difference between two annual average concentrations is statistically significant. Statistical tests, such as the Spearman rho test or the Kendall tau test, are specifically designed to characterize the statistical significance of trends. Such detailed statistical analyses are not part of the scope of this project.

Figure 3-1 (Page 1 of 6)
Geometric Mean Concentrations for Selected VOC

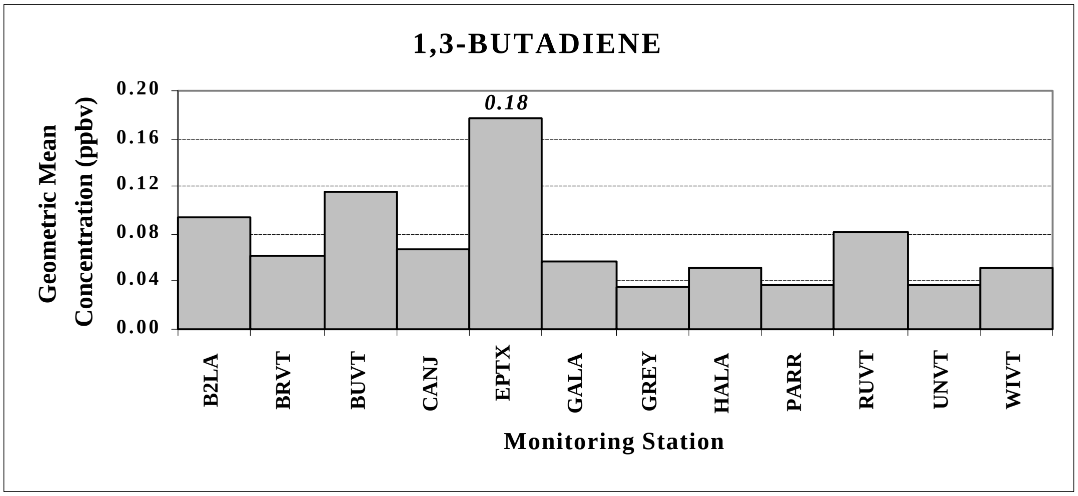


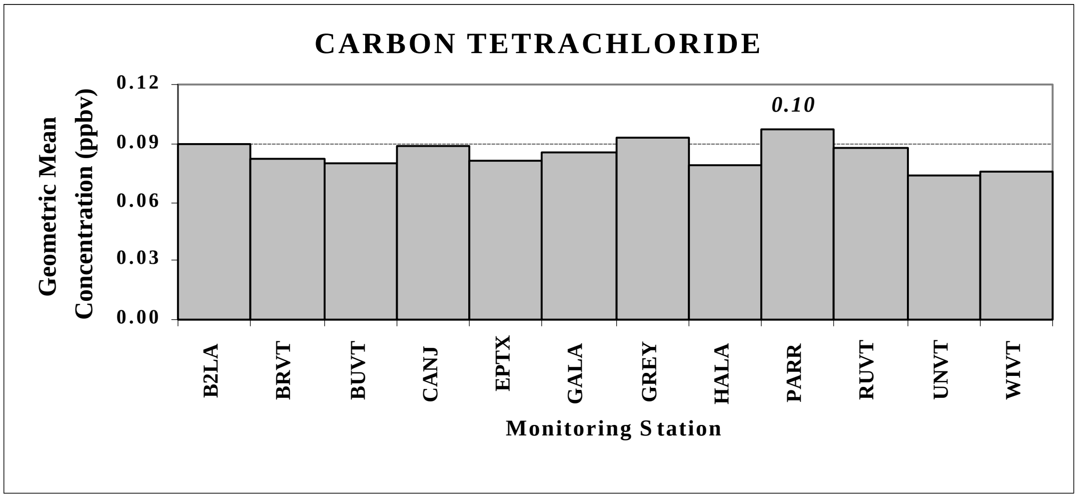


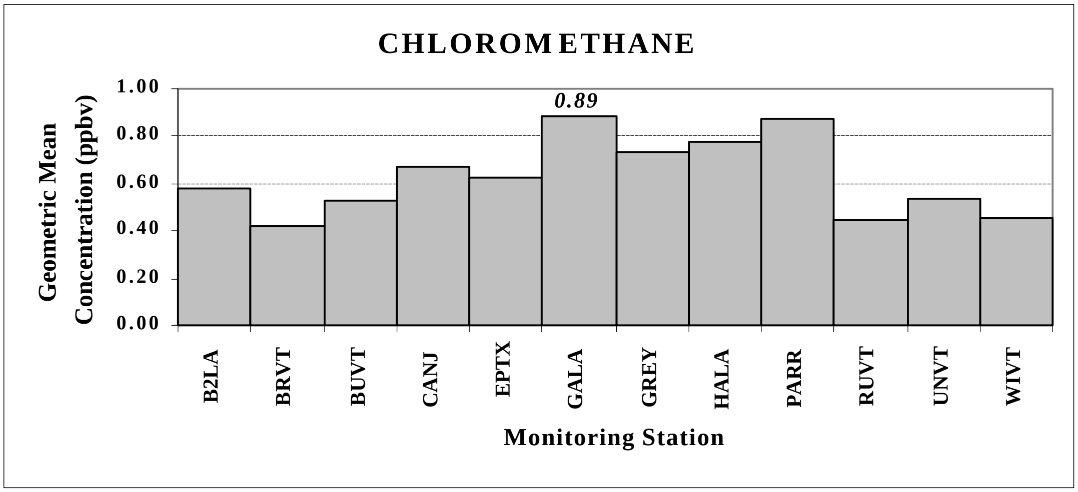


Note: Each figure is shown on a different scale.

Figure 3-1 (Page 2 of 6)
Geometric Mean Concentrations for Selected VOC

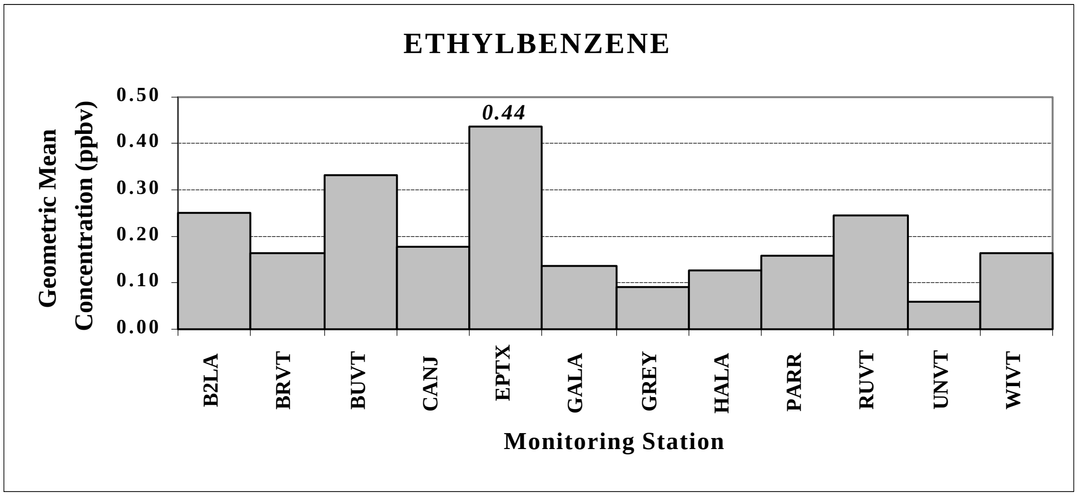


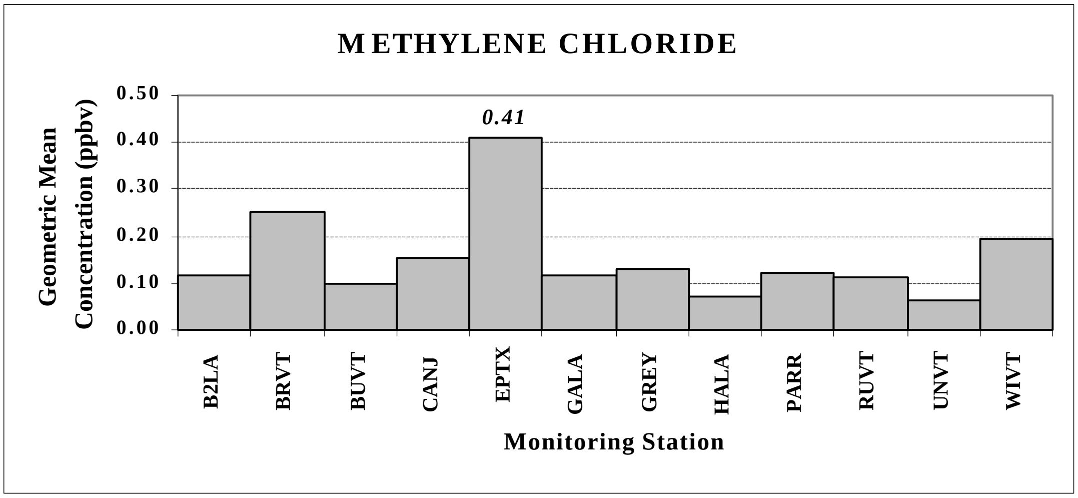


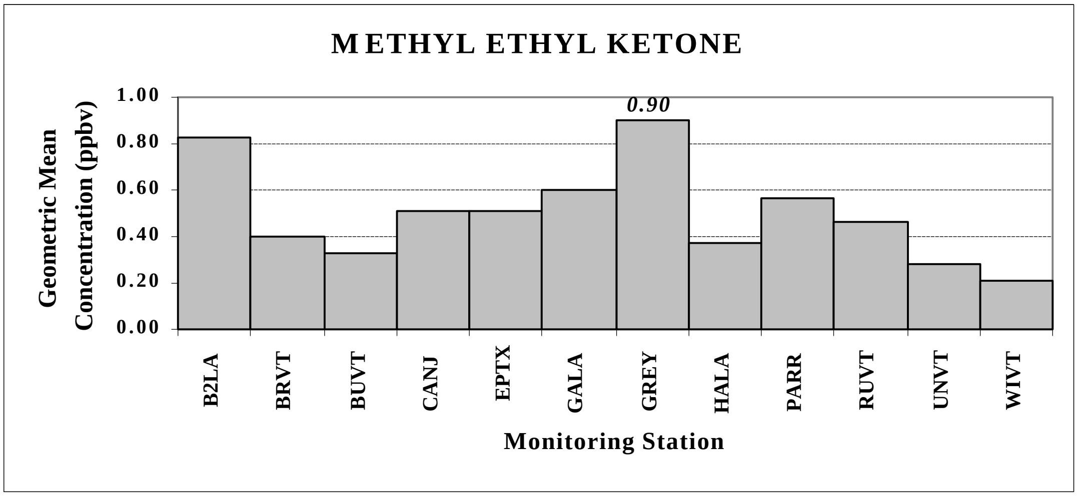


Note: Each figure is shown on a different scale.

Figure 3-1 (Page 3 of 6)
Geometric Mean Concentrations for Selected VOC

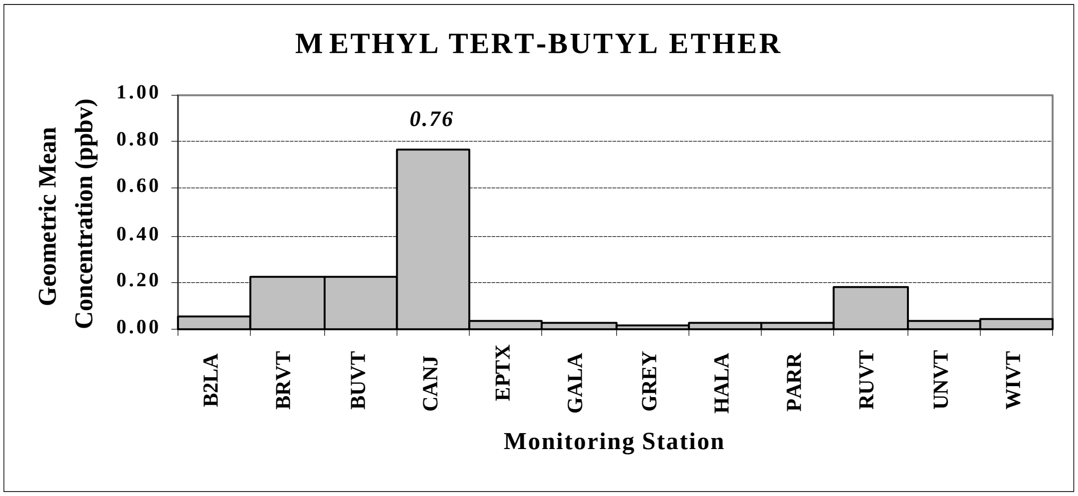


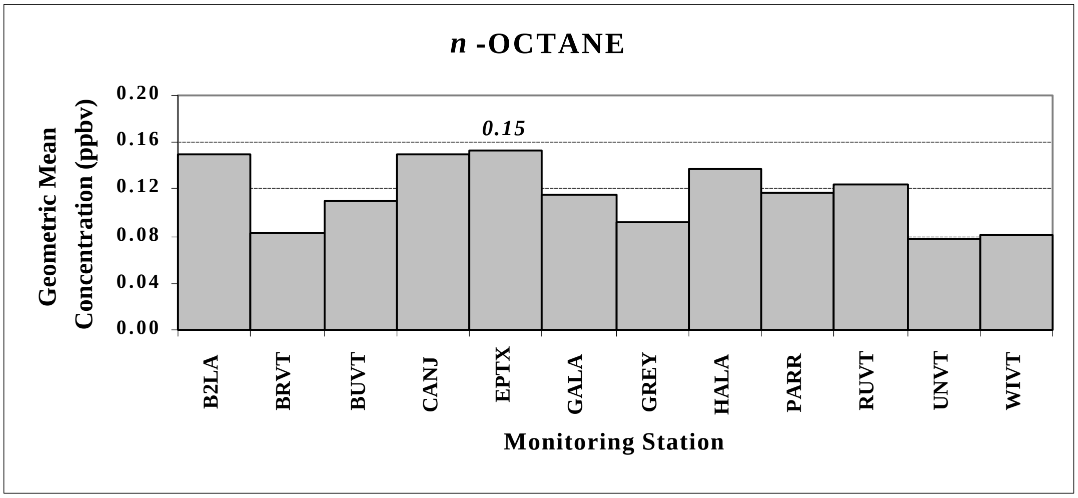


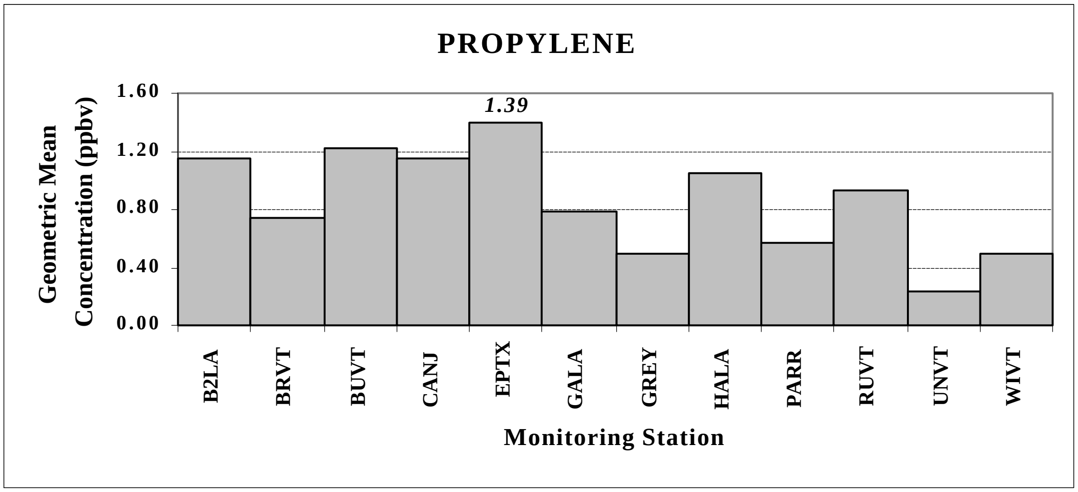


Note: Each figure is shown on a different scale.

Figure 3-1 (Page 4 of 6)
Geometric Mean Concentrations for Selected VOC

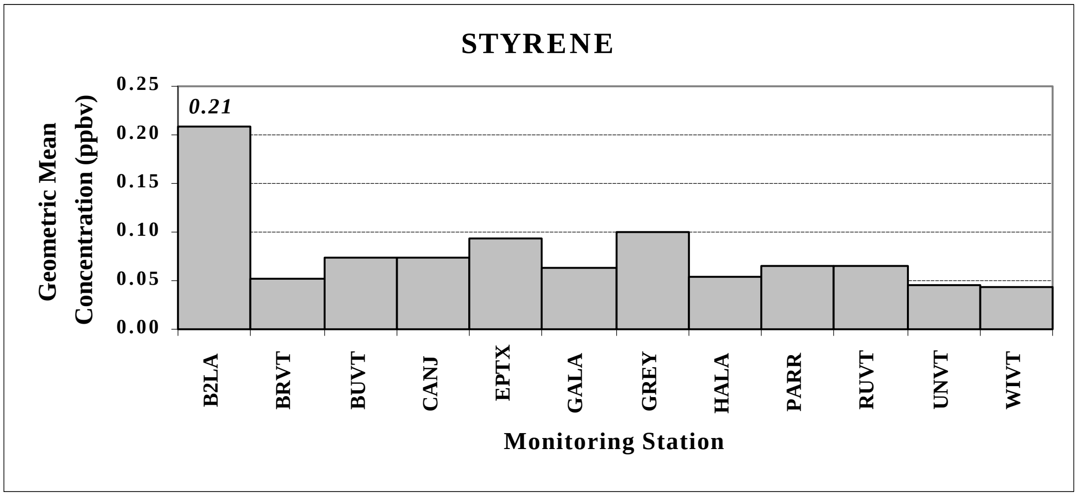


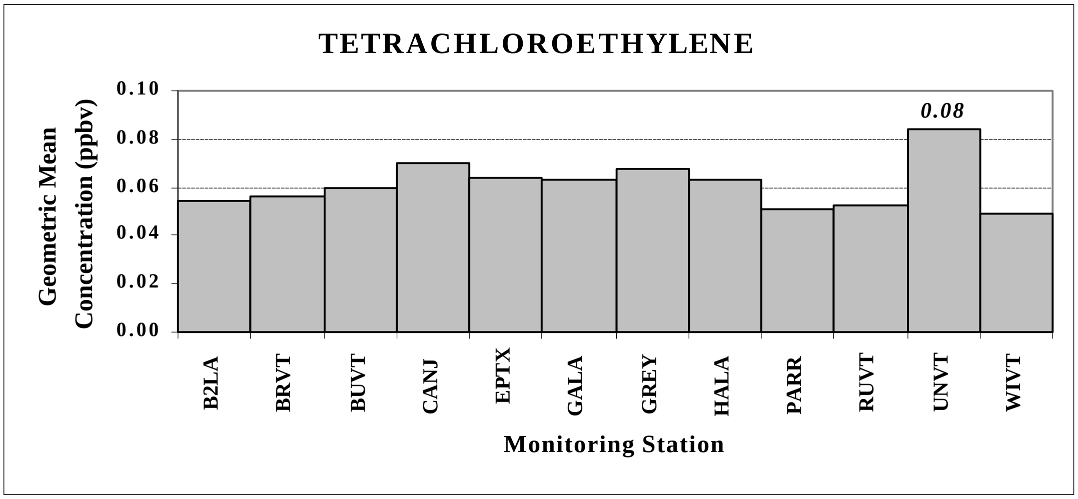


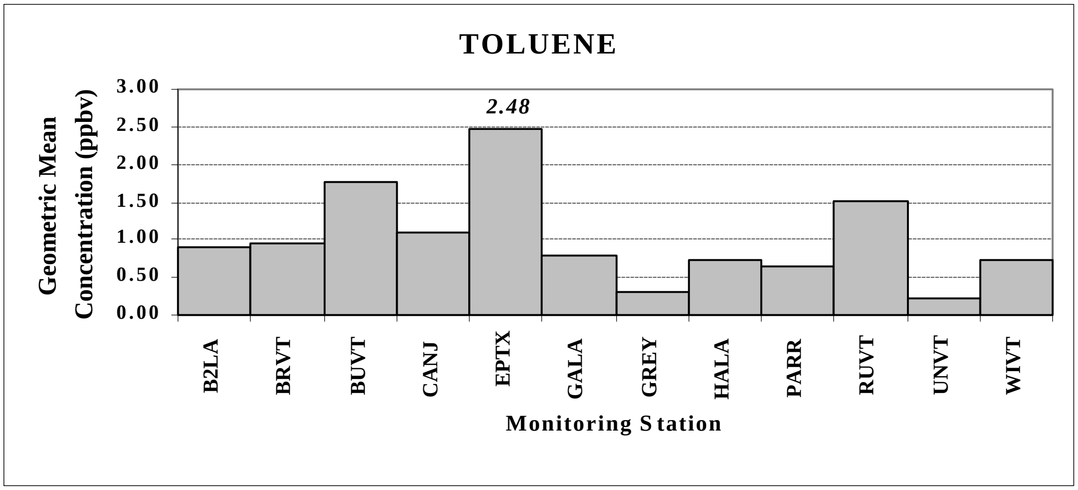


Note: Each figure is shown on a different scale.

Figure 3-1 (Page 5 of 6)
Geometric Mean Concentrations for Selected VOC

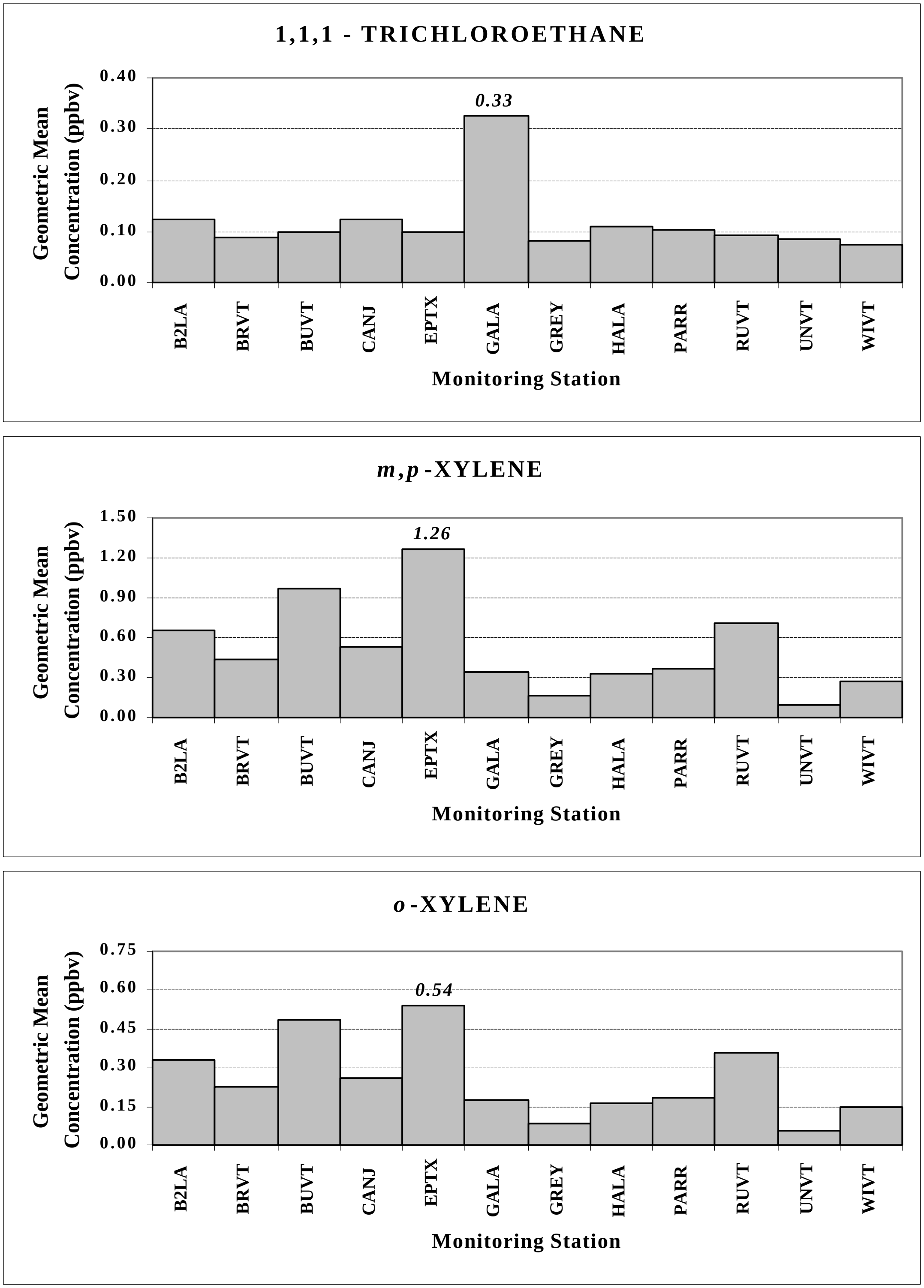






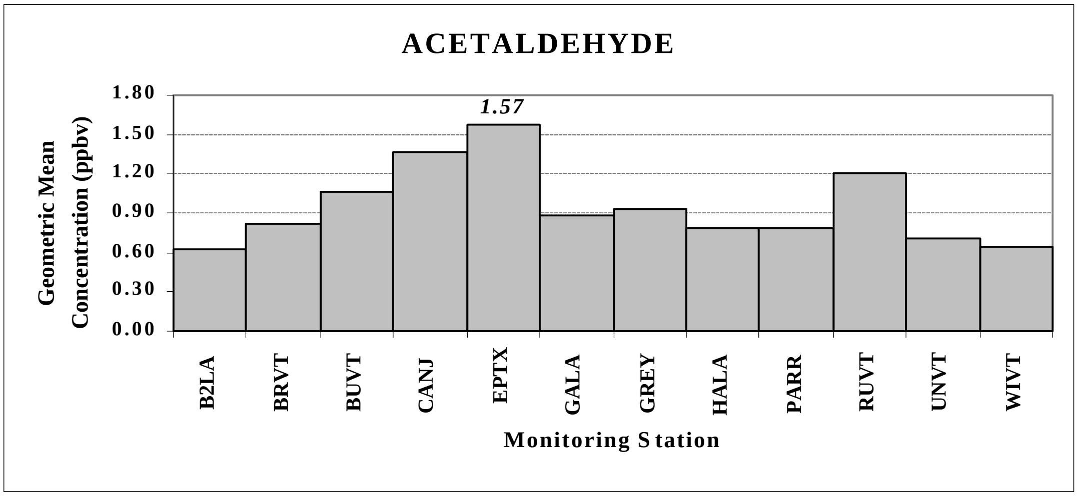
Note: Each figure is shown on a different scale.

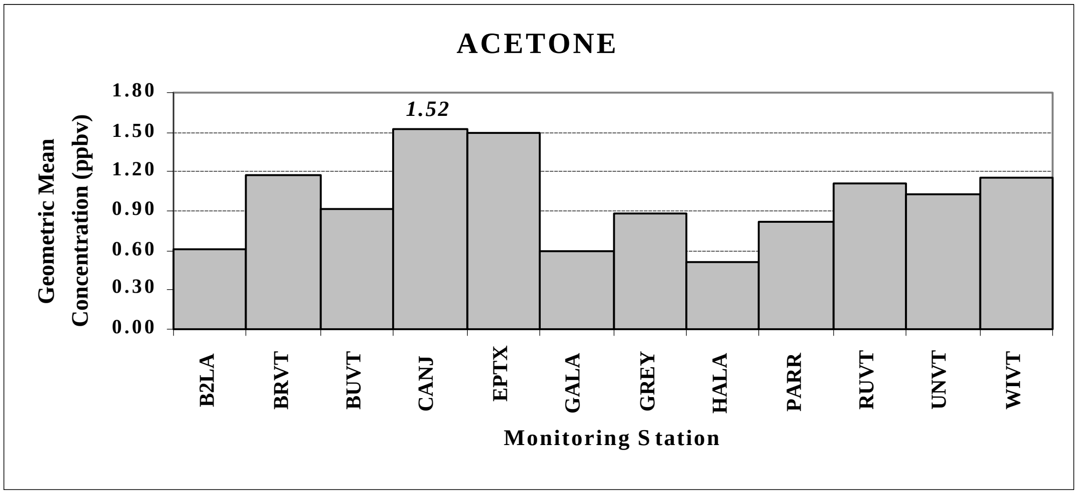
Figure 3-1 (Page 6 of 6)
Geometric Mean Concentrations for Selected VOC

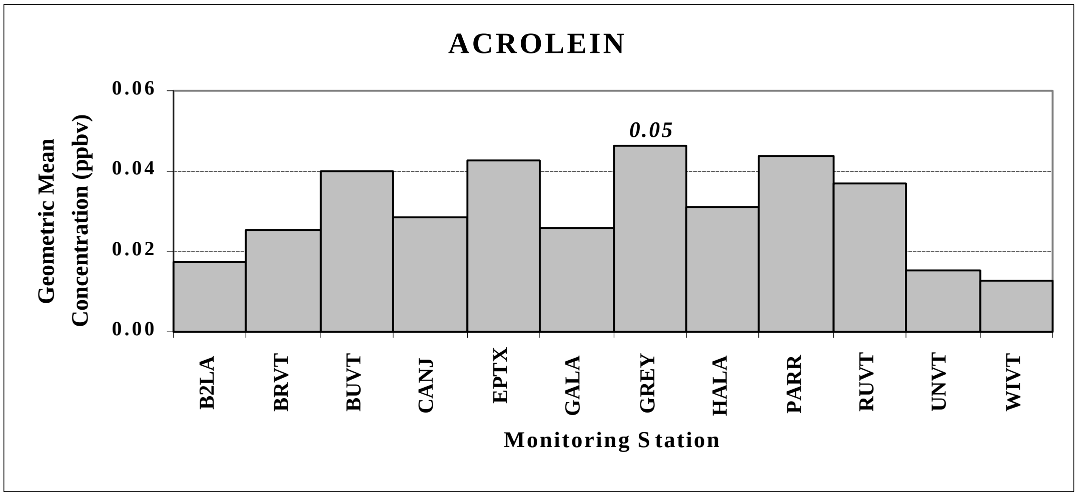


Note: Each figure is shown on a different scale.

Figure 3-2 (Page 1 of 4)
Geometric Mean Concentrations for Selected Carbonyls

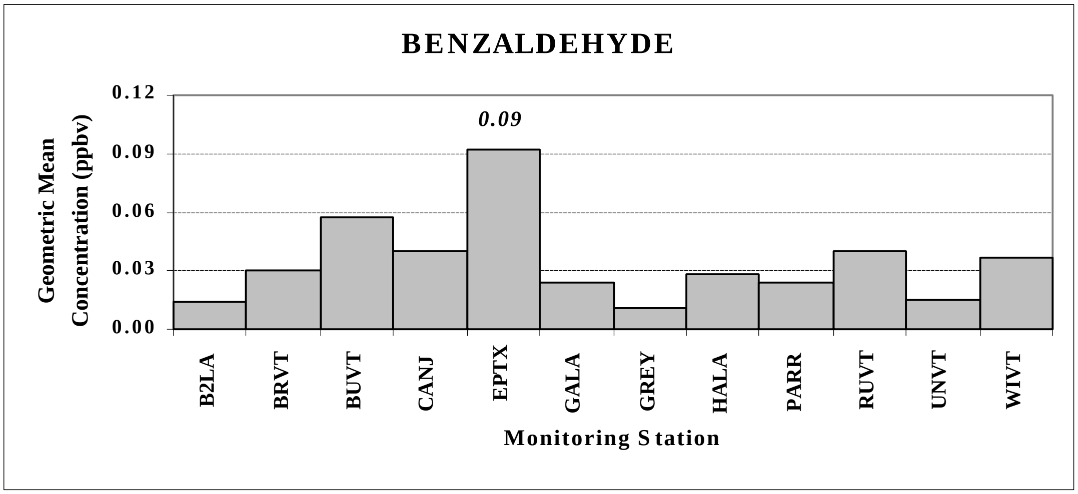


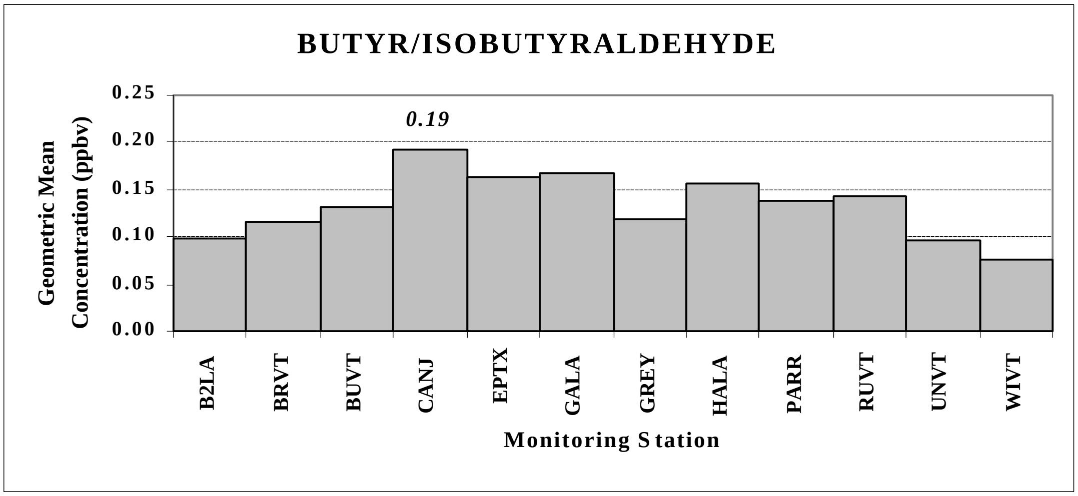


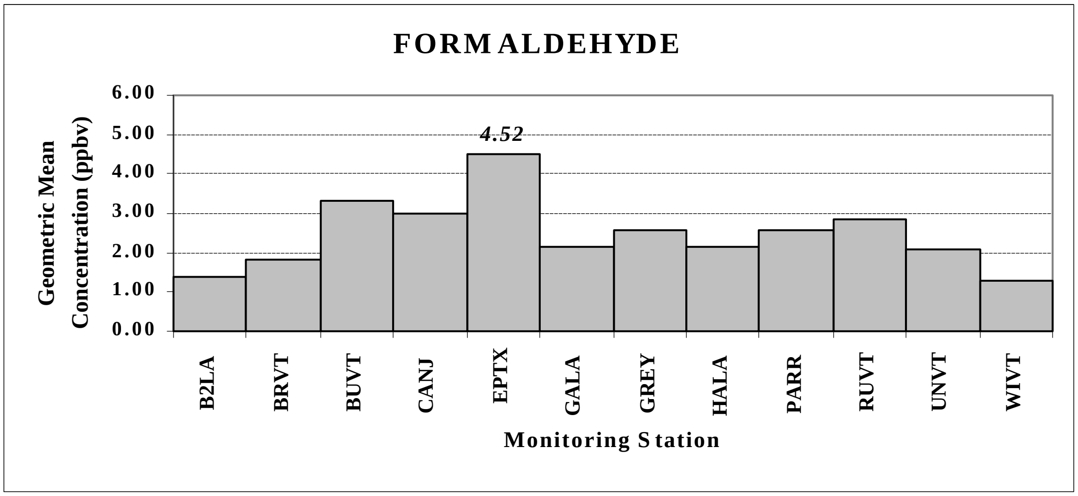


Note: Each figure is shown on a different scale.

Figure 3-2 (Page 2 of 4)
Geometric Mean Concentrations for Selected Carbonyls

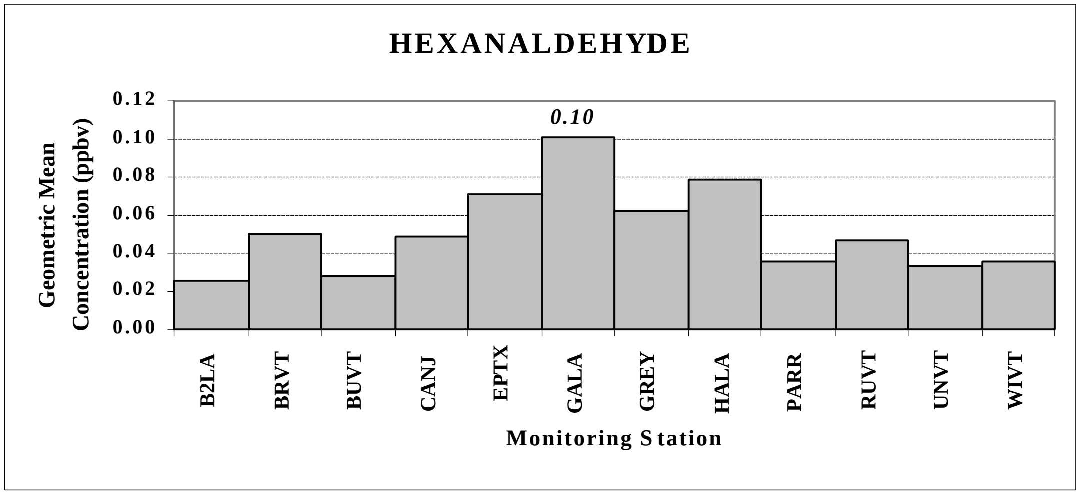


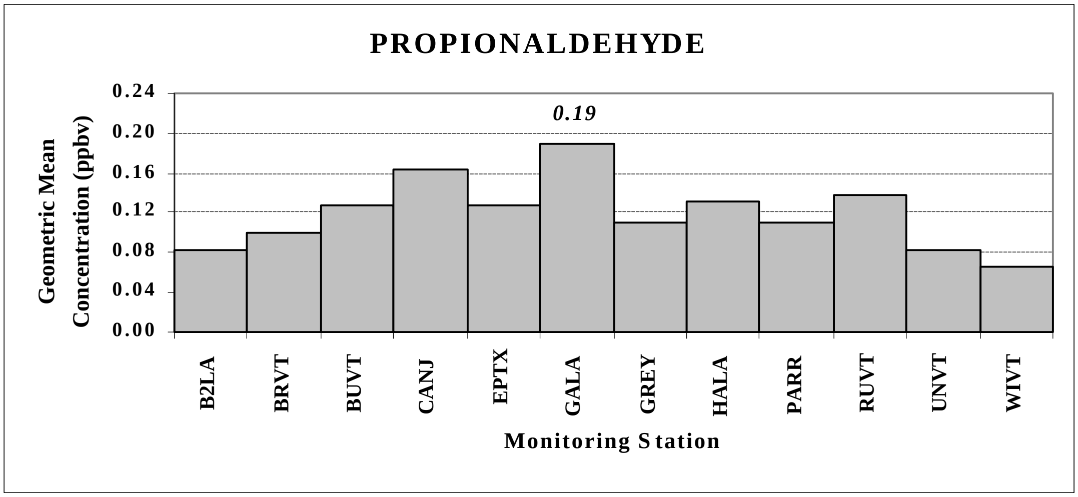


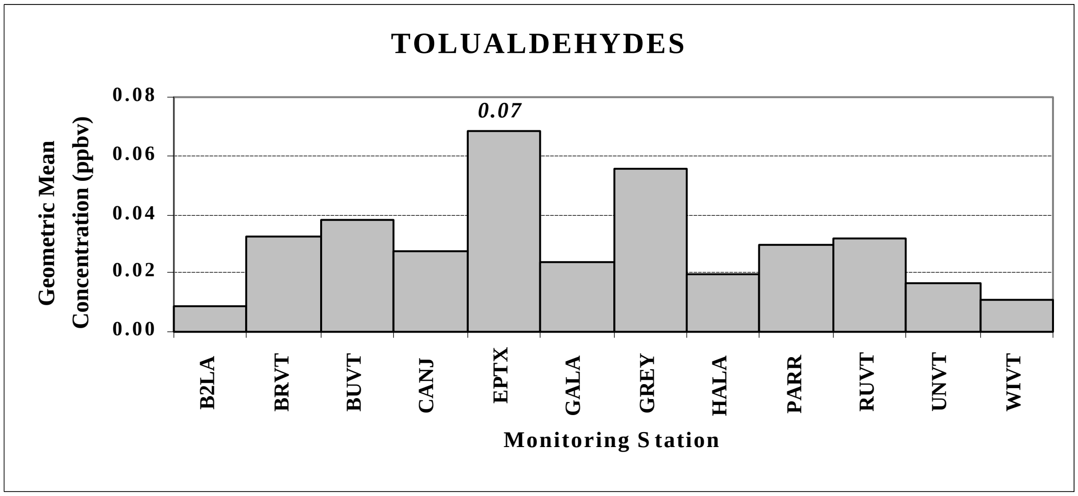


Note: Each figure is shown on a different scale.

Figure 3-2 (Page 3 of 4)
Geometric Mean Concentrations for Selected Carbonyls







Note: Each figure is shown on a different scale.

Figure 3-2 (Page 4 of 4)
Geometric Mean Concentrations for Selected Carbonyls

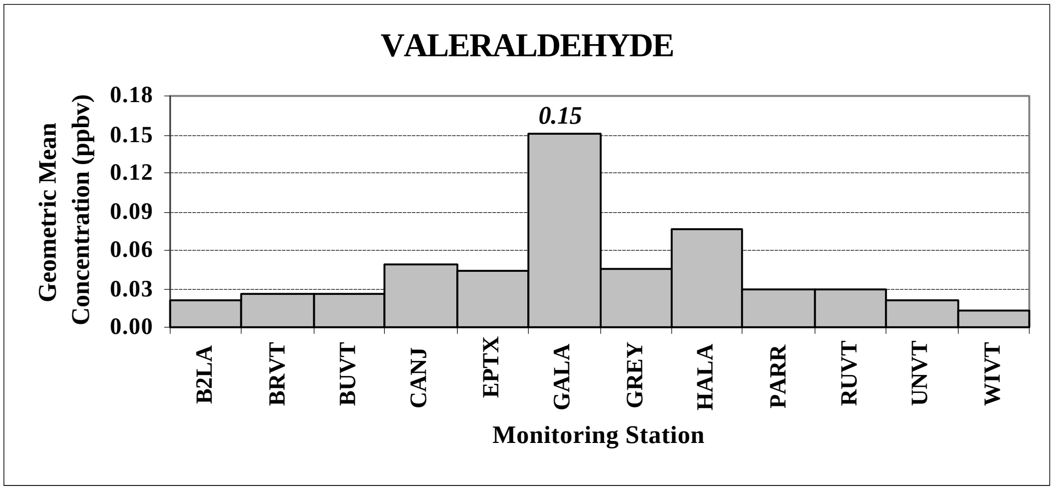


Table 3-1
Availability of UATMP Monitoring Data from Previous Program Years

Monitoring Station	Program Years During Which Station Participated in the UATMP			
	1994	1995	1996	1997
Baton Rouge, LA (B2LA)		✓	✓	✓
Brattleboro, VT (BRVT)		✓	✓	✓
Burlington, VT (BUVT)		✓	✓	✓
Camden, NJ (CANJ)	✓	✓	✓	✓
El Paso, TX (EPTX)		✓	✓	✓
Garyville, LA (GALA)		✓	✓	✓
Hahnville, LA (HALA)		✓	✓	✓
North Little Rock, AR (PARR)				✓
Rutland, VT (RUVT)		✓	✓	✓
Texarkana, AR (GREY)				✓
Underhill, VT (UNVT)		✓	✓	✓
Winooski, VT (WIVT)		✓	✓	✓

Notes: As Section 3.3 describes, some of the stations shown in the table participated in UATMPs prior to the 1994 program. However, this report only considers ambient air monitoring data collected during the current procurement (i.e., UATMP program years 1994 through 1997).

The monitoring station at Brattleboro, Vermont, collected air samples only during a small portion of the 1995 UATMP. Section 5.3 describes the significance of this limited sampling.

As Section 2.3 notes, the monitoring stations at North Little Rock, Arkansas (PARR), Texarkana, Arkansas (GREY), and Winooski, Vermont (WIVT) did not collect air samples throughout the 1997 UATMP.

4.0 Monitoring Results for Baton Rouge, LA (B2LA), Garyville, LA (GALA), and Hahnville, LA (HALA)

This section summarizes and interprets ambient air monitoring data collected over the last 3 years in three Louisiana cities along the Mississippi River: Baton Rouge, Garyville, and Hahnville. Because two of the air monitoring stations (GALA and HALA) are located within 15 miles of each other, the air quality in these two cities may be influenced by some of the same factors. Air quality at the Baton Rouge monitoring station (B2LA) may not be influenced by the same factors as air at GALA and HALA, since it is roughly 75 miles away from these sites. However, showing the B2LA data along with the GALA and HALA data may reveal regional trends in the air quality of southeast Louisiana. For these reasons, results from the three stations are presented in this one section, instead of in three separate sections.

Figures 4-1, 4-2, and 4-3 illustrate the land use in the area immediately surrounding the Baton Rouge, Garyville, and Hahnville monitoring stations. The B2LA station is located in a highly industrial area of Baton Rouge. Approximately 335,000 people live, and numerous industrial facilities operate, within 10 miles of the B2LA station, and Interstate 110 passes within 2 city blocks of the monitoring station. Southeast of B2LA, the GALA and HALA monitoring stations are located in two smaller towns within 15 miles of one another. HALA is located directly across the Mississippi River from a large refinery, and numerous other industrial facilities are located near the monitoring site. The GALA station is on the roof of a high school in a residential area; a large refinery and other industries are located nearby.

Table 4-1 presents completeness data for the B2LA, GALA, and HALA monitors. The completeness of VOC and carbonyl sampling at the three stations ranged from 81 to 92 percent. These high completeness figures suggest that the 1997 UATMP was efficiently managed at B2LA, GALA, and HALA. With relatively few void samples, the air monitoring data for these stations are expected to represent actual annual trends in air pollution.

The remainder of this section summarizes the 1997 UATMP monitoring data for B2LA, GALA, and HALA (Section 4.1), analyzes in detail ambient air concentrations of selected nitriles and oxygenated compounds at these three stations (Section 4.2), and illustrates how ambient air concentrations of certain compounds have changed in southeast Louisiana since the 1995 UATMP (Section 4.3). For quick reference, this section concludes with a brief summary that highlights the most notable air quality trends observed for this area (Section 4.4).

4.1 Data Summary Parameters for the 1997 UATMP

Tables 4-2 through 4-4 and 4-6 through 4-8 use the data summary parameters defined in Section 3.1 to thoroughly describe the ambient air monitoring data collected at the B2LA, GALA, and HALA monitoring stations. The format used in these tables is the same as that used in earlier reports, thus facilitating comparisons of selected summary statistics from one year to the next.

4.1.1 Data Summary of VOC

Tables 4-2, 4-3, and 4-4 reveal the following notable trends regarding ambient air concentrations of VOC at B2LA, GALA, and HALA, respectively:

- *Prevalence.* According to the data summary tables, the following 15 compounds were detected in more than half of the ambient air samples collected at the monitoring stations in Baton Rouge, Garyville, and Hahnville:

  Acetylene
  Benzene
  Carbon tetrachloride
  Chloromethane
  Ethylbenzene
  Methylene chloride
  Methyl ethyl ketone
  n-Octane
  Propylene
  Styrene
  Toluene
  1,1,1-Trichloroethane
  m,p-Xylene
  o-Xylene

  In addition, acetonitrile, 1,3-butadiene, and tetrachloroethylene were detected in more than half of the samples at B2LA, but not at GALA or HALA. Most of the analyses in this section focus on the compounds with highest prevalence: their summary statistics are least affected by nondetect observations, which are replaced in the UATMP database with an estimated concentration of one-half the detection limit.

The high prevalence of acetonitrile at B2LA appears to be a unique, site-specific trend. The compound was detected in every valid sample at Baton Rouge, but was detected in fewer than 30 percent of the samples at every other monitoring station in the 1997 UATMP. Section 4.2 discusses air quality trends for this compound in greater detail.

Despite the emphasis this section places on the most prevalent compounds, it should not be inferred that the other compounds are not present in the ambient air in southeast Louisiana. The least prevalent compounds may exist in the air, but at levels consistently below what the VOC analytical method can measure. Thus, statistically meaningful air quality trends cannot be calculated for these compounds.

- *Concentration range.* Tables 4-2 through 4-4 also show the range of ambient air concentrations measured at B2LA, GALA, and HALA. At all three monitoring stations, at least one 24-hour average concentration was higher than 1.0 ppbv for the following eight compounds: acetonitrile, acetylene, benzene, methyl ethyl ketone, propylene, toluene, and *m,p*-xylene.

  In addition, some other compounds had 24-hour average concentrations above 1.0 ppbv at only one or two of the monitoring sites. These compounds include acrylonitrile (at HALA), 1,3-butadiene (at B2LA), chloroform (at B2LA), chloromethane (at GALA and HALA), chloroprene (at GALA), methylene chloride (at GALA and HALA), methyl *tert*-butyl ether (at B2LA), *n*-octane (at HALA), and 1,1,1-trichloroethane (at GALA and HALA). The fact that so many compounds had relatively high concentrations at one or two sites, but not at all three, suggests that local emissions sources, and probably not emissions sources common to all three areas, account for the peak concentrations of these compounds.

  Two compounds—acetonitrile and 1,1,1-trichloroethane—had particularly high peak concentrations at some, or all, of the monitors in southeast Louisiana. For instance, the highest concentrations of acetonitrile at B2LA (402.0 ppbv), GALA (30.53 ppbv), and HALA (6.54 ppbv) were among the highest concentrations of this compound observed at all 12 UATMP monitoring stations. In fact, even the *lowest* concentration of acetonitrile at B2LA (6.16 ppbv) was much higher than the *highest* concentration of most other compounds at this and other stations. Section 4.2 discusses ambient air concentrations for acetonitrile in greater detail. In the case of 1,1,1-trichloroethane, the highest concentration at GALA (138.76 ppbv) was the highest level of this compound measured during the entire 1997 UATMP; yet, concentrations of 1,1,1-trichloroethane at B2LA and HALA never exceeded 1.03 ppbv. This spatial variation can be best explained by a predominant emissions source of the compound being located closest to the GALA monitoring station. Analyses later in this section revisit this issue.

When interpreting data on highest concentrations, it is important to note that the UATMP monitors did not collect samples daily. Thus, the concentration ranges in the summary tables probably do not represent the actual span of ambient air concentrations in southeast Louisiana; ambient air concentrations probably rose to higher levels on days when samples were not collected.

- *Central tendency*. Table 4-5 lists the geometric mean concentrations of the 15 most prevalent compounds detected at the three monitoring sites in southeast Louisiana. Clearly, the geometric mean concentrations for these compounds vary among the three monitoring stations. These spatial variations can be classified into three categories: compounds with no notable spatial variations, compounds with highest levels at B2LA, and compounds with highest levels at GALA. The following provides a description of these categories in detail:

  (1) Two of the 15 most prevalent compounds, carbon tetrachloride and methylene chloride, have geometric mean concentrations that are not notably different at the B2LA, GALA, and HALA monitoring locations. The final report for the 1996 UATMP demonstrated that concentrations of carbon tetrachloride are relatively constant, regardless of geographical location, time of year, and proximity to industrial or motor vehicle emissions sources. The data in Figure 3-1 support this hypothesis. For these reasons (and other reasons documented in the 1996 report), concentrations of carbon tetrachloride in southeast Louisiana are believed to represent a “global background level,” influenced little by local emissions sources. As noted in the discussions on variability (below), the relatively similar concentrations of methylene chloride at B2LA, GALA, and HALA appear to be linked to industrial emissions sources. Though the predominant sources of this compound in each area are not known, they probably include the several facilities in the area that reported releases of methylene chloride to TRI and the countless smaller facilities in the area that use the compound but are not required to report releases to TRI. The similarity in the ambient air concentrations implies, though certainly does not prove, that industries in the vicinity of the B2LA, GALA, and HALA monitoring stations emit comparable quantities of methylene chloride.

  (2) As Table 4-5 shows, the following 11 compounds had higher geometric mean concentrations at B2LA than at GALA and HALA: acetylene, benzene, ethylbenzene, methyl ethyl ketone, *n*-octane, propylene, styrene, toluene, *m*,*p*-xylene, and *o*-xylene. Statistical analyses indicate that concentrations of acetylene, benzene, ethylbenzene, toluene, and the xylene

isomers are highly correlated at each of the monitoring stations. These results suggest that an emissions source found at all three monitoring locations predominantly affects ambient air concentrations of these compounds: both motor vehicles and industrial emissions sources (particularly oil refineries) are found throughout the area. The higher geometric mean concentrations for these compounds at B2LA probably results from a higher level of vehicular traffic near the monitoring site.

Though motor vehicle exhaust is known to contain propylene, no significant correlations were found between concentrations of propylene and concentrations of other hydrocarbons measured at the B2LA, GALA, and HALA monitors. The lack of correlations suggest that other factors, most likely industrial emissions, significantly affect ambient air concentrations of this compound. The TRI data for reporting year 1995 support this hypothesis: three facilities within the Baton Rouge city limits reported emitting over 300,000 pounds of propylene to the air in 1995; a facility located in very close proximity to the HALA monitoring station reported emitting over 1,300,000 pounds; and several other facilities in southeast Louisiana also released propylene to the air, but at locations far from the monitoring stations. Therefore, a combination of motor vehicle emissions and industrial emissions most likely accounts for the spatial variations in propylene concentrations in southeast Louisiana.

Similar to the spatial variations observed for propylene, the spatial variations for methyl ethyl ketone, *n*-octane, and styrene are expected to result from some combination of emissions from motor vehicle and industrial sources. Section 4.2 considers the data patterns for methyl ethyl ketone in greater detail, and the relative contributions of different sources for *n*-octane are difficult to assess since industrial facilities are not required to disclose releases of the compound to TRI. The spatial variations in levels of styrene, however, appear to be linked primarily to emissions from industrial sources, for three reasons. First, the geometric mean concentration at B2LA was over three times higher than that at GALA and HALA; yet, compounds typically associated with motor vehicle exhaust exhibited far less pronounced concentration differences among these monitoring locations. Second, according to the 1995 TRI data, the combined emissions of styrene from six industrial facilities in the Baton Rouge city limits was over 150,000 pounds, and emissions from facilities near GALA and HALA were approximately an order of magnitude lower. Third, because the geometric mean concentration of styrene at B2LA was more than twice as high as that at EPTX (the station believed to be most affected by emissions from motor vehicles), it is highly unlikely that emissions from motor vehicles alone explain the relatively high levels of styrene at B2LA. More detailed inventories of local sources, including those not required to report to TRI, may help identify other notable sources of styrene in the area.

(3) Of the 15 compounds listed in Table 4-5, only chloromethane and 1,1,1-trichloroethane had geometric mean concentrations that were higher at GALA than at either B2LA or HALA. Though the geometric mean concentration of chloromethane differs among the monitoring locations in southeast Louisiana, the difference in concentrations is only marginal: the geometric mean concentration at GALA is only 14 percent higher than that at HALA and just over 50 percent higher than that at B2LA. It is uncertain whether such a marginal difference reflects spatial variations in an emissions source or simply natural fluctuations in air quality.

On the other hand, geometric mean concentrations of 1,1,1-trichloroethane at GALA were nearly three times higher than those at HALA and B2LA. Closer inspection of the monitoring data reveals that two outlier concentrations at GALA (57.3 ppbv and 138.76 ppbv) account for much of the higher central tendency figures at this station. Even disregarding these outliers, however, the geometric mean concentration at GALA would be 0.22 ppbv, which is still nearly twice as high as the geometric mean concentrations at B2LA and HALA. Therefore, an emissions source (or sources) near the GALA monitoring station probably best explains the spatial variations in 1,1,1-trichloroethane observed for these monitors. Only one industrial facility in the area—an oil company in Garyville, Louisiana—reported air releases of the compound to TRI in 1995, but the magnitude of the air releases (60 pounds) is far too low to account for the spatial variations in air quality. Further research is encouraged to identify additional sources of 1,1,1-trichloroethane in the vicinity of GALA.

To compare ambient concentrations of VOC in southeastern Louisiana with those at other UATMP monitoring stations, Figure 3-1 shows geometric mean concentrations for selected VOC. This figure reveals several important features of the data gathered during the 1997 UATMP. First and most apparent of these features is the geometric mean concentration of acetonitrile at B2LA (86.86 ppbv) being more than two orders of magnitude higher than that at every other UATMP monitoring station. The most logical explanation for the elevated concentration in just one city is an emissions source specific to the area. The 1995 TRI data indicate that two facilities in the Baton Rouge city limits emitted a total of 10,428 pounds of acetonitrile to the air in a year, but the emissions from these sources (if accurately reported) are notably lower than those for other compounds in the area. It is possible that the high levels of acetonitrile at B2LA may result from the fact that the compound is relatively unreactive in ambient air (see Section 3.2)—once emitted to the air, acetonitrile probably gradually transports to regions of lower concentration, rather than decomposing in the air or reacting with other compounds in the air. Section 4.2 discusses the measured levels of acetonitrile in greater detail.

Other important features apparent from Figure 3-1 are that B2LA had the highest geometric mean concentration of styrene and the second highest of methyl ethyl ketone and that GALA had the highest geometric mean concentration of 1,1,1-trichloroethane. (Note: GALA also had the highest geometric mean concentration of chloromethane, but levels of this compound at GALA were only marginally higher than those at the other stations.) As noted above, industrial emissions most likely account for these trends; Section 4.2 considers spatial variations of methyl ethyl ketone in greater detail.

Note: When interpreting the graphs in Figure 3-1, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within these areas. Since the 1997 UATMP did not sample air in most urban centers in the United States, the fact that B2LA and GALA had the highest geometric mean concentrations of certain compounds does not necessarily mean that levels of air pollution in these areas are worse than those in every other urban area.

- *Variability*. With four exceptions, coefficients of variation for the most prevalent VOC at the three monitoring stations in southeast Louisiana were lower than 2.0. The exceptions were: methylene chloride at GALA and HALA, methyl ethyl ketone at GALA, and 1,1,1-trichloroethane at GALA. The relatively higher variability for these compounds provides evidence that they originated primarily from emissions sources at discrete locations (e.g., industrial emissions sources), because the monitors would probably detect the compound only when emissions from these specific locations blew toward the station.

To provide more information on trends and patterns among VOC monitoring data in southeast Louisiana, Section 4.2 describes in detail the monitoring data for nitriles and oxygenated compounds and Section 4.3 comments on annual variations.

4.1.2 Data Summary of Carbonyls

Tables 4-6 through 4-8 reveal the following notable trends regarding ambient air concentrations of carbonyls at B2LA, GALA, and HALA, respectively:

- *Prevalence.* The prevalence data in Tables 4-6 through 4-8 indicate that all but six of the carbonyl compounds (crotonaldehyde, 2,5-dimethylbenzaldehyde, isovaleraldehyde, and tolualdehydes) were detected in at least half of the samples collected at the B2LA, GALA, and HALA monitoring stations. Of these six, isovaleraldehyde and the tolualdehyde isomers were detected in over half of the valid samples at GALA and HALA, but not at B2LA. Since almost every carbonyl was detected at measurable levels at these stations, summary statistics for most of the carbonyls are likely not influenced by large numbers of nondetect observations. Therefore, most of the summary statistics are expected to represent actual air quality trends for carbonyls in southeast Louisiana.

- *Concentration range.* Only acetaldehyde, acetone, and formaldehyde had at least one 24-hour average concentration higher than 1.0 ppbv at all three monitoring stations. Concentrations of hexanaldehyde at HALA and GALA and concentrations of butyr/isobutyraldehyde and valeraldehyde at HALA also exceeded this threshold. At all three monitoring stations, formaldehyde had the highest concentration of all 16 carbonyls. Again, the highest and lowest concentrations shown in Tables 4-6 through 4-8 are only estimates of the actual concentration ranges, since concentrations may have reached higher and lower levels on days when samples were not collected.

- *Central tendency.* At all three stations, the combined geometric mean concentrations of acetaldehyde, acetone, and formaldehyde account for over 80 percent of the concentration of total carbonyls measured during the 1997 UATMP, and formaldehyde accounts for more than 47 percent at each site. To highlight the spatial variations in concentrations of carbonyls, Table 4-9 lists the geometric mean concentrations of the 10 most prevalent compounds detected at the B2LA, GALA, and HALA monitoring stations. In comparison to Table 4-5, which shows a great degree of difference among geometric mean concentrations for some VOC, Table 4-9 indicates a notable similarity in the geometric mean concentrations across all three stations for most every carbonyl. Of particular significance, geometric mean concentrations of the three carbonyls consistently detected at highest levels (acetaldehyde, acetone, and formaldehyde) differed by no more than 55 percent among the three monitoring stations; geometric mean concentrations of some VOC, on the other hand, differed by more than 300 percent among the three stations. This different spatial variation provides some evidence that the factors most affecting ambient levels of carbonyls in southeast Louisiana differ from those affecting concentrations of VOC. Further research is needed to determine the extent to which different factors (such as emissions from natural sources, emissions from motor vehicles, and photochemical reactions) explain the notably weaker spatial variations for carbonyls.

Figure 3-2 compares the geometric mean concentrations of carbonyls in southeast Louisiana with those at the other 1997 UATMP monitoring stations. Except for a few compounds at GALA, geometric mean concentrations of the most prevalent carbonyls at the monitoring stations in southeast Louisiana were not unusually higher or lower than those at any other UATMP monitoring station. As the exceptions, GALA had the highest geometric mean concentrations for hexanaldehyde, propionaldehyde, and valeraldehyde. Of these three, only levels of valeraldehyde were notably higher at GALA—by more than a factor of two—than levels at the other UATMP stations. Though carbonyls are emitted by motor vehicles, mobile sources probably do not explain the higher levels of certain carbonyls at GALA, since the surrounding area has little motor vehicle traffic in comparison to the areas surrounding most of the UATMP monitoring stations. It is difficult to determine whether industrial sources account for the relatively high levels of carbonyls at GALA because (1) facilities are not required to disclose information on releases of hexanaldehyde and valeraldehyde to TRI, (2) no facilities in the immediate vicinity of GALA reported releases of propionaldehyde to TRI in 1995, and (3) sources not subject to the 1995 TRI reporting requirements (e.g., electrical utilities and incinerators) may have emitted large quantities of these carbonyls. Section 12.1 comments further on what these spatial variations indicate about the sources of carbonyls in urban ambient air.

- *Variability*. Tables 4-6 through 4-8 show that the coefficients of variation for the most prevalent carbonyls at B2LA and GALA are all lower than 1.5. These similar, relatively low coefficients of variation suggest that these carbonyls are consistently found in ambient air and their concentrations do not change dramatically from one sample to the next, regardless of changing meteorological conditions. At HALA, however, the coefficients of variation for five carbonyls exceeded 1.5. The reason for the greater variability observed at this site is unknown, and warrants further investigation.

For further information on air quality trends for carbonyls, readers should refer to Section 4.3.2 for an overview of how their levels have changed in southeast Louisiana since 1995 and to Section 12.1 for a general summary of carbonyl monitoring data collected at all 12 monitoring stations that participated in the 1997 monitoring program.

4.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

As Section 2.2.1 described, improvements to the VOC analytical method prior to the 1997 UATMP have enabled the detection of nine compounds (all nitriles and oxygenated compounds) that could not be detected in earlier UATMPs. Though the majority of these compounds were rarely detected at all three monitoring stations, the air monitoring data for the remaining compounds provide useful insight into levels of air pollution in southeast Louisiana. The following discussion summarizes air monitoring data collected at B2LA, GALA, and HALA for these compounds:

- *Compounds that were rarely, if ever, detected.* Of the nine nitriles and oxygenated compounds measured during the 1997 UATMP, five (ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, methyl methacrylate, and *tert*-amyl methyl ether) were detected in fewer than 20 percent of the valid samples at the monitoring stations in southeast Louisiana. As a result, little can be said about the air quality trends for these compounds. Nonetheless, a review of industrial emissions of these compounds follows:

  The 1995 TRI data indicate that a facility within 3 miles of the HALA monitoring station released over 57,000 pounds of ethyl acrylate to the air in 1995. However, these emissions apparently did not influence ambient air concentrations at HALA during the 1997 UATMP, possibly because the facility now releases less (or no) ethyl acrylate to the air or because the compound might decompose in air before it reaches the air monitoring station. (As Section 3.2 noted, ethyl acrylate is very reactive in ambient air.) As Tables 4-2 through 4-4 show, methyl isobutyl ketone and methyl methacrylate were both more prevalent in the air at B2LA than they were at both GALA and HALA. Consistent with this observation, the 1995 TRI indicates that three facilities located in Baton Rouge, and no facilities near GALA and HALA, reported releasing methyl isobutyl ketone to the air. However, no facilities in all of southeast Louisiana reported releasing methyl methacrylate, though there are undoubtedly many facilities in the area that use some quantities of the compound. Facilities currently are not required to report releases of ethyl *tert*-butyl ether or *tert*-amyl methyl ether to TRI, but the fact that they were rarely detected at the three monitoring stations suggests that industrial emissions of these compounds are probably relatively insignificant.

- *Acetonitrile.* As Section 4.1.1 noted, ambient air concentrations of acetonitrile at B2LA were, on average, over 100 times higher than those at every other monitoring station. In fact, acetonitrile accounted for over 90 percent of the total VOC detected in most every sample collected at B2LA. These concentrations exhibited significant seasonal variations: the average concentration during the warmer summer months (May to August) was more than six times lower than the average concentration during other times of the year. Such seasonality in ambient air concentrations is typical for compounds that are consumed by photochemical reactions, which reach their peak during the summer months. However, this explanation should be verified by reviewing ambient air monitoring data collected in future years, especially because acetonitrile is relatively unreactive in ambient air (see Section 3.2).

Since no other UATMP monitoring station, including the two other stations in southeast Louisiana, detected acetonitrile at comparable levels, the only logical explanation for the concentrations observed in B2LA is that a source (or sources) that is unique to the area emits the compound. Emissions from motor vehicles probably account for little, if any, of the measured concentrations, because this source is common to all urban environments. Consistent with this observation is the fact that concentrations of acetonitrile at B2LA were very weakly correlated, if not completely uncorrelated, with ambient air concentrations of each one of the most prevalent VOC and carbonyls, including those commonly found in motor vehicle exhaust. Therefore, the predominant emissions source for acetonitrile is probably different from the predominant sources of the various VOC and carbonyls.

The 1995 TRI reveals a significant industrial source of acetonitrile (ranked 25 in acetonitrile releases out of 89 total facilities nationwide) located within 3 miles of B2LA, and a less significant source within the Baton Rouge city limits. Combined, these sources reportedly emitted 10,428 pounds of acetonitrile in 1995—an emissions level that is probably too low to account for the observed levels of acetonitrile. It is unknown whether emissions from these facilities were reported accurately or whether they have increased since the 1995 TRI reporting year. Given the magnitude of the ambient air concentrations of acetonitrile measured at B2LA during the 1997 UATMP, further research into local emissions sources of the compound is encouraged. Note, the analyses in Section 11 list several similarities between the acetonitrile data at B2LA and those at Texarkana, Arkansas (GREY).

- *Acrylonitrile.* Acrylonitrile was detected in eight samples at HALA, but in none of the samples at GALA or B2LA. Almost every detection at HALA was in the months of June, July, and August. Given that acrylonitrile was never detected at GALA and the more densely populated B2LA, the levels of observed at HALA most likely originated from a local industrial source and not from motor vehicles. According to the 1995 TRI, releases of acrylonitrile to the air were reported by facilities within 10 miles of GALA and B2LA (including a facility near B2LA that ranked 28 in acrylonitrile releases out of 105 nationwide), but they were not reported by a single facility near HALA. This apparent inconsistency between TRI data and the UATMP monitoring data highlights the fact that these two methods of evaluating air quality do not always support the same conclusions. The actual source of acrylonitrile releases near the HALA monitoring station is not known.

- *Methyl ethyl ketone.* According to the data summary tables, methyl ethyl ketone was detected in at least 79 percent of the valid samples at all three monitoring stations in southeast Louisiana. The geometric mean concentration of this compound was highest at B2LA, which detected the second highest geometric mean concentration out of all stations that participated in the 1997 UATMP. It is interesting to note that the geometric mean concentration of methyl ethyl ketone at B2LA was almost twice as high as that at EPTX (the monitoring station believed to be most influenced by motor vehicle emissions). Since higher levels of the compound were observed at B2LA (a site assumed to be less influenced by motor vehicle emissions), it can be inferred that methyl ethyl ketone in the air at B2LA probably originated, to a large extent, from industrial sources. According to the TRI, four industrial facilities located within the Baton Rouge city limits together released over 120,000 pounds of methyl ethyl ketone to the air in 1995. Emissions from these sources, plus those from sources not subject to TRI reporting, likely contributed to the relatively high levels of methyl ethyl ketone at B2LA.

  Also consistent with the spatial variations in this compound is the fact that only one facility in the vicinity of GALA and HALA reported emitting methyl ethyl ketone to the air, according to the 1995 TRI. Just as ambient air concentrations of the compound are lower at GALA and HALA than they are at B2LA, the reported emissions of methyl ethyl ketone for this one facility near GALA and HALA (86,000 pounds) are also lower than the reported emissions near B2LA. Although TRI emissions data are consistent with the observed spatial variations in methyl ethyl ketone, many other sources of this compound undoubtedly exist throughout the area.

- *Methyl tert-butyl ether*. Of the three stations in southeast Louisiana, B2LA detected methyl *tert*-butyl ether, an ingredient of reformulated fuels, most frequently. On average, concentrations of methyl *tert*-butyl ether at B2LA were at least three times higher than those at GALA and HALA. Since EPA does not require that motor vehicles in southeast Louisiana use reformulated fuels, it is not likely that motor vehicle emissions explain the spatial variations for this compound.

  Emissions from industrial sources, however, appear to be quite consistent with the varying levels of methyl *tert*-butyl ether in the area. For instance, the facility that reported the highest amount of air emissions of methyl *tert*-butyl ether to TRI in 1995 (356,629 pounds) is located in Baton Rouge, as is another facility that reported far less emissions (6,400 pounds). On the other hand, only two industrial facilities in the vicinity of GALA and HALA reported releasing the compound, and in far less quantities (7,553 pounds and 77,500 pounds). The extent to which the 1995 emissions data represent emissions during the 1997 UATMP is not known. Ongoing analyses of ambient air monitoring data collected in the area and emissions data reported by nearby facilities are encouraged, especially because production demand for methyl *tert*-butyl ether is expected to continue to increase in the coming years (Kirk Othmer, 1985).

For more information on concentrations of methyl *tert*-butyl ether in an area where EPA requires motor vehicles to use reformulated gasoline, readers should refer to the analyses for the Camden monitoring station in Section 7.2.

4.3 Annual Variations

Most of the compounds sampled at the three monitoring stations in southeast Louisiana during the 1997 UATMP were also sampled during the 1995 and 1996 programs, allowing an analysis of yearly trends in concentrations of individual compounds. Comparing annual average concentrations of the most prevalent compounds in this region across the different program years can provide insight into how air quality has changed over this 3-year period. This section does not consider annual variations for the least prevalent compounds, since their summary statistics are highly uncertain due to the many nondetect observations.

Figures 4-4 and 4-5 show the annual average concentrations and their corresponding confidence intervals for each of the most prevalent VOC and carbonyls (except for methyl ethyl ketone, which was not measured during the 1995 UATMP and 1996 UATMP). For the most prevalent compounds, average concentrations are expected to vary, to a certain extent, from one program year to the next, but these changes do not necessarily represent a statistically significant change in air quality. Section 3.3 explains that “significant” changes likely occur when the entire 95-percent confidence interval of an annual average concentration is higher or lower than that of another year’s average concentration. Statistically significant changes in air quality may result from decreased or increased emissions, fluctuating meteorological conditions, and other factors.

When reading the following discussion of “annual” changes in average concentrations, it is important to note that the UATMP year does not correspond with the calendar year. The

UATMP year generally begins in September and ends in August of the following calendar year. Therefore, a significant portion of the data collected in a given UATMP year actually represents air quality during the following calendar year.

4.3.1 Annual Variations for VOC

Figure 4-4 shows how concentrations of the 14 most prevalent VOC changed at the three monitoring stations in southeast Louisiana between the 1995 UATMP and the 1997 UATMP. The common trend among these VOC is that, for the majority of the most prevalent compounds, there were no significant changes in average concentration from one year to the next. Further, no compound exhibited a significant change in average concentration at all three monitoring stations from the 1995 to the 1997 UATMPs. However, Figure 4-4 shows occasions on which significant changes in average concentration occurred for compounds at one or two monitoring stations, but not across all three stations. The following analysis describes the annual variations for different subsets of VOC:

- *BTEX compounds*. The average air concentrations of benzene, toluene, ethylbenzene, and the xylene isomers, as shown in Figure 4-4, did not change significantly between the 1995 and 1997 UATMPs at any of the monitoring stations in southeast Louisiana. Average concentrations of toluene decreased dramatically between the 1995 and 1996 UATMP seasons at HALA (from 5.73 to 0.77 ppbv); however, the lower bound of the 95-percent confidence interval for the 1995 concentration was well below the lower bound of the 95-percent confidence interval for the 1996 concentration. Thus, this change in magnitude may simply be an artifact of basing annual average concentrations on limited samples from a population (i.e., the 365 possible 24-hour average concentrations). In addition to the insignificant changes for the entire BTEX compound group, the average concentrations for benzene, ethylbenzene, and the xylene isomers were all below 1.0 ppbv, so any yearly difference was not only statistically insignificant, but also relatively small. These unchanging levels imply that emissions of BTEX compounds from nearby sources (e.g., cars and refineries) have also changed little over the same time period.

- *Halogenated hydrocarbons*. Four of the most prevalent VOC—carbon tetrachloride, chloromethane, methylene chloride, and 1,1,1-trichloroethane—are halogenated hydrocarbons. Of these, Figure 4-4 shows that only ambient air concentrations of chloromethane had changes that appeared to be statistically significant: chloromethane increased at GALA and HALA between the 1996 and 1997 UATMPs by 56 and 85 percent, respectively. On the other hand, average concentrations at B2LA were relatively consistent throughout all three UATMPs. The high chloromethane concentrations at GALA and HALA during the 1997 UATMP were within the upper level bound for the 1995 UATMP concentrations. Therefore, it is difficult to determine the long-term trend of average concentrations of this compound at these monitoring stations.

Though changes in ambient air concentrations of carbon tetrachloride, methylene chloride, and 1,1,1-trichloroethane do not appear to be statistically significant, some of the estimated annual average concentrations changed dramatically over the last 3 years: (1) levels of methylene chloride at GALA during the 1997 UATMP were about five times higher than levels observed at the station previously; (2) levels of methylene chloride at HALA during the 1996 and 1997 UATMP were over ten times less than they were during the 1995 program; and (3) levels of 1,1,1-trichloroethane at GALA during the 1997 UATMP were over ten times higher than they were during earlier programs. More sophisticated statistical analyses should be performed and additional monitoring data collected and reviewed to determine whether these notable changes are part of a trend over the longer term.

- *Other compounds*. The three other prevalent VOC (acetylene, propylene, and *n*-octane) each exhibited different trends, even though all three are found, to a certain extent, in emissions from the same types of combustion and industrial sources. Figure 4-4 indicates that average concentrations of acetylene decreased significantly between the 1995 and 1996 UATMP seasons at B2LA. Average concentrations at GALA decreased over 50 percent (from 2.69 to 1.15 ppbv) for the same time period; however, the lower bound of the 95-percent confidence interval for the 1995 average concentration extends well below the lower bound for the 1996 average concentration. At HALA, average concentrations decreased between the 1995 and 1997 UATMPs, but this change also does not appear to be statistically significant. The exact reason (or reasons) for these annual variations in acetylene concentrations is not known.

  Average concentrations for *n*-octane increased at all three monitoring stations in southeast Louisiana between the 1996 and 1997 UATMP seasons. However, these increases were all less than 0.1 ppbv; the only significant increase was at GALA, where the average concentration increased by over 100 percent. This statistically significant increase probably results from several different factors, like increases in vehicular traffic and increases in emissions from oil refineries and other industrial sources.

Levels of airborne propylene at B2LA, GALA, and HALA did not show any consistent or significant changes between the 1995 and 1997 UATMPs. Average concentrations have steadily decreased at B2LA and steadily increased at HALA over the three UATMPs, but these changes do not appear to be statistically significant. At GALA, average concentrations were nearly identical during the 1995 and 1996 UATMPs and rose by nearly 50 percent between 1996 and 1997. Review of the 1996 and 1997 TRI data, once available, may put these annual variations for propylene into perspective.

4.3.2 Annual Variations for Carbonyls

Figure 4-5 shows how concentrations of the 10 most prevalent carbonyls have changed in southeast Louisiana since the 1995 UATMP. For each of the prevalent aldehydes (except acrolein), there was a notable and statistically significant decrease in average concentration at all three monitoring stations in southeast Louisiana between the 1995 and 1996 UATMPs, followed by an insignificant change in average concentration between 1996 and 1997. In fact, annual average concentrations for these aldehydes decreased by roughly a factor of three at each monitoring station from the 1995 to the 1996 UATMPs. It is difficult to explain the dramatic difference in aldehyde concentrations for these years. Though significant sources of carbonyls include motor vehicle exhaust, combustion sources, and industrial processes, the average concentrations of other compounds typically originating from these types of sources did not exhibit a similar, dramatic decrease between the 1995 and 1996 UATMP. Further research should explore possible reasons for the notable decrease in carbonyl concentrations in southeast Louisiana during this time.

Contrary to the annual variations observed for aldehydes, the annual variations for acetone (a ketone) were not consistent across the three monitoring stations: levels were essentially unchanged at B2LA from the 1995 UATMP to the 1997 program; levels at GALA decreased by almost a factor of three from the 1995 UATMP to the 1996 UATMP, and then were essentially unchanged from the 1996 to the 1997 programs; and levels at HALA decreased by a factor of two over the last 3 years, but this change may not be statistically significant. Since industrial facilities are no longer required to report releases of acetone to TRI, it is difficult to conclude what factors account for the annual variations observed at B2LA, GALA, and HALA.

4.4 Summary

Overall, the last 3 years of UATMP monitoring data characterize levels of air pollution at three locations along the Mississippi River in southeast Louisiana. Ambient air concentrations of VOC and carbonyls at all three monitoring locations are expected to be influenced, to a certain extent, by motor vehicle emissions, emissions from industrial sources (particularly large oil refineries), and photochemical reactions.

Of the three monitoring stations in the area, geometric mean concentrations of most of the prevalent VOC were highest at B2LA. The higher levels of some of these compounds at B2LA (e.g., benzene, ethylbenzene, and toluene) appear to be caused by the high level of motor vehicle traffic in the immediate vicinity of the monitoring station; the higher levels of other compounds at B2LA (e.g., methyl ethyl ketone and styrene) likely result from nearby industrial emissions sources. Industrial emissions sources also appear to account for the relatively higher concentrations of 1,1,1-trichloroethane observed at the GALA monitoring station. Though ambient air concentrations of most carbonyls differed among the three stations, the spatial variations for carbonyls did not seem as pronounced as those for VOC. At all three stations, acetaldehyde, acetone, and formaldehyde accounted for more than 80 percent of the total carbonyls measured.

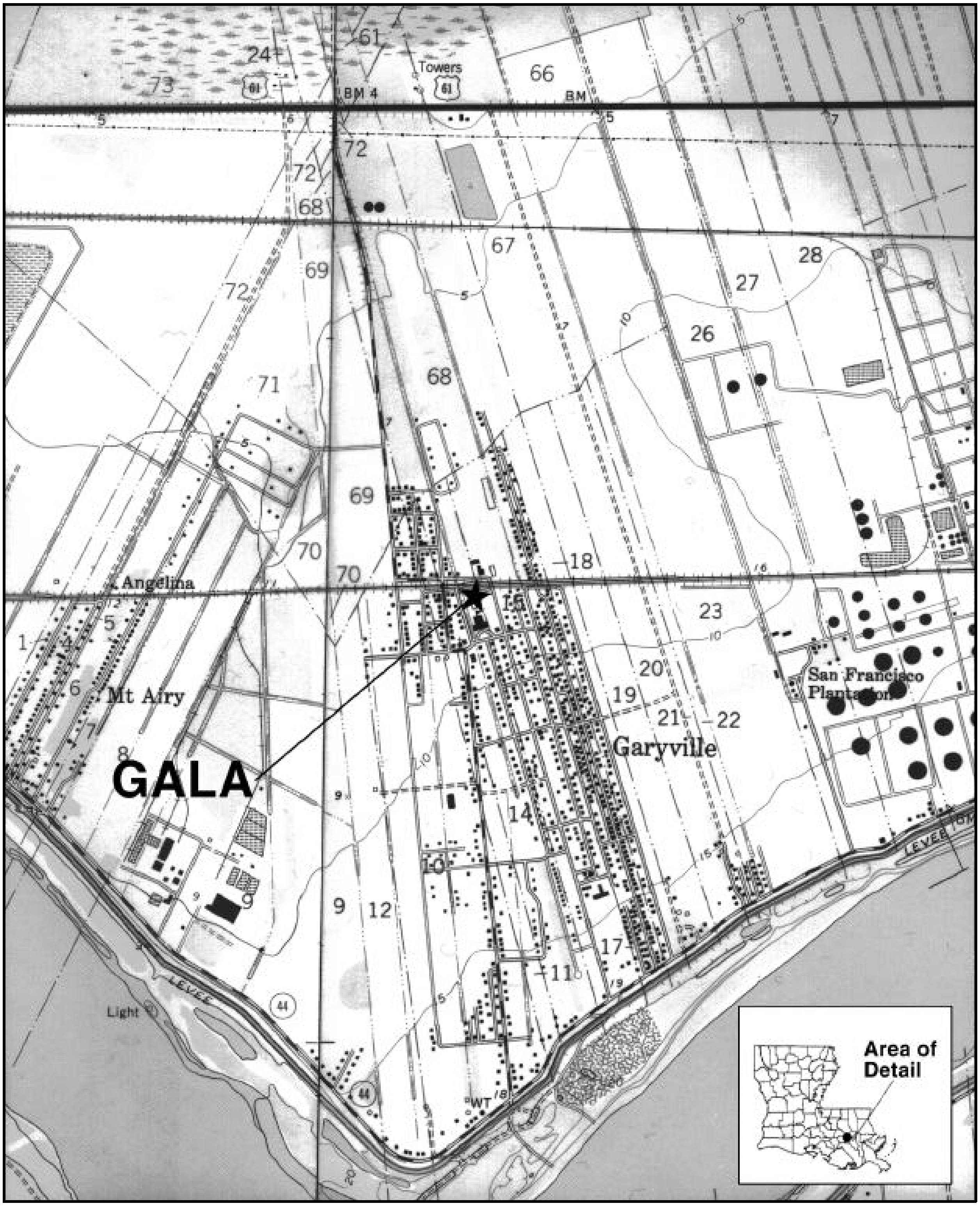
Improvements to the laboratory analytical method for VOC allowed the 1997 UATMP to measure concentrations of nine compounds—all nitriles and oxygenated compounds—that previous UATMPs could not measure. Of these nine compounds, two exhibited notable spatial variations in southeast Louisiana: the geometric mean concentration of acetonitrile at B2LA was over 100 times higher than those observed at GALA and HALA, and the geometric mean concentration of methyl *tert*-butyl ether at B2LA was over three times higher than those observed at GALA and HALA. The analyses in this section provide compelling evidence that industrial emissions sources in the Baton Rouge area account for most, if not all, of the elevated concentrations of acetonitrile and methyl *tert*-butyl ether at B2LA. The air quality trends for these compounds are inconsistent with motor vehicle emissions being the predominant source.

Annual measurements of VOC at B2LA, GALA, and HALA show a variety of trends; however, no trend common to logical groupings of compounds is readily apparent. Therefore, perhaps the most notable air quality trend for VOC at these stations is the absence of significant annual variations. Annual measurements of carbonyls at B2LA, GALA, and HALA, however, revealed a more consistent temporal trend than the VOC. Between the 1995 and 1996 UATMPs, average concentrations of the most prevalent aldehydes (except for acrolein) had a notable and statistically significant decrease. This decrease was followed by a similarly consistent, but negligible, change in average concentrations between the 1996 and 1997 UATMPs. Without detailed emissions data for the 3 years encompassing these UATMP seasons, it is difficult to explain these annual trends. However, the fact that annual variations for many carbonyls are similar at the three monitoring stations in southeast Louisiana provides some evidence that air quality trends for these compounds may be regional in nature. This hypothesis can be investigated further by collecting and reviewing several more years of ambient air monitoring data in this area.

Figure 4-1
Baton Rouge, Louisiana (B2LA), Monitoring Station

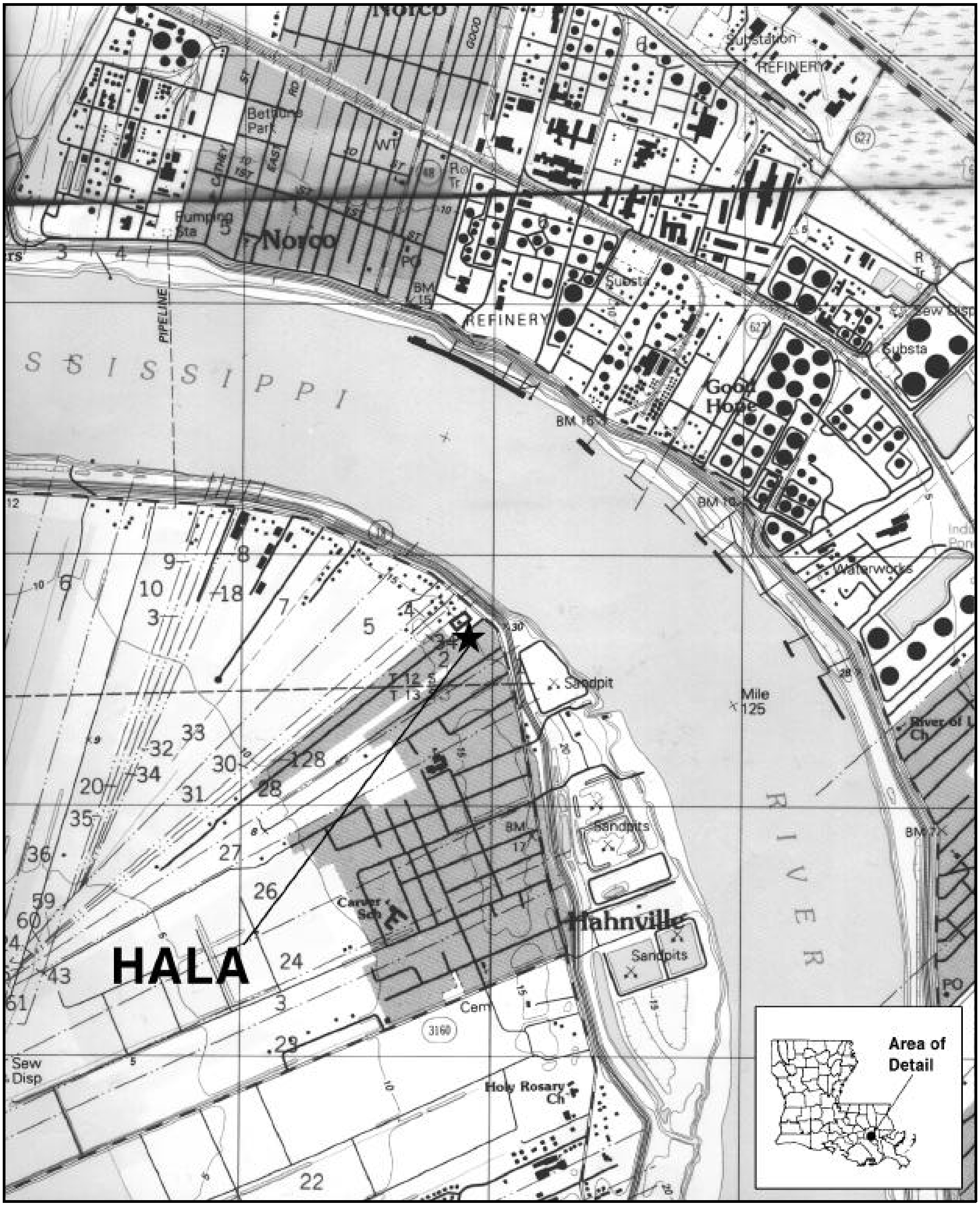
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 4-2
Garyville, Louisiana (GALA), Monitoring Station



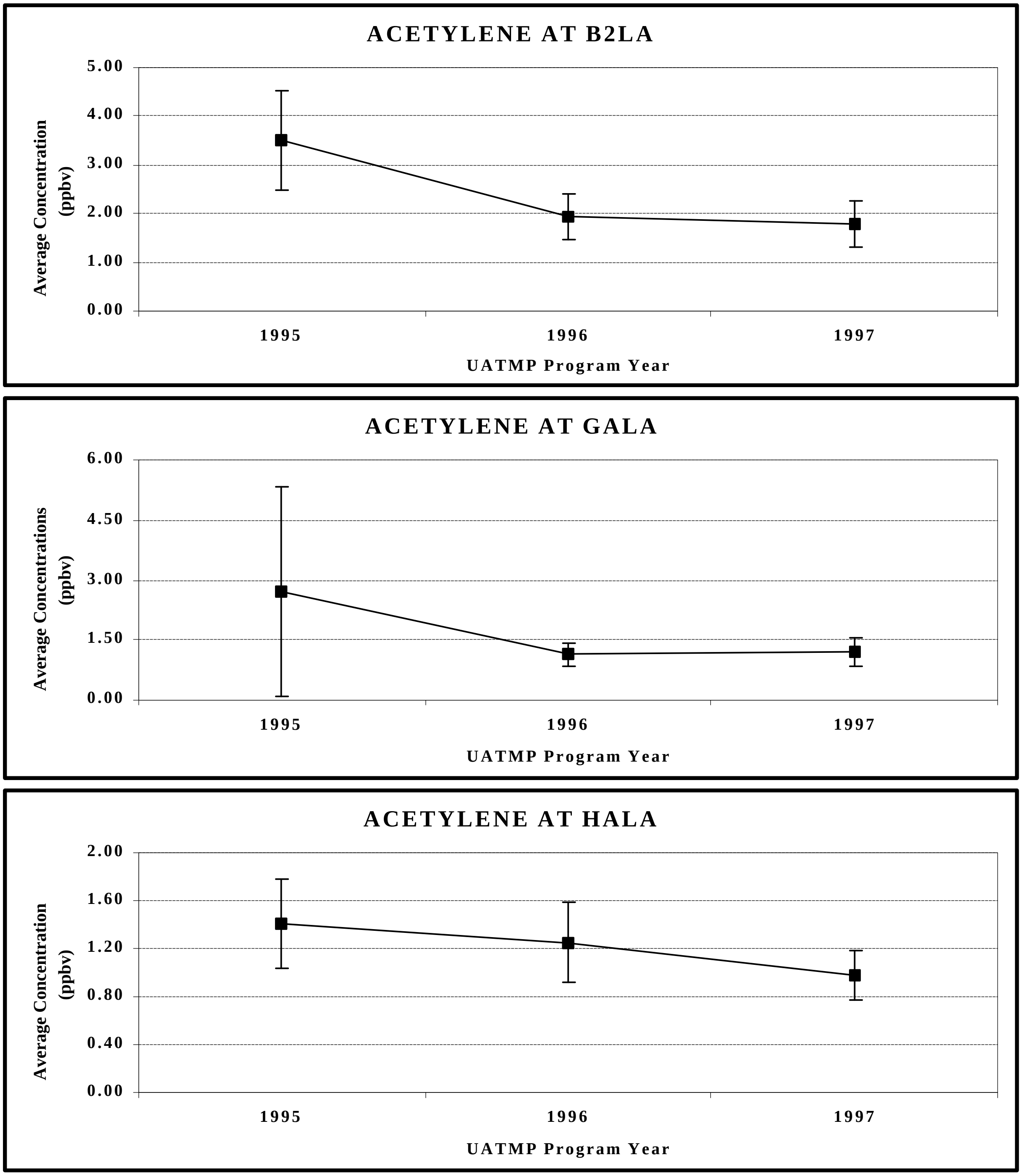
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 4-3
Hahnville, Louisiana (HALA), Monitoring Station



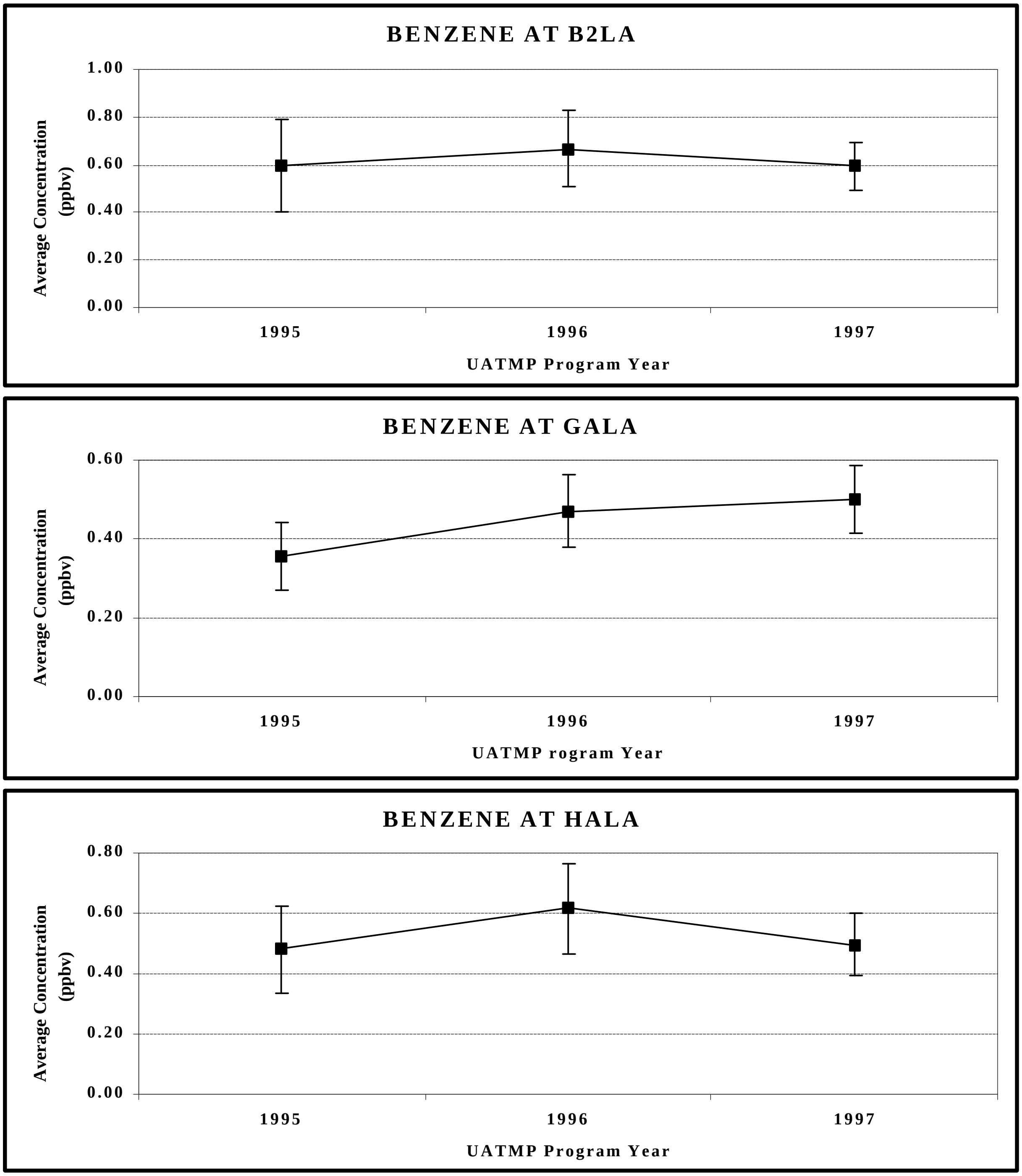
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 4-4 (Page 1 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA



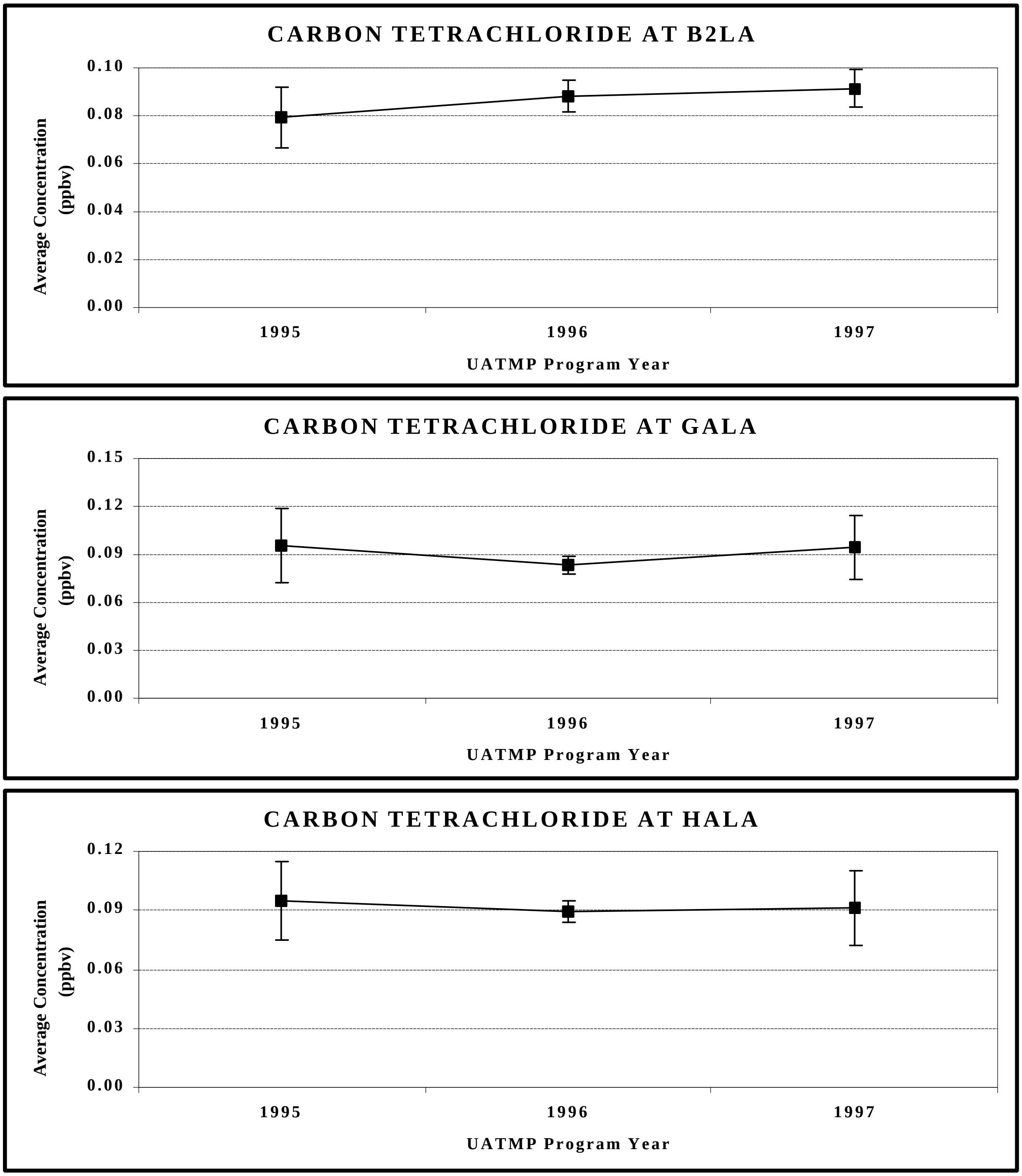
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 2 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA



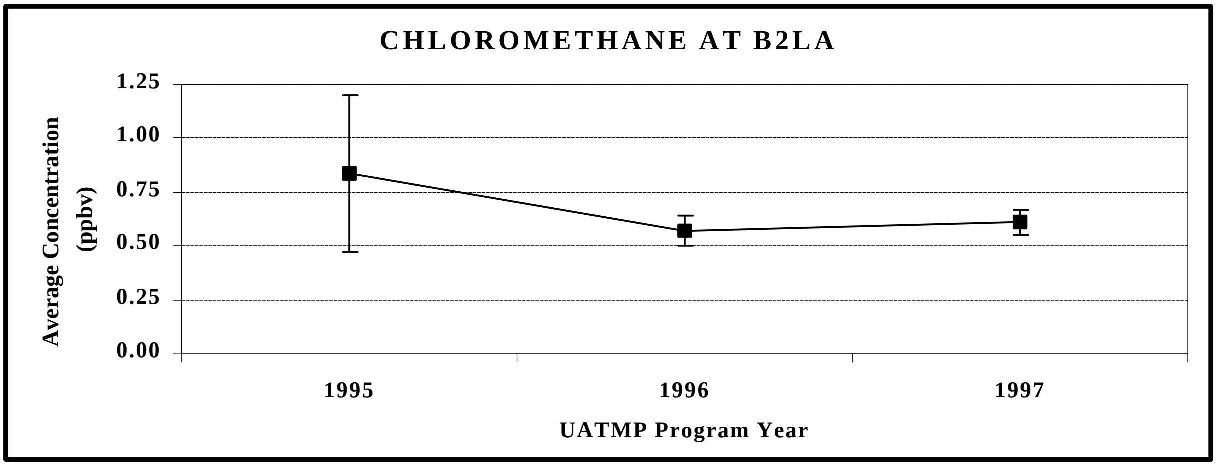
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

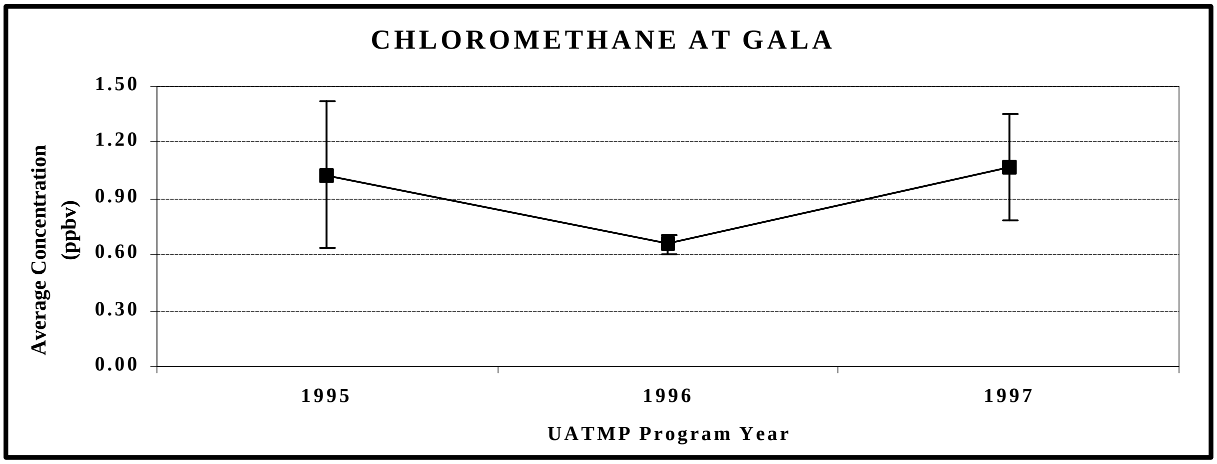
Figure 4-4 (Page 3 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

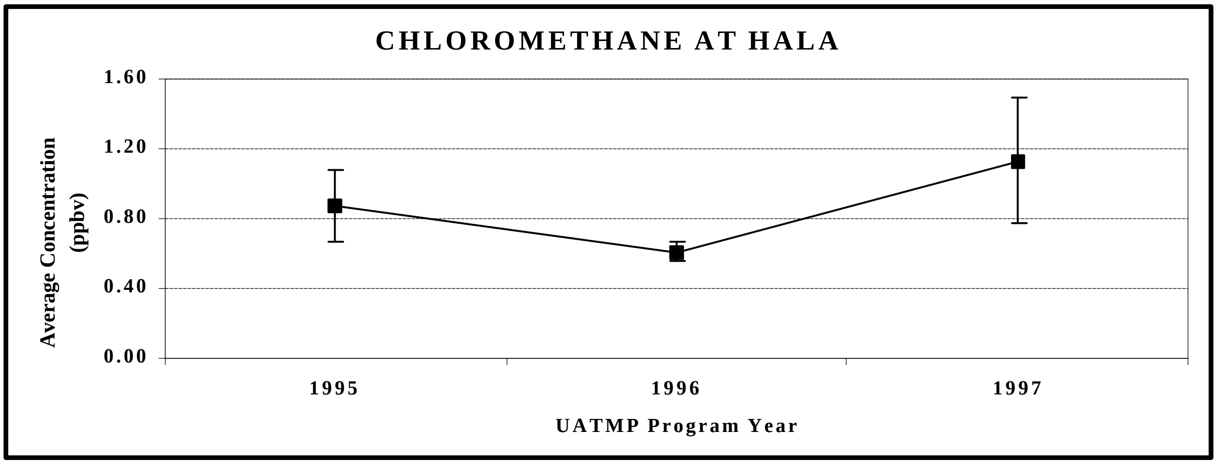


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 4 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

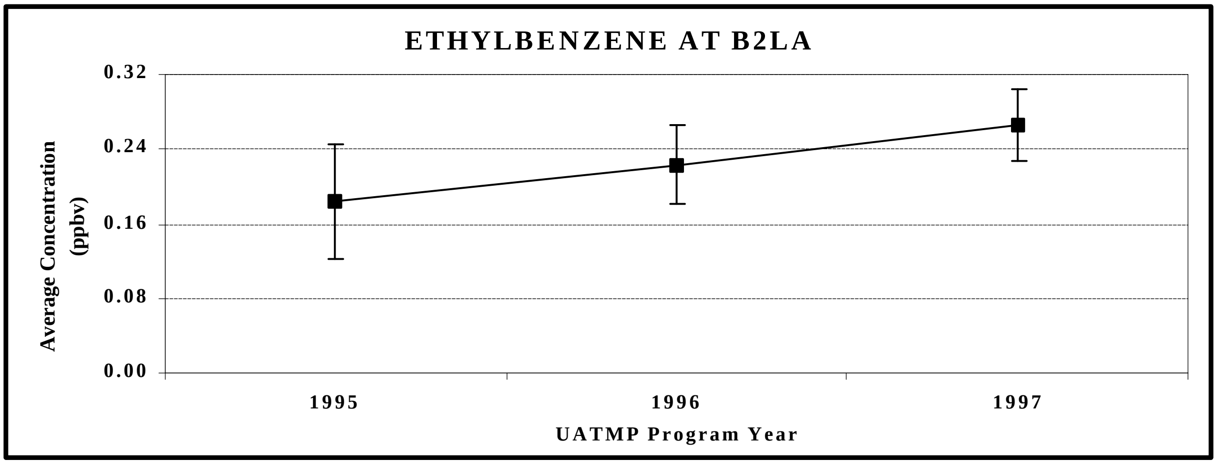


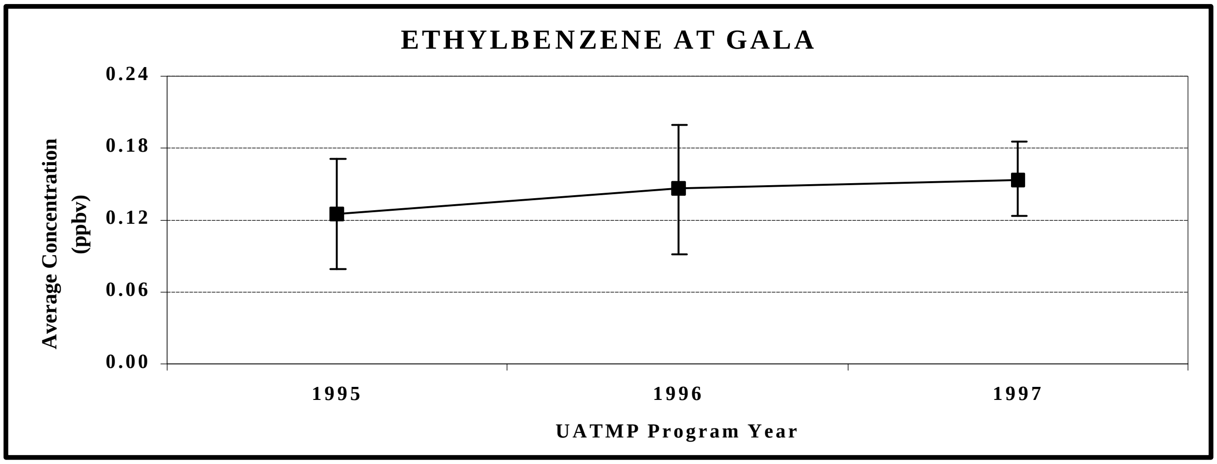


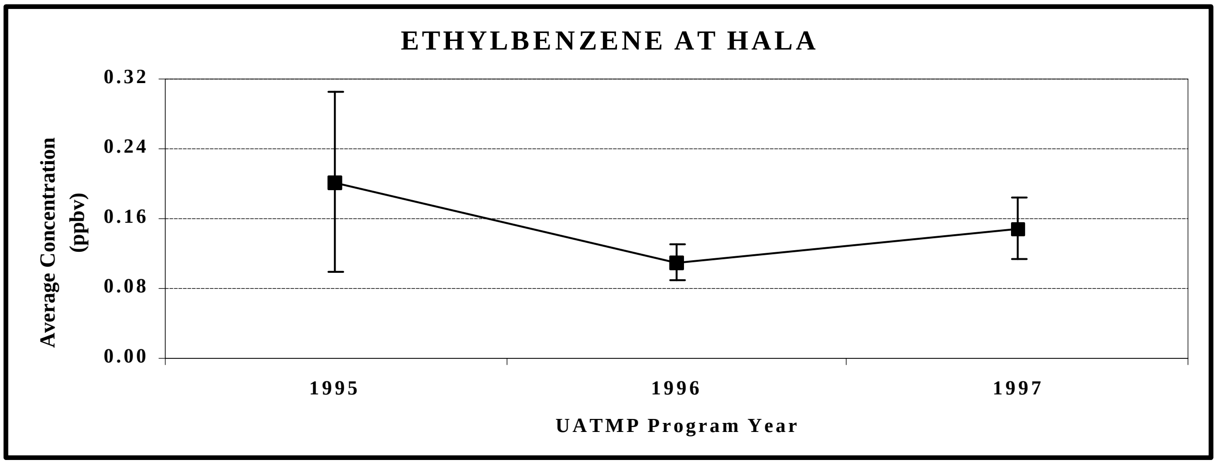


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 5 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

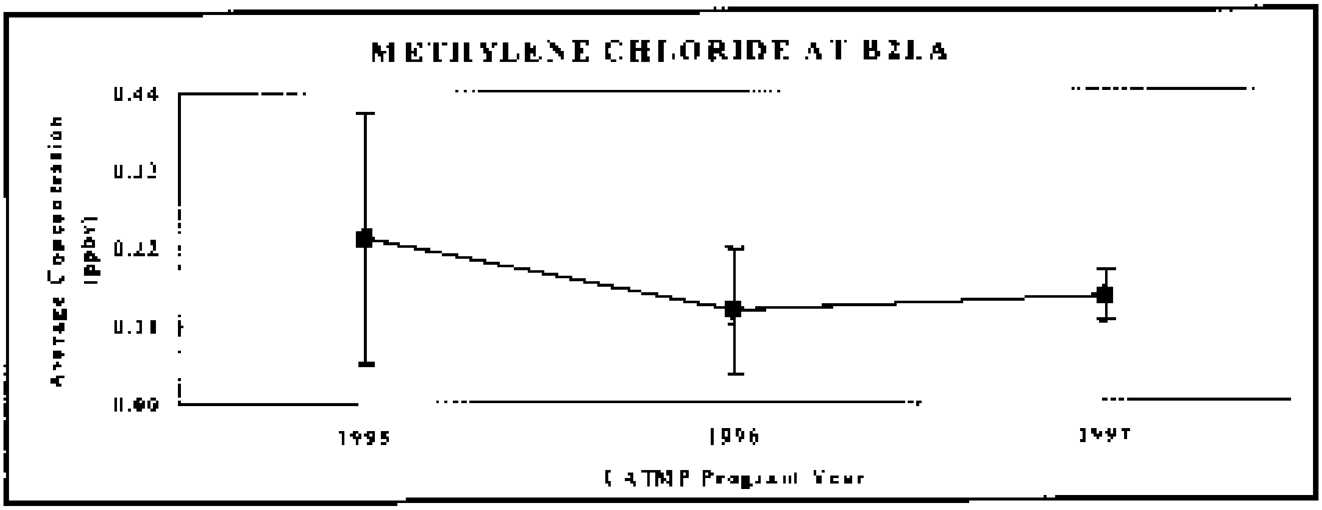


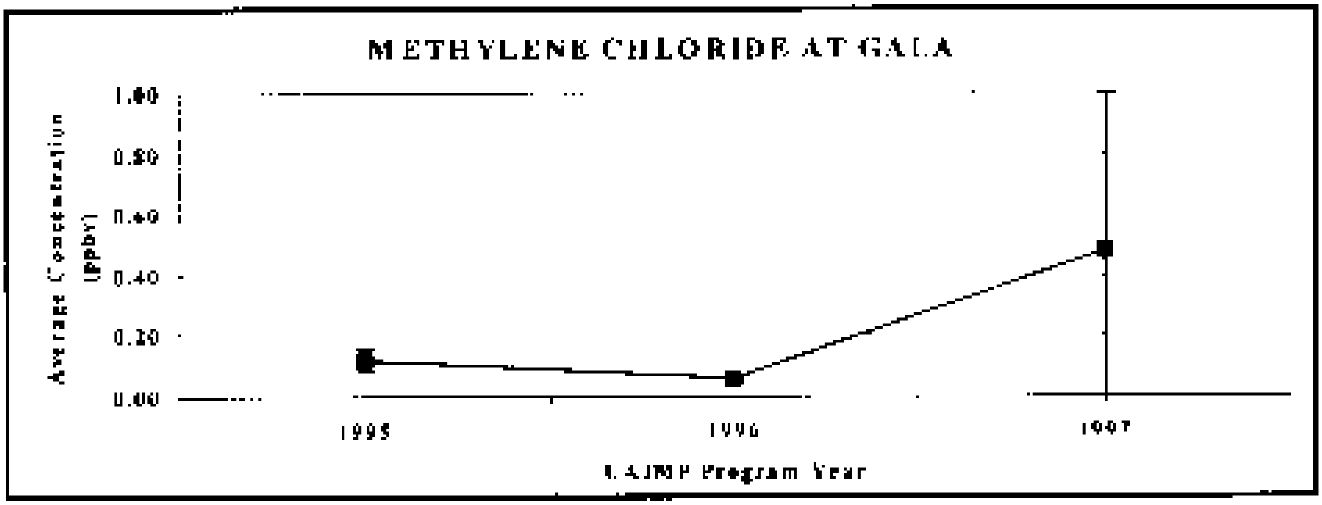


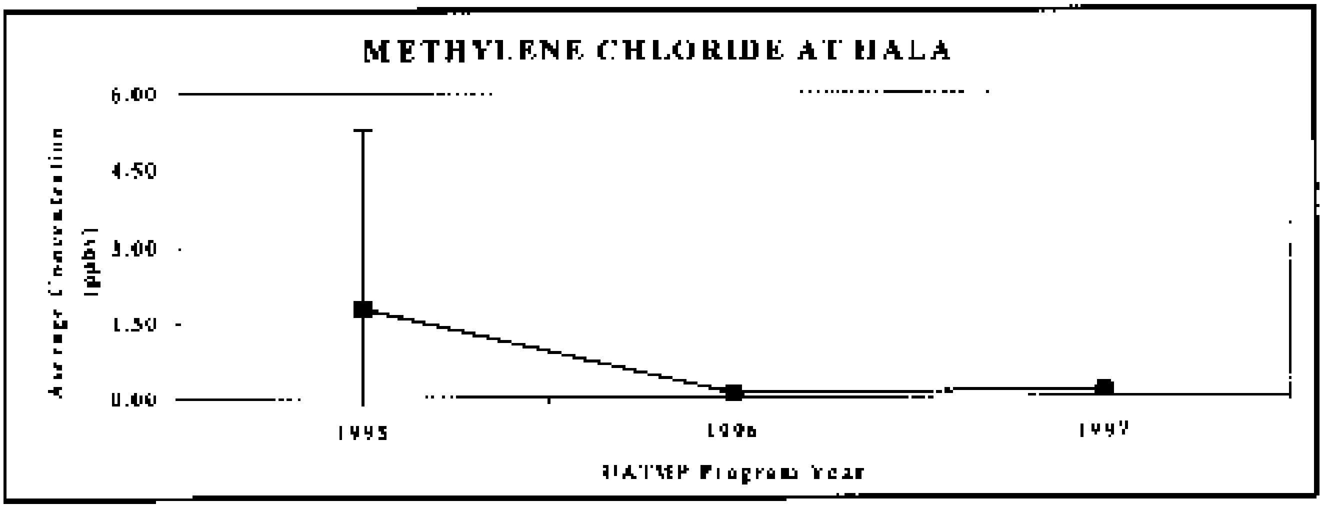


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 6 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

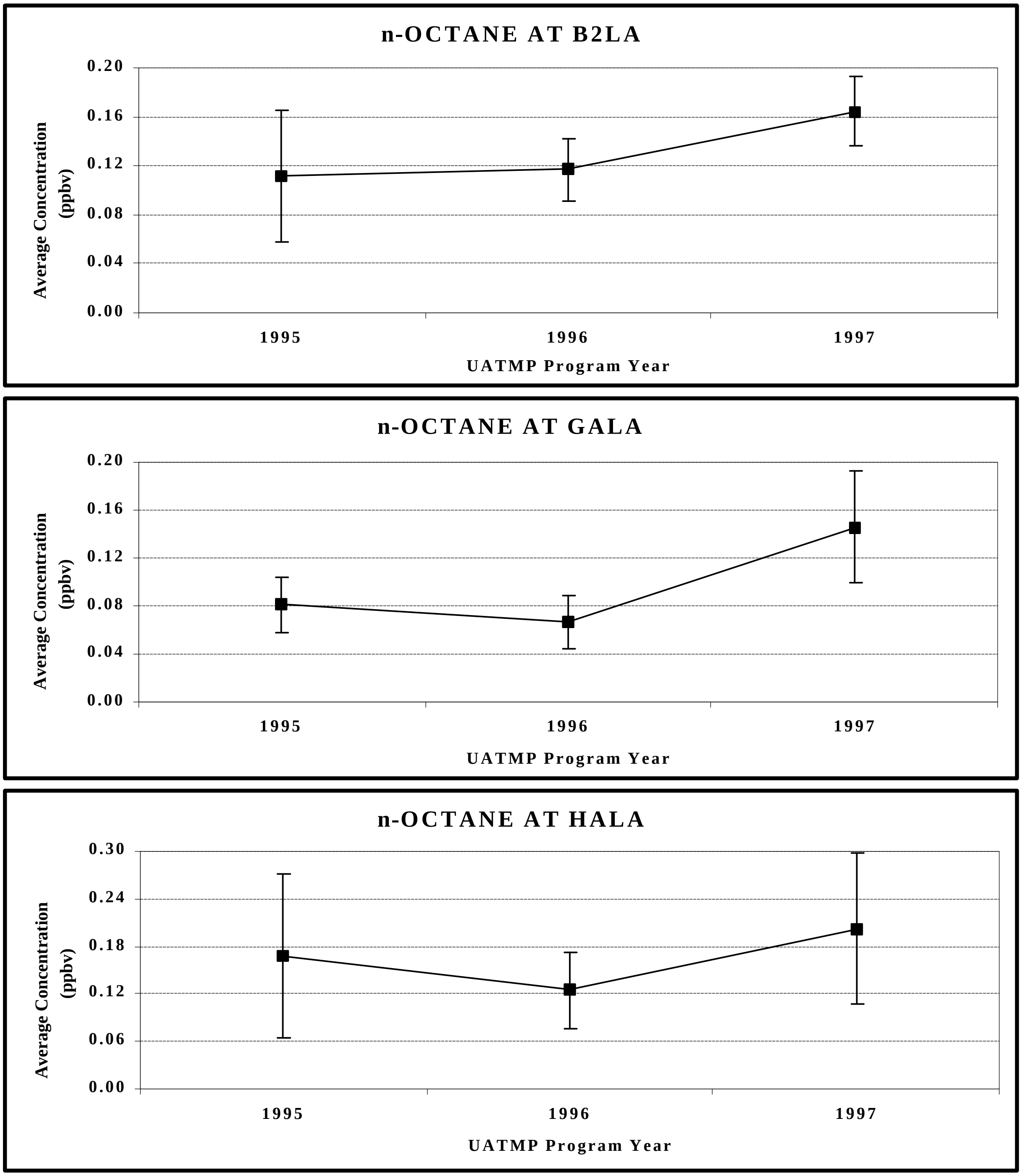






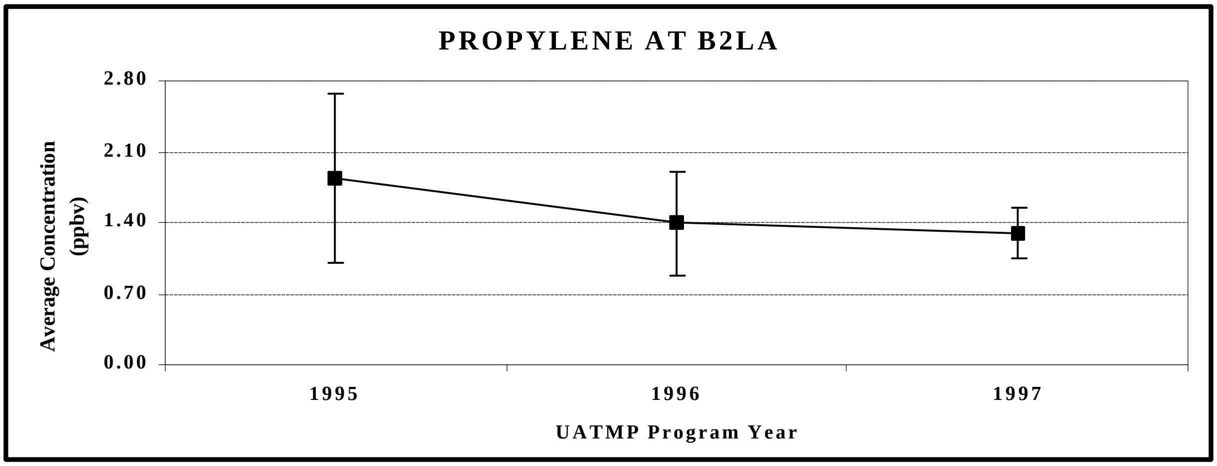
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration

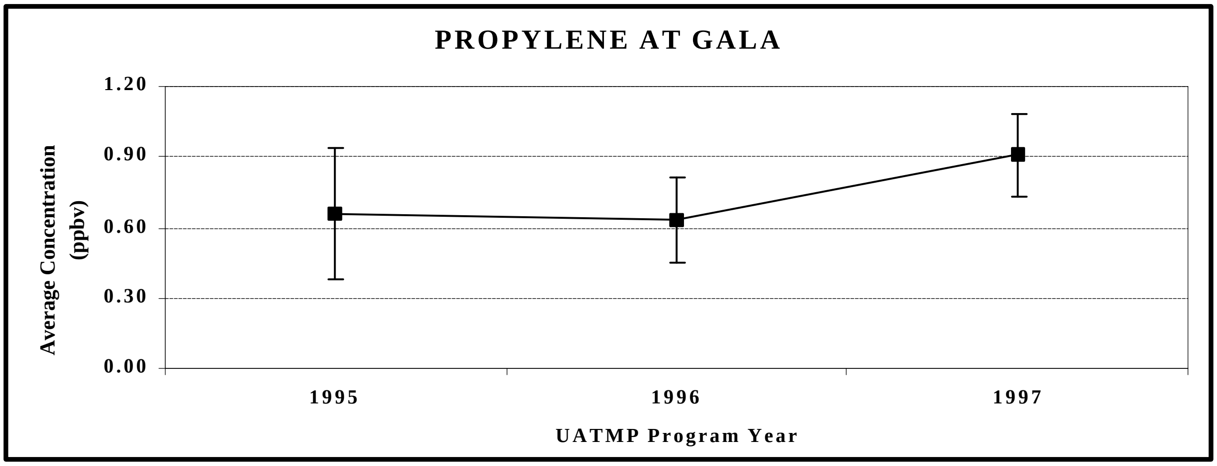
Figure 4-4 (Page 7 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC
at B2LA, GALA, and HALA

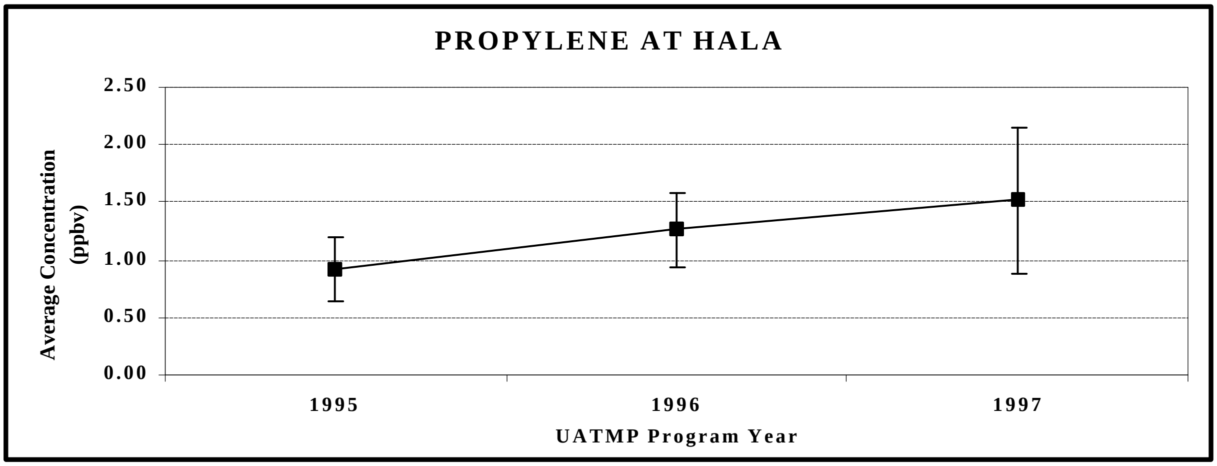


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 8 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

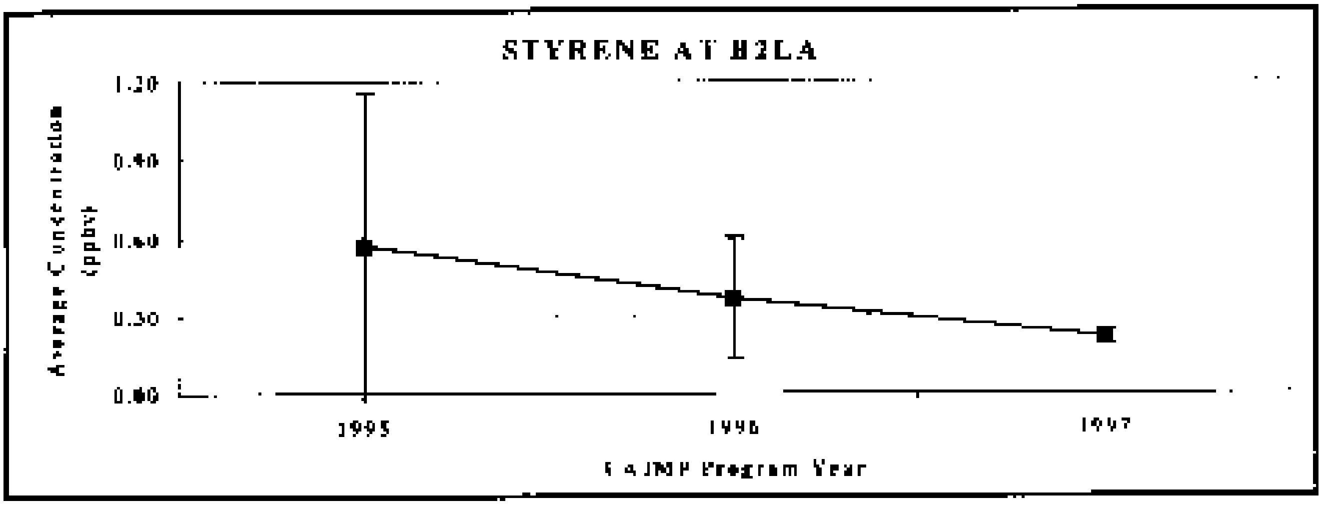


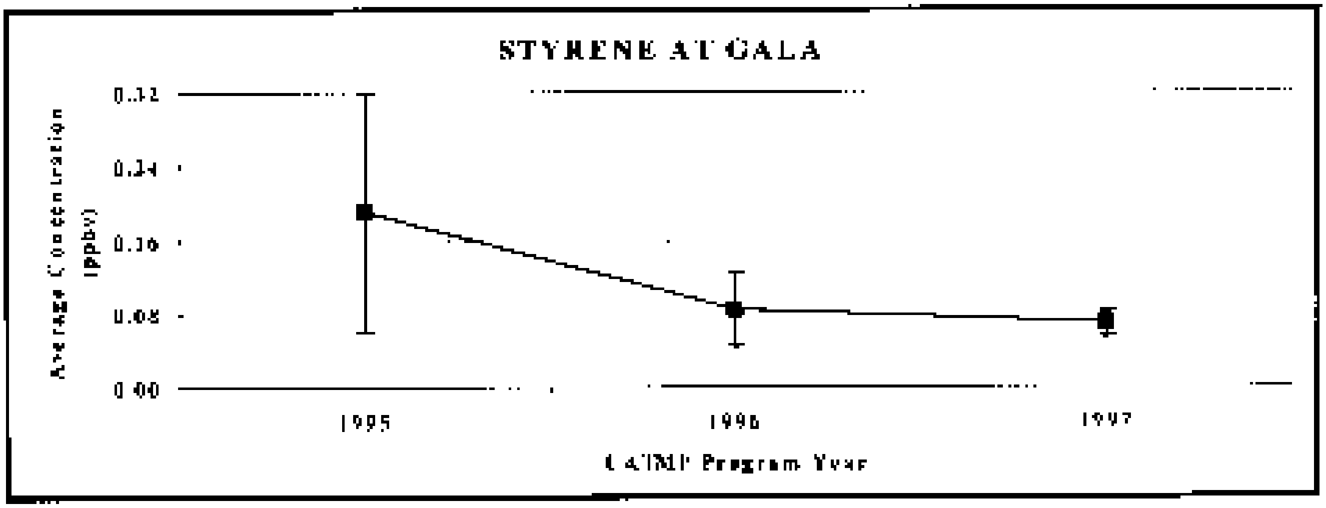


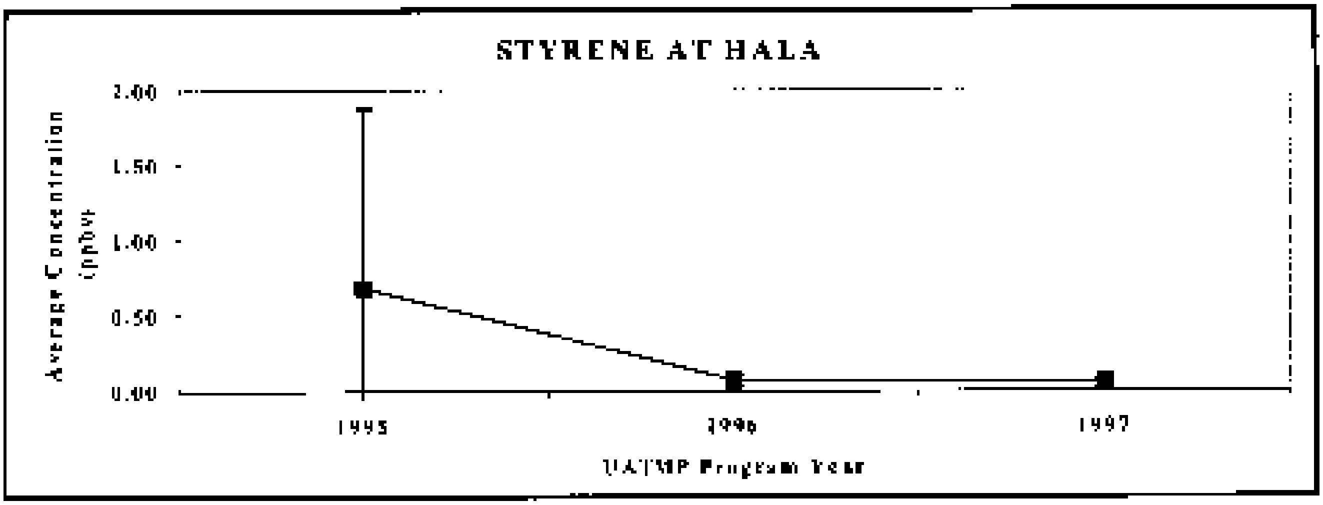


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 9 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

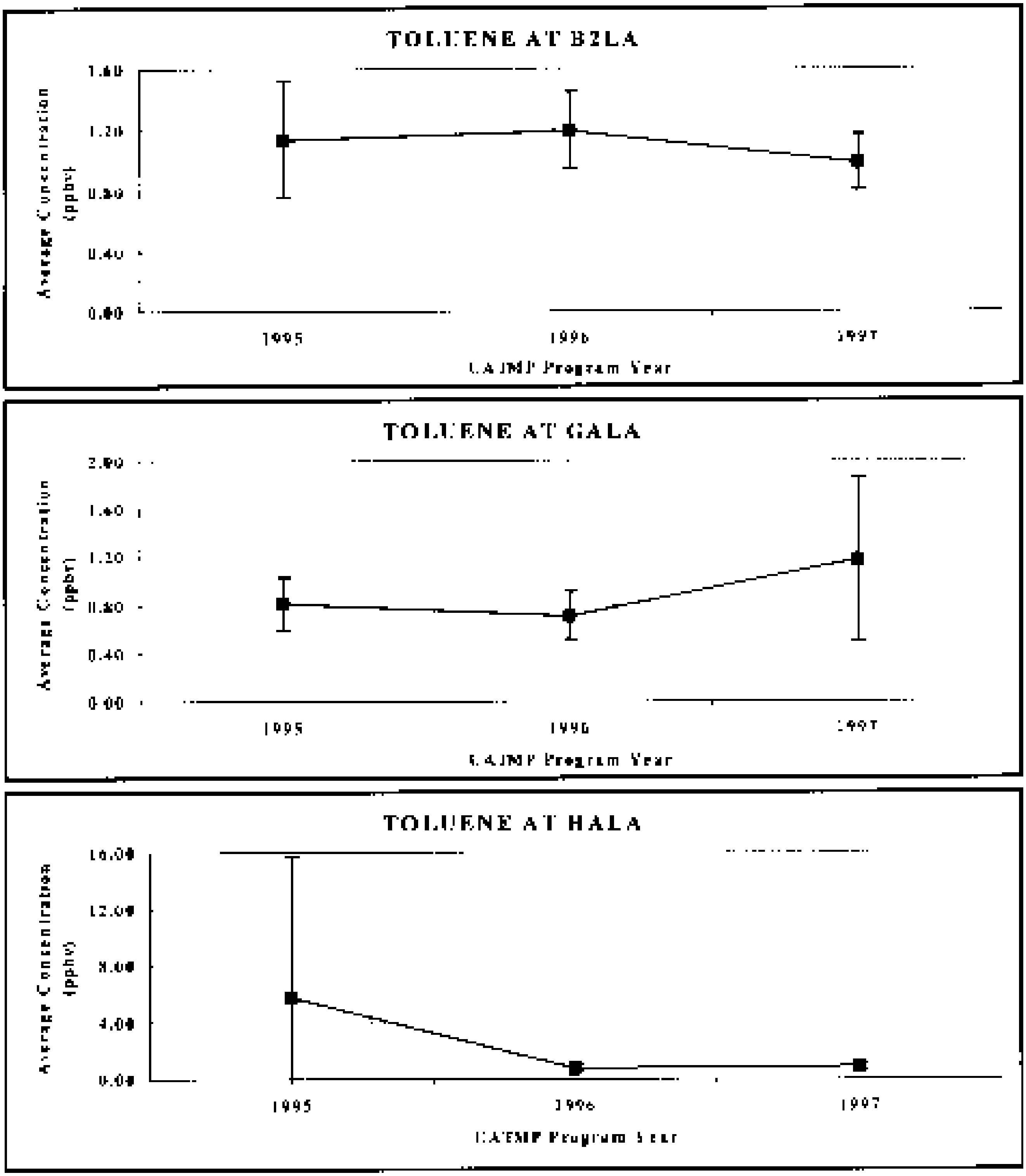






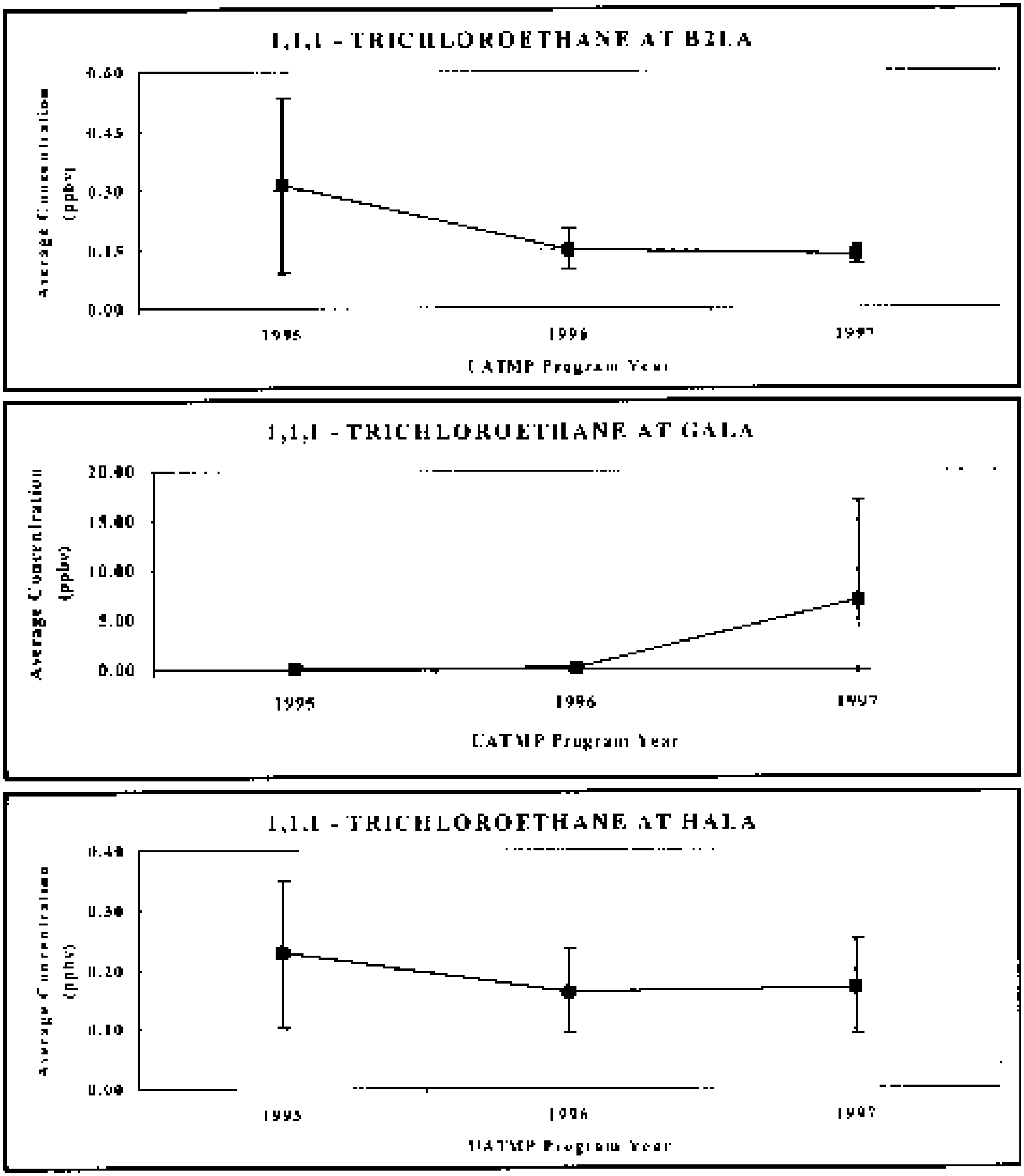
Note Every plot on this page is shown on a different scale. "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 10 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA



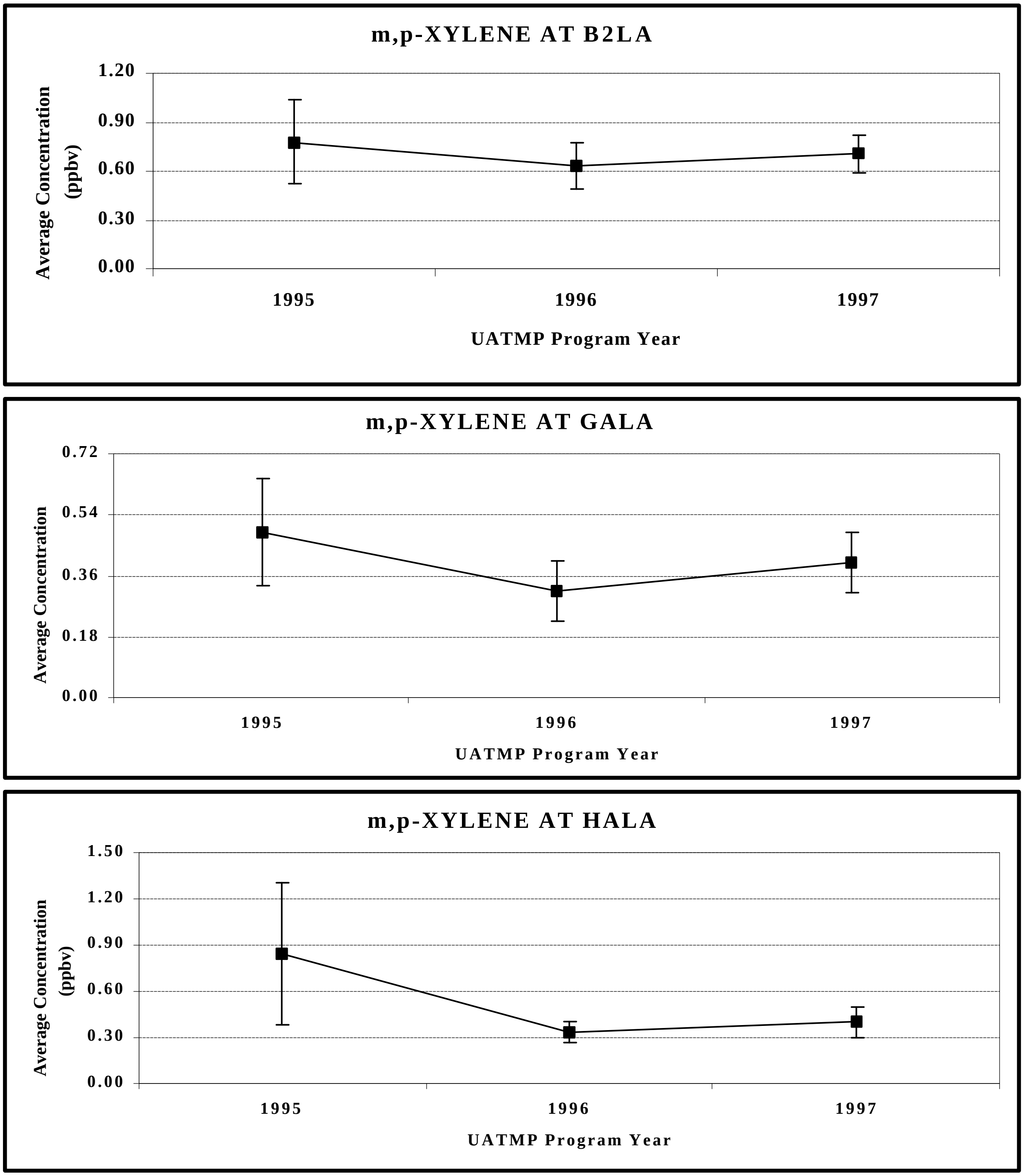
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 11 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA



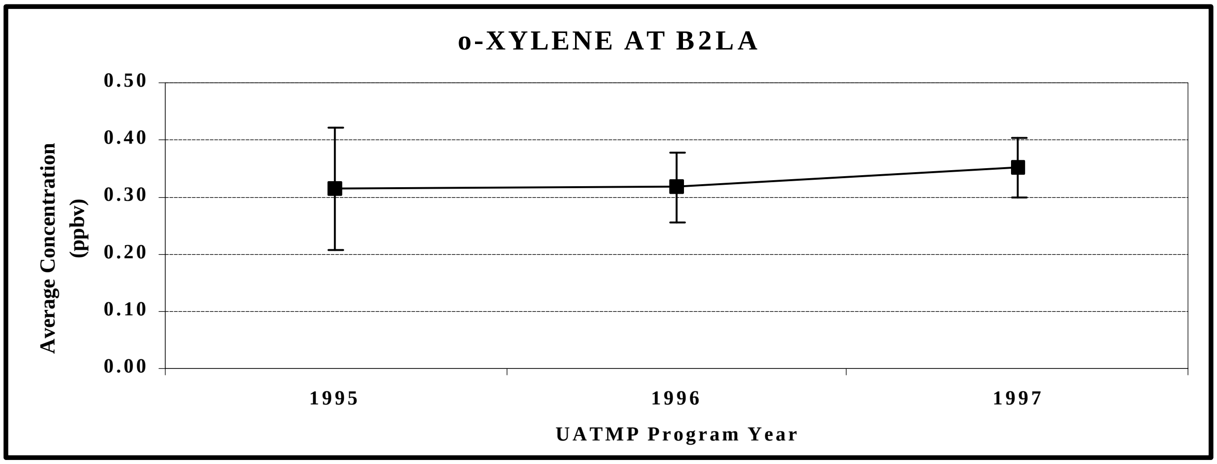
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

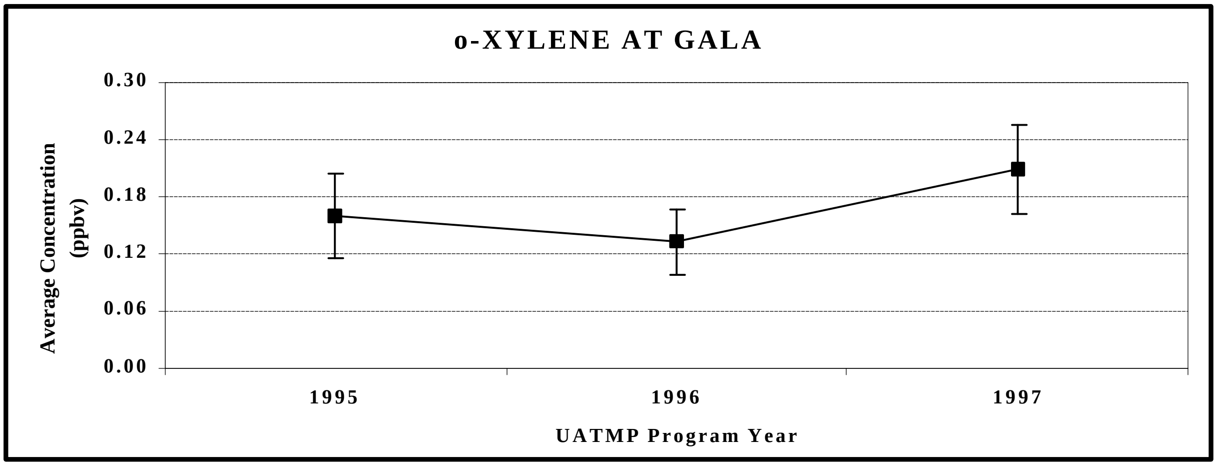
Figure 4-4 (Page 12 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

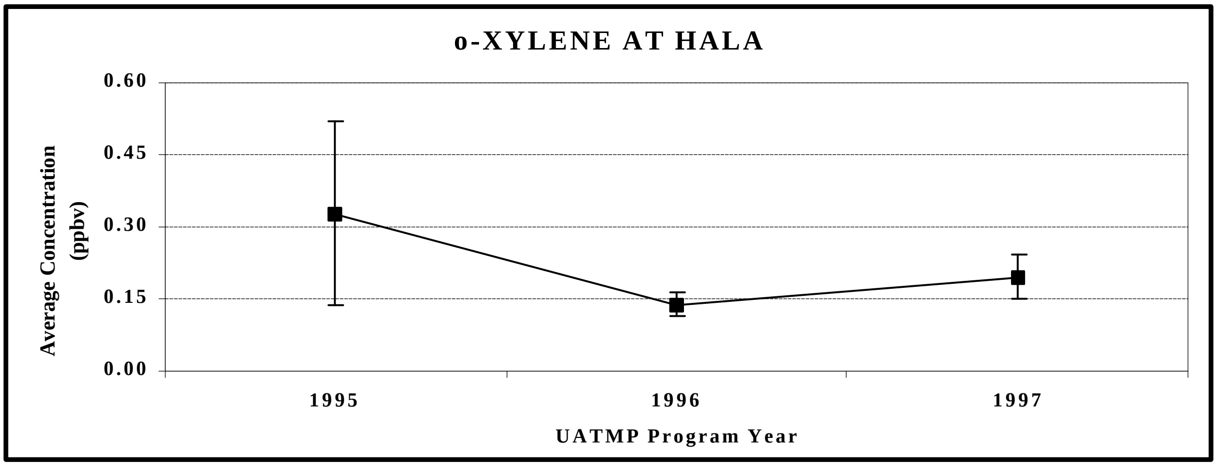


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 4-4 (Page 13 of 13)
Annual Variations in Average Concentrations of the Most Prevalent VOC at B2LA, GALA, and HALA

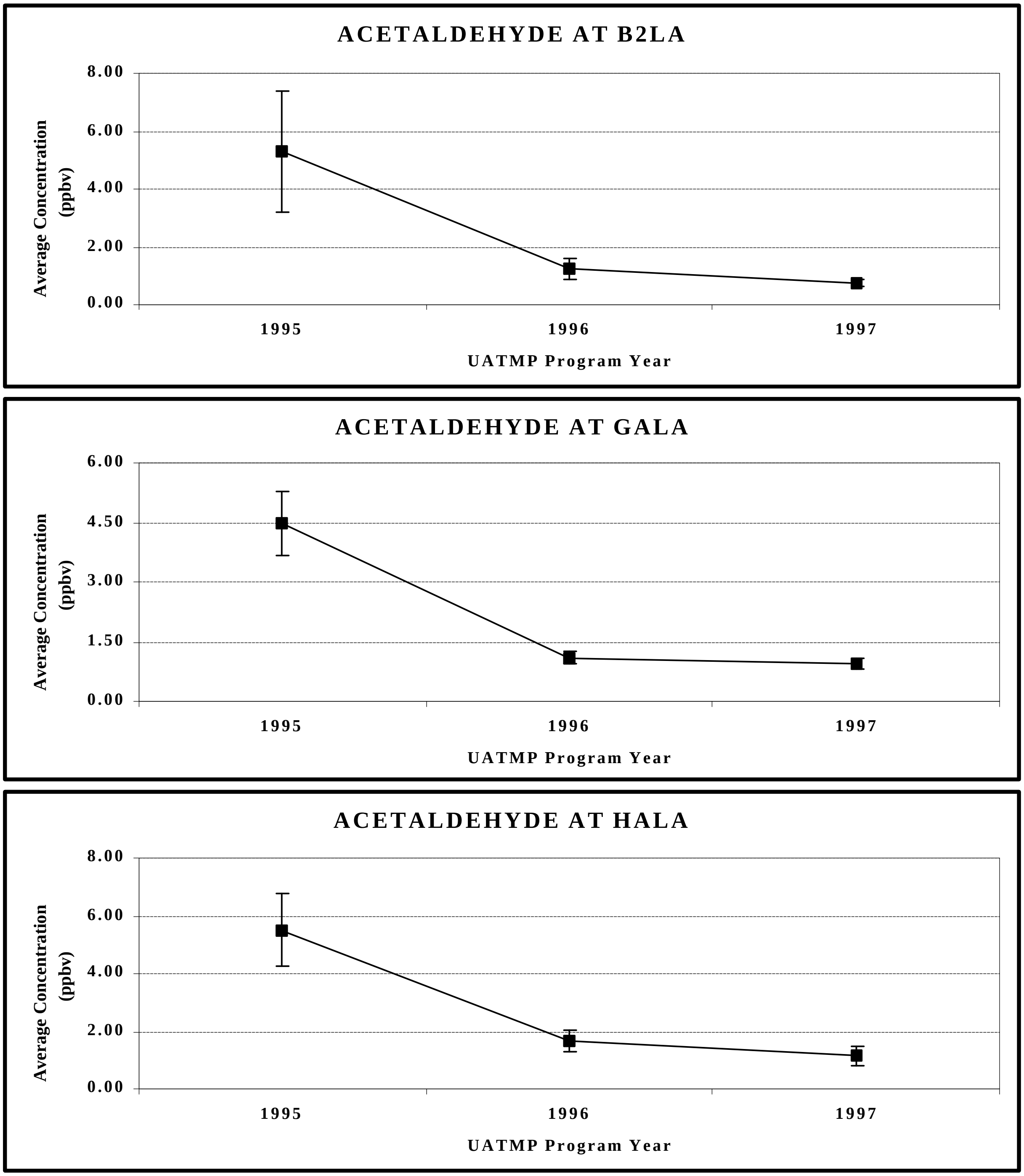






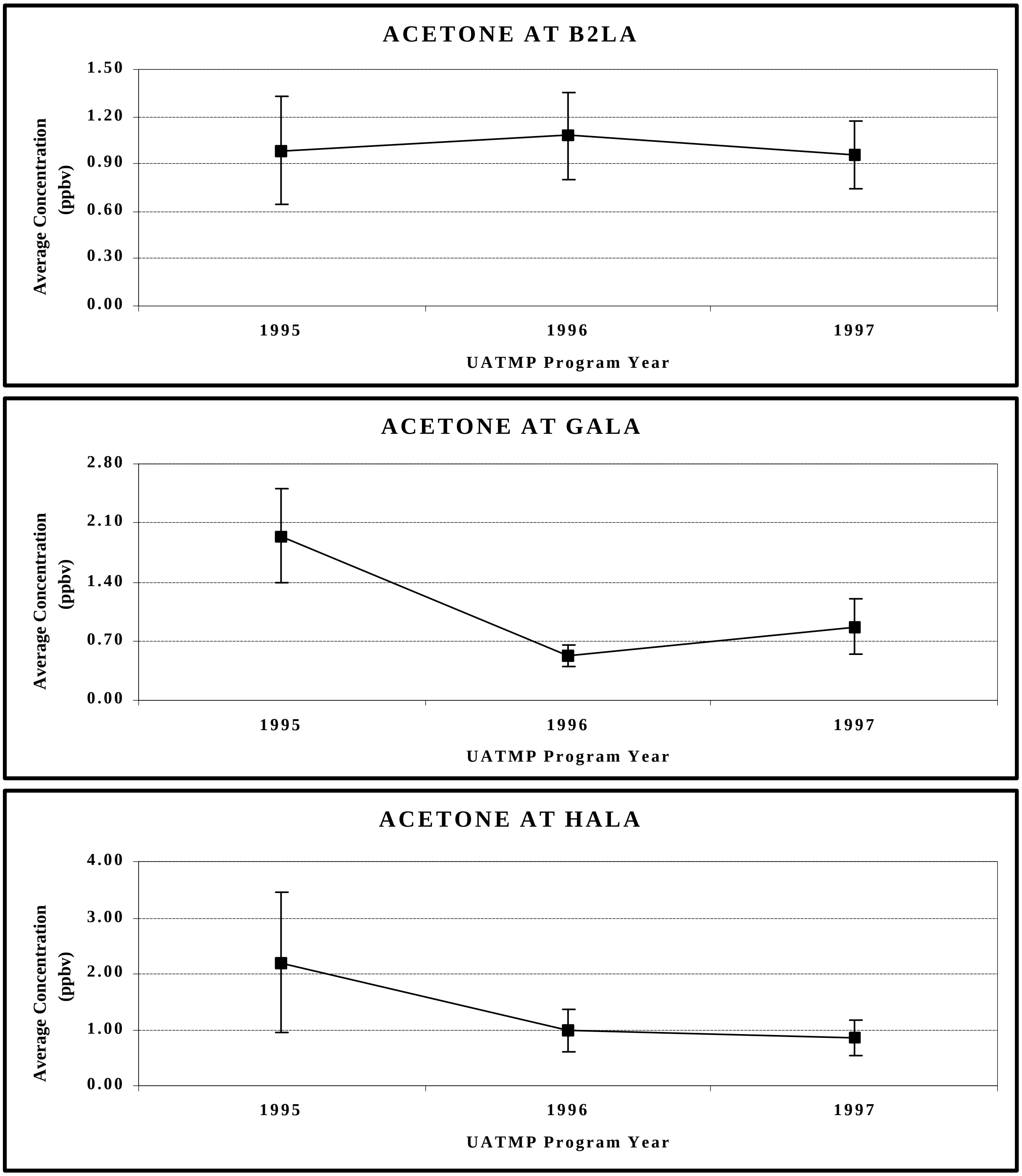
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-5 (Page 1 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls
at B2LA, GALA, and HALA



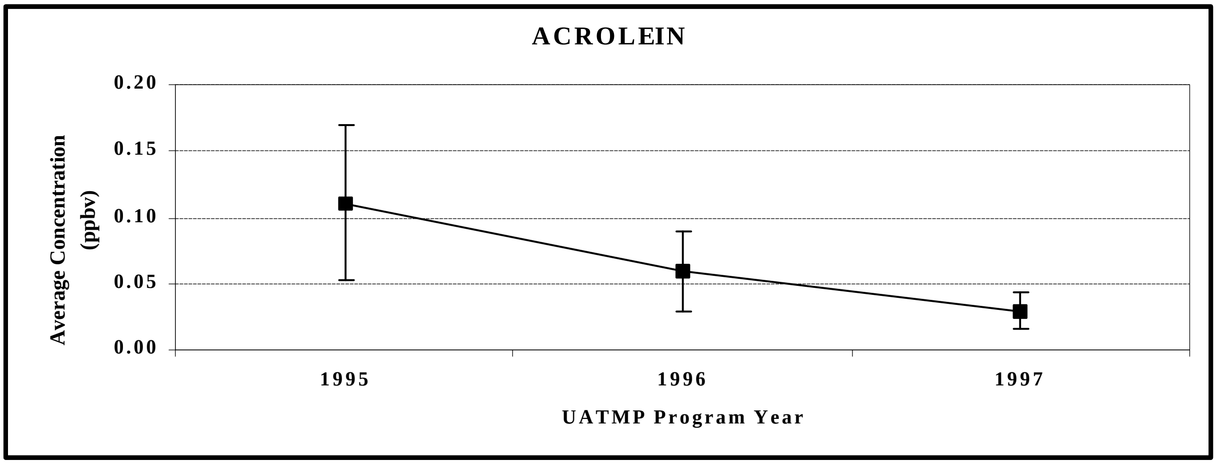
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

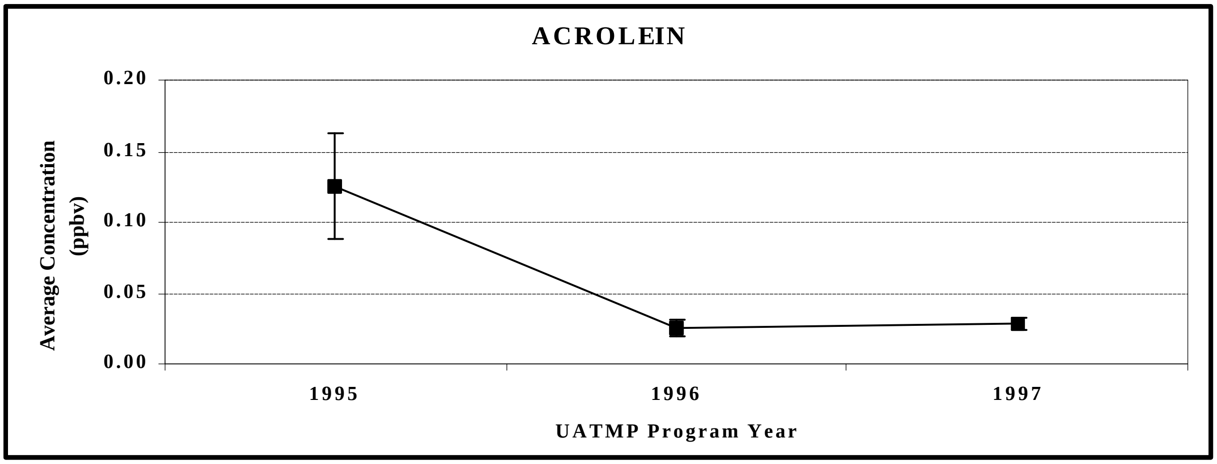
Figure 4-5 (Page 2 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA

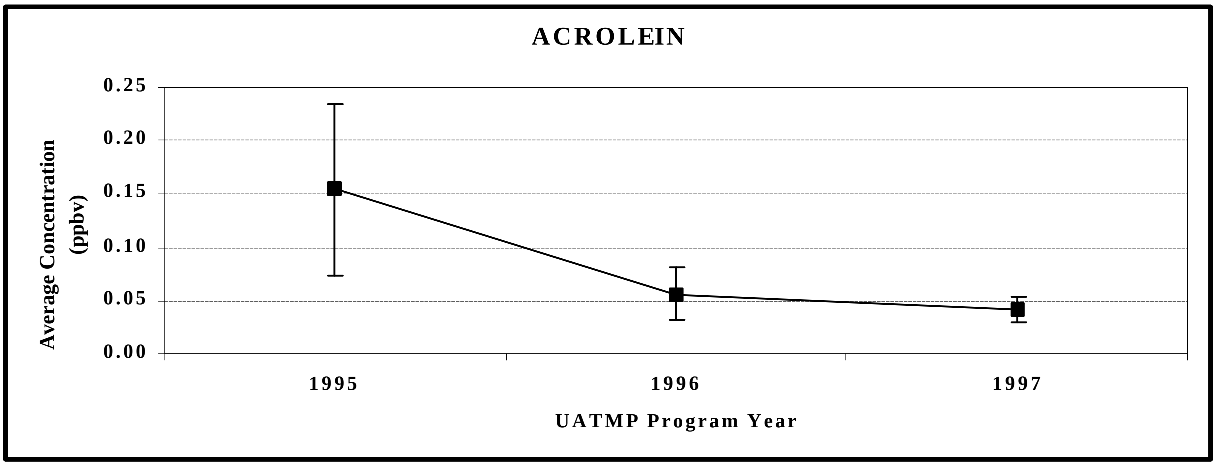


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-5 (Page 3 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA

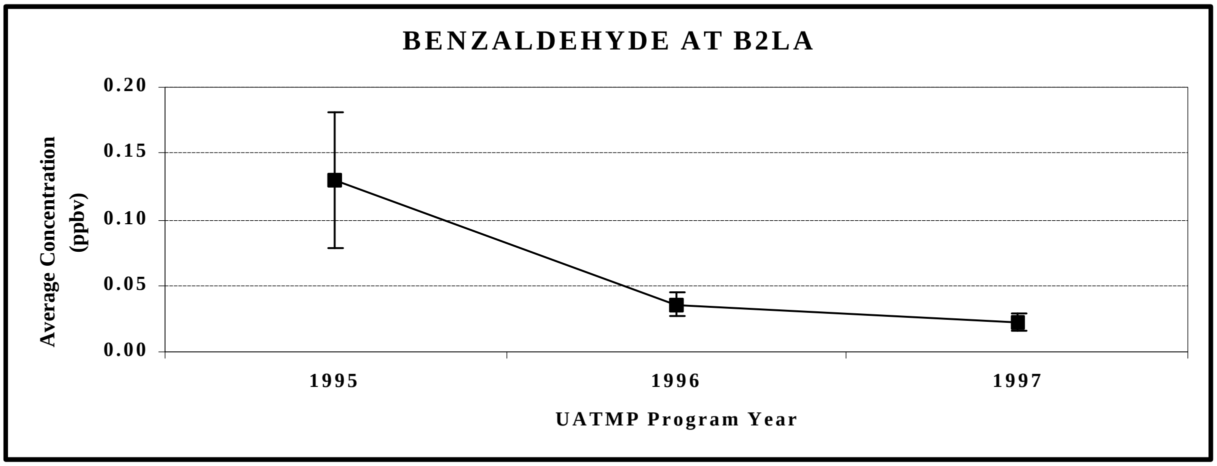


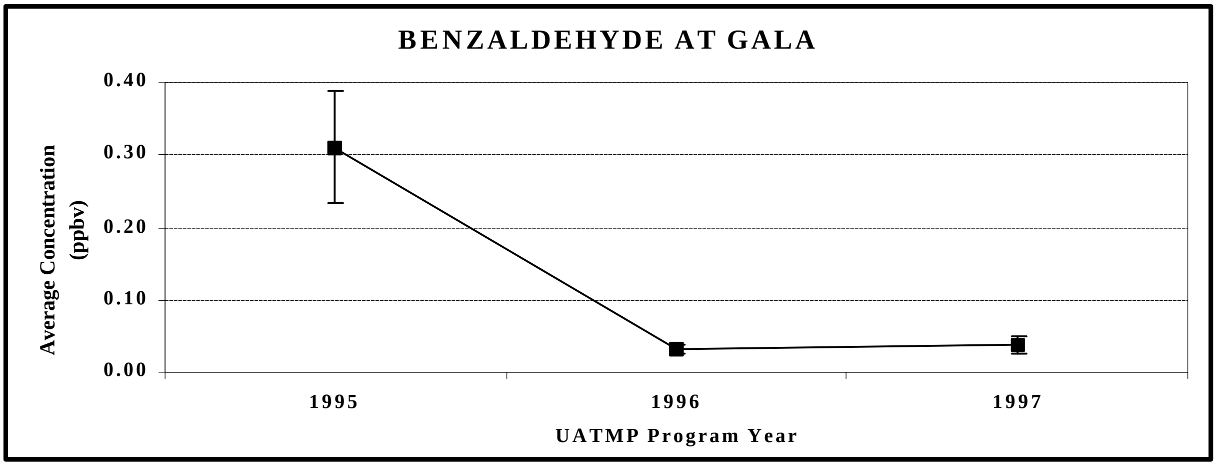


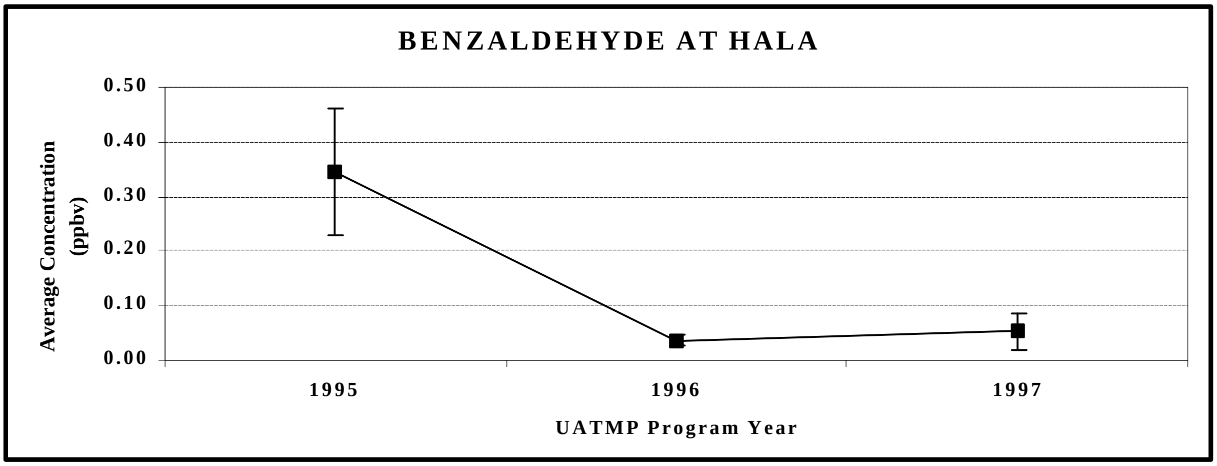


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-5 (Page 4 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA

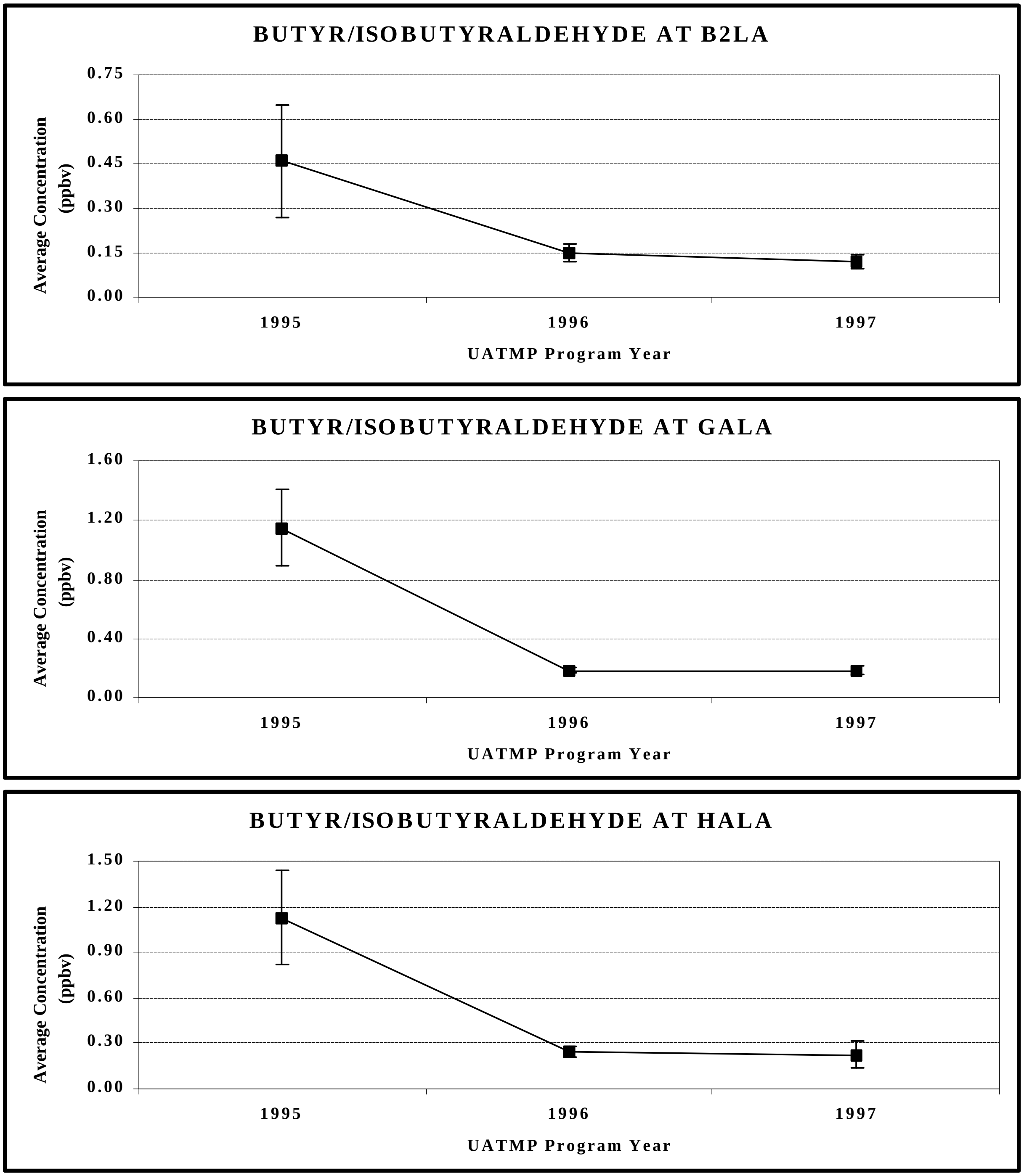






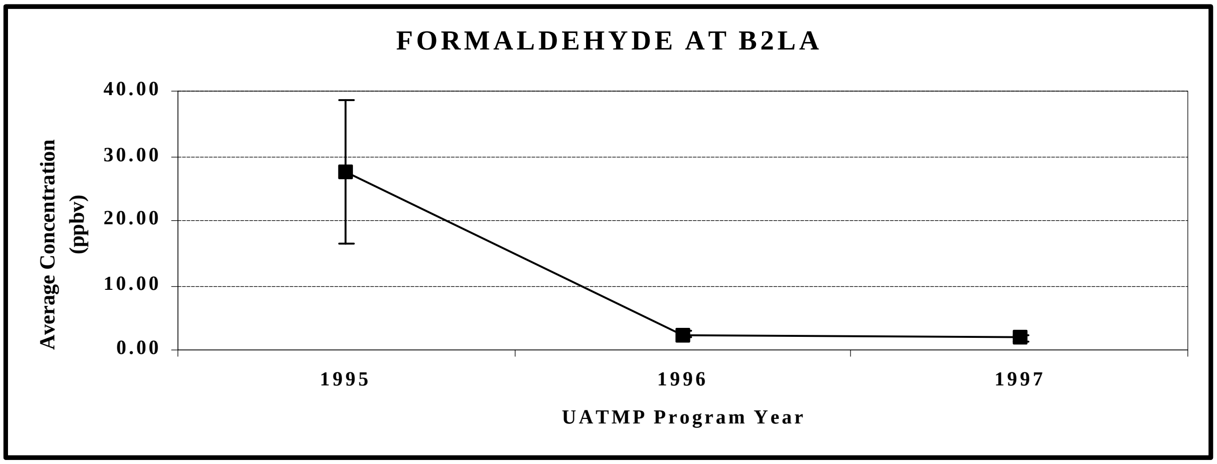
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

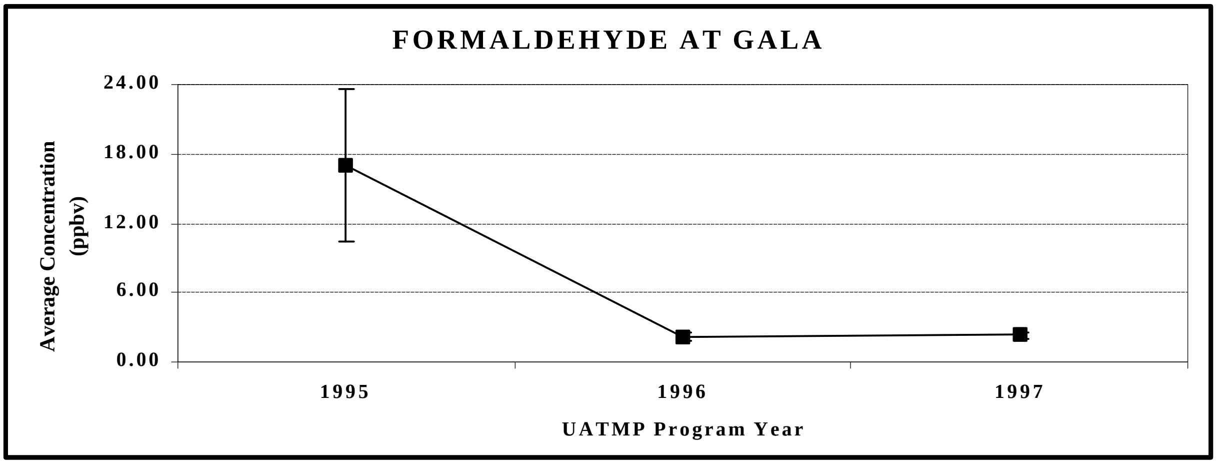
Figure 4-5 (Page 5 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA

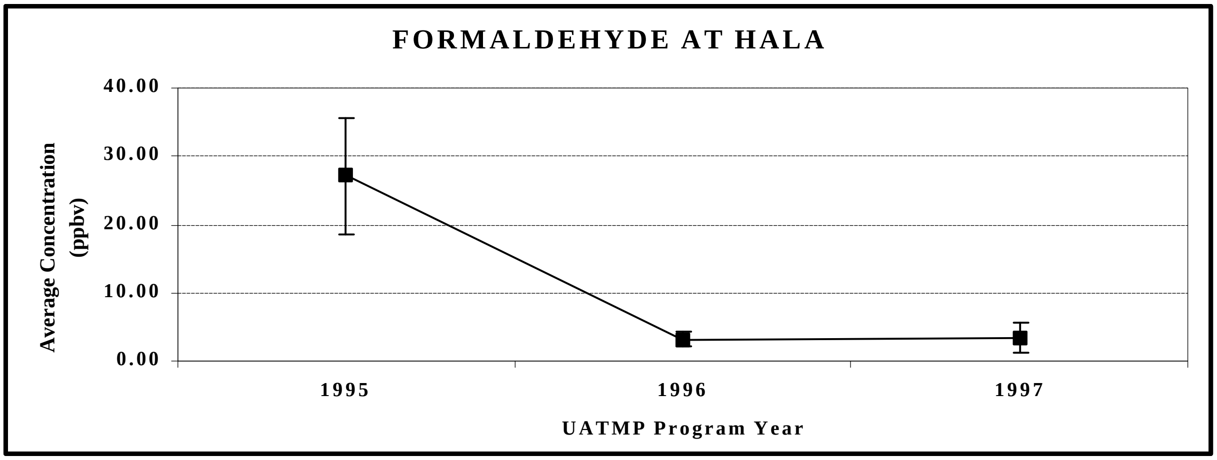


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 4-5 (Page 6 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA

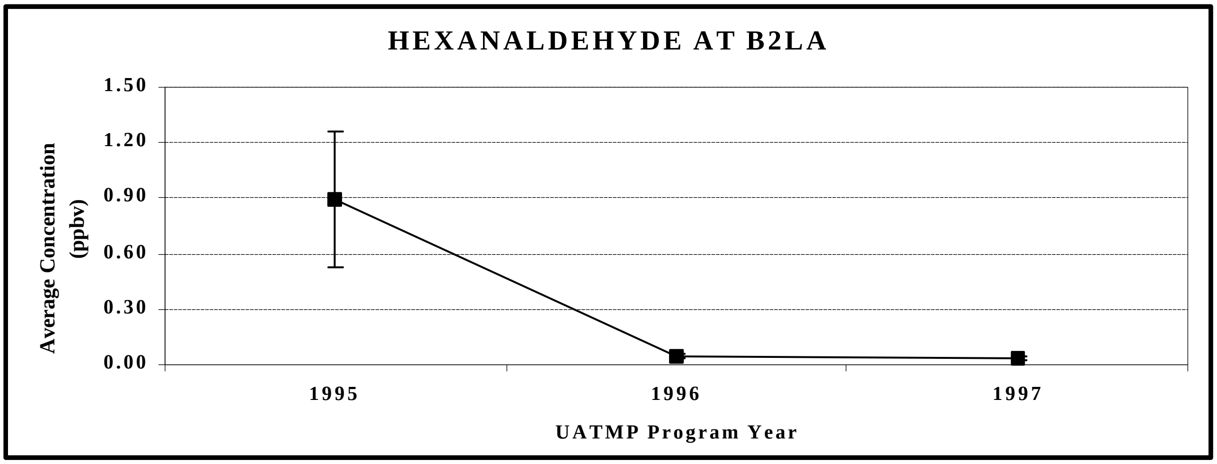


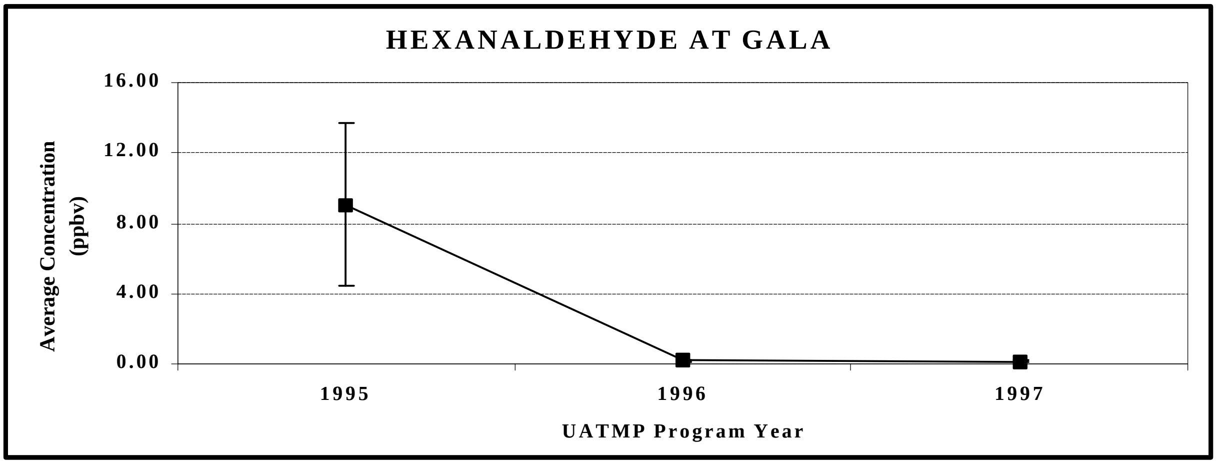


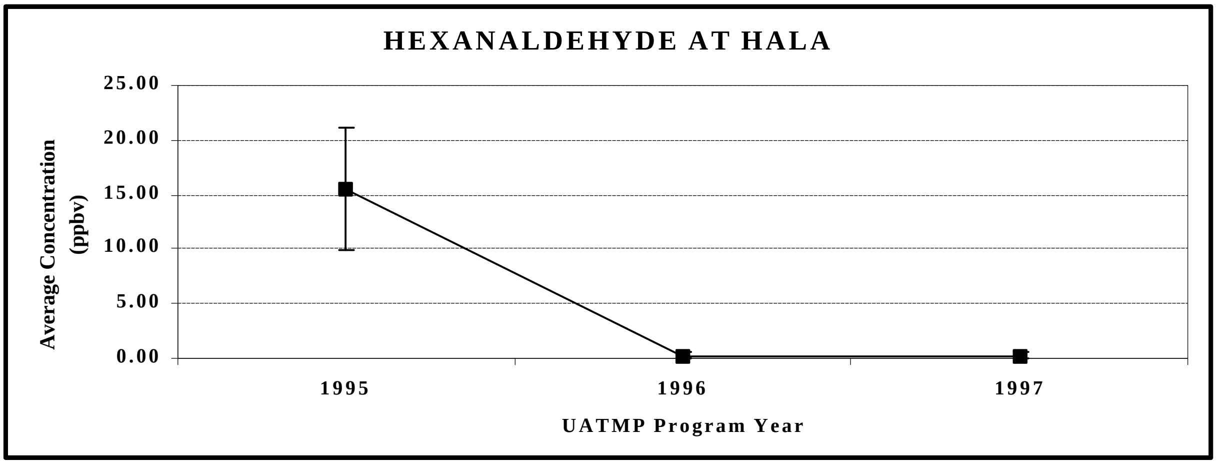


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-5 (Page 7 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA

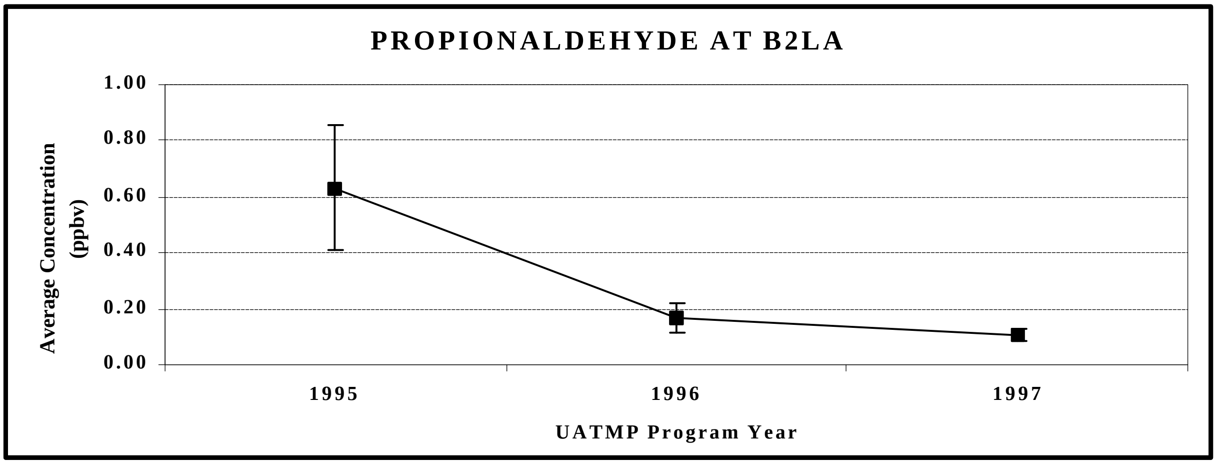


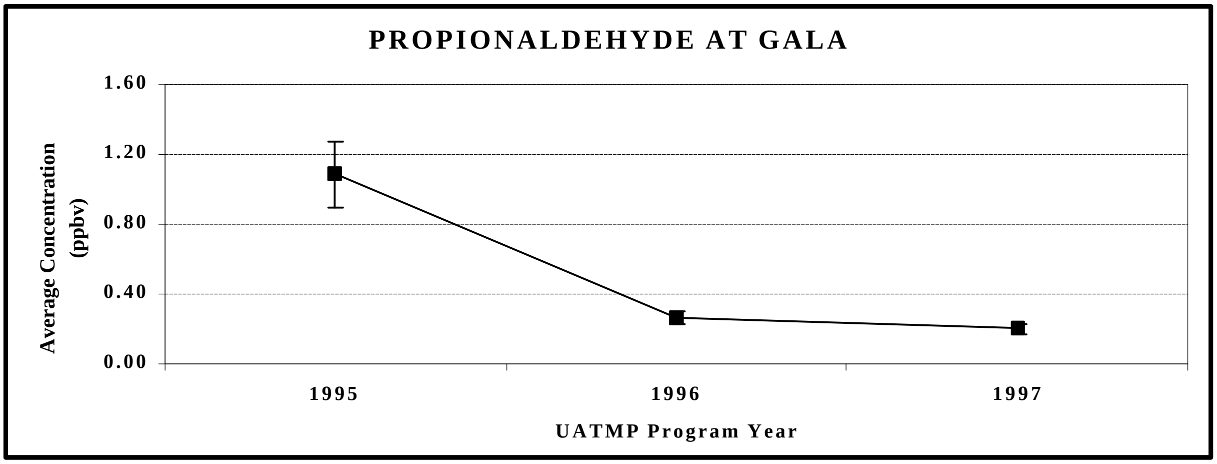


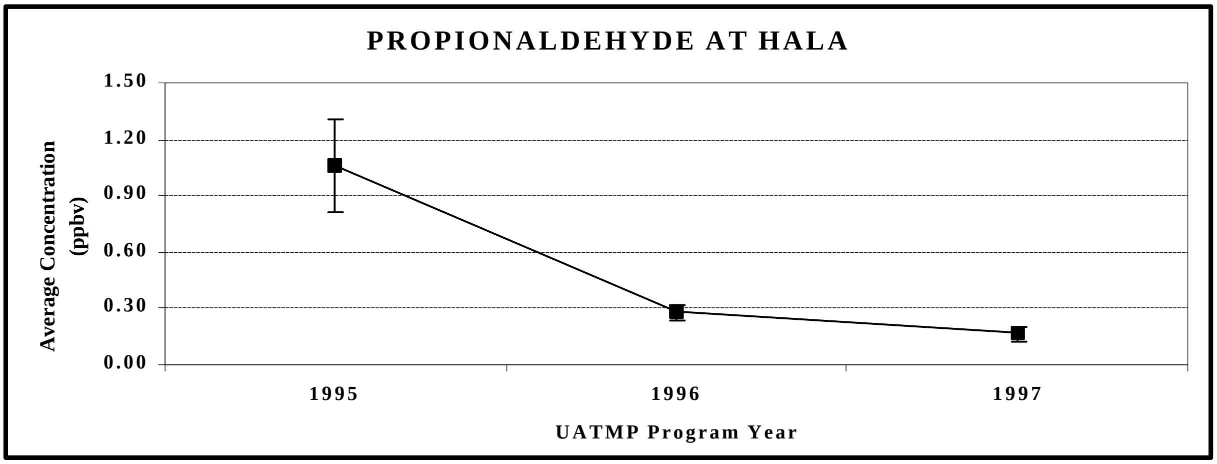


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 4-5 (Page 8 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA

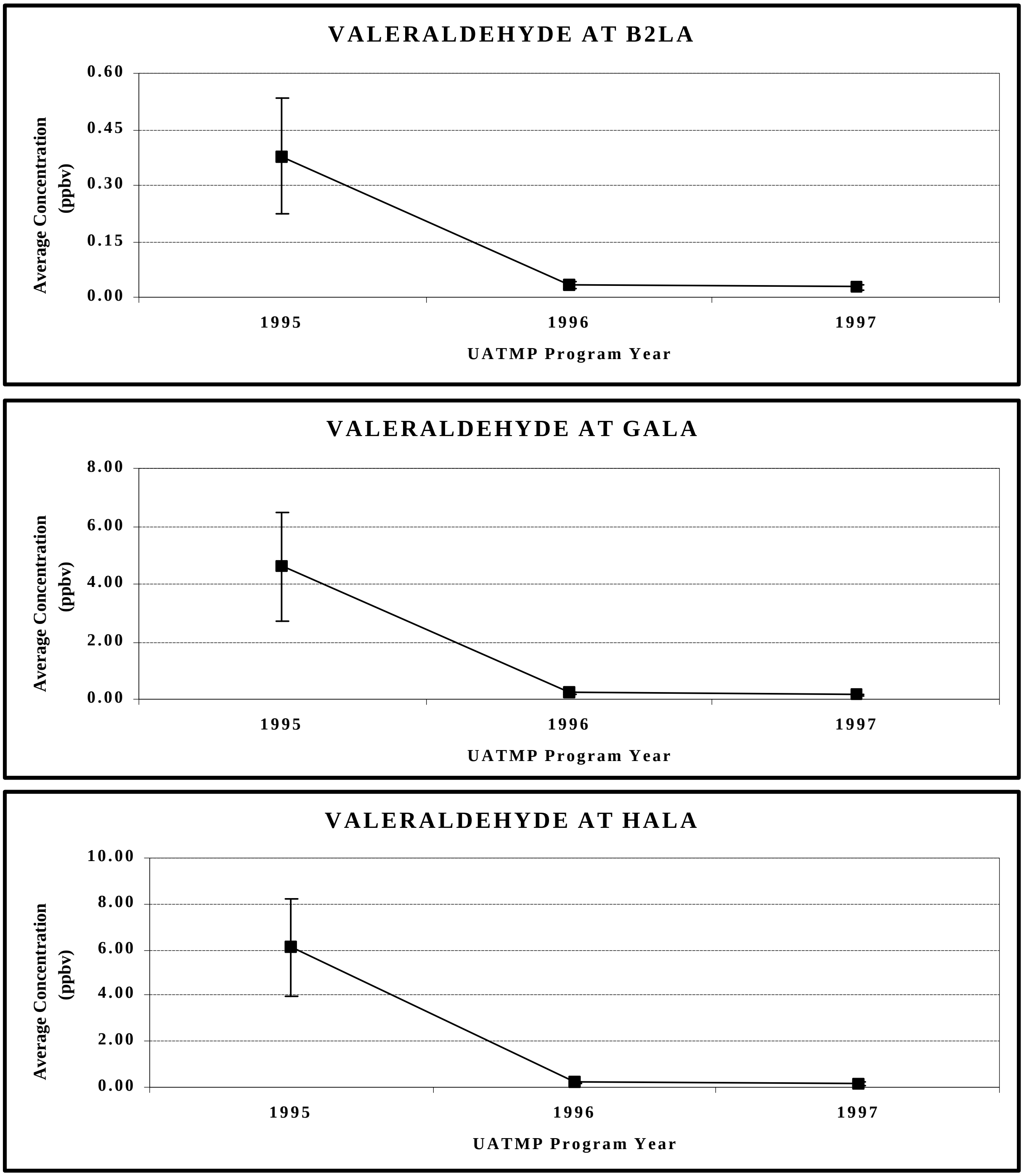






Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 4-5 (Page 9 of 9)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at B2LA, GALA, and HALA



Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Table 4-1
Completeness Data for the B2LA, GALA, and HALA Monitoring Stations

Parameter	Monitoring Station		
	Baton Rouge, Louisiana (B2LA)	Garyville, Louisiana (GALA)	Hahnville, Louisiana (HALA)
Number of days when VOC samples were collected	35	35	39
Number of days with valid VOC samples	30	30	33
Completeness for VOC	86 %	86 %	85 %
Number of days when carbonyl samples were collected	38	36	37
Number of days with valid carbonyl samples	33	33	30
Completeness for carbonyls	87 %	92 %	81 %

Table 4-2
Summary Statistics for VOC Concentrations Measured at Baton Rouge, Louisiana (B2LA)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	**0**	**100%**	**6.16**	**402.00**	**98.60**	**139.50**	**86.86**	**122.63**	**0.88**
Acetylene	**0**	**100%**	**0.47**	**7.11**	**1.46**	**1.80**	**1.53**	**1.27**	**0.70**
Acrylonitrile	30	0%	ND	ND	0.11	0.09	0.08	0.03	0.37
Benzene	**0**	**100%**	**0.22**	**1.50**	**0.55**	**0.59**	**0.54**	**0.28**	**0.46**
Bromochloromethane	30	0%	ND	ND	0.05	0.04	0.04	0.01	0.27
Bromodichloromethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	30	0%	ND	ND	0.08	0.07	0.07	0.01	0.09
Bromomethane	25	17%	ND	0.05	0.07	0.06	0.05	0.02	0.38
1,3-Butadiene	**8**	**73%**	**ND**	**1.09**	**0.07**	**0.17**	**0.09**	**0.24**	**1.42**
Carbon tetrachloride	**0**	**100%**	**0.06**	**0.14**	**0.10**	**0.09**	**0.09**	**0.02**	**0.22**
Chlorobenzene	30	0%	ND	ND	0.04	0.03	0.03	0.01	0.20
Chloroethane	28	7%	ND	0.49	0.03	0.05	0.03	0.09	1.74
Chloroform	16	47%	ND	1.64	0.03	0.14	0.06	0.31	2.15
Chloromethane	**0**	**100%**	**0.27**	**0.95**	**0.63**	**0.61**	**0.58**	**0.16**	**0.27**
Chloroprene	29	3%	ND	0.38	0.05	0.05	0.04	0.06	1.21
Dibromochloromethane	30	0%	ND	ND	0.08	0.06	0.06	0.02	0.38
m-Dichlorobenzene	29	3%	ND	0.03	0.08	0.07	0.07	0.01	0.22
o-Dichlorobenzene	29	3%	ND	0.04	0.08	0.07	0.07	0.01	0.19

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-2 (Continued)
Summary Statistics for VOC Concentrations Measured at Baton Rouge, Louisiana (B2LA)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	25	17%	ND	0.08	0.07	0.06	0.05	0.02	0.27
1,1-Dichloroethane	30	0%	ND	ND	0.05	0.04	0.04	0.02	0.36
1,2-Dichloroethane	22	27%	ND	0.44	0.03	0.08	0.05	0.09	1.20
trans-1,2-Dichloroethylene	30	0%	ND	ND	0.06	0.05	0.05	0.02	0.29
1,2-Dichloropropane	30	0%	ND	ND	0.02	0.03	0.02	0.01	0.42
cis-1,3-Dichloropropylene	30	0%	ND	ND	0.03	0.03	0.03	0.01	0.24
trans-1,3-Dichloropropylene	30	0%	ND	ND	0.06	0.05	0.04	0.02	0.38
Ethyl acrylate	30	0%	ND	ND	0.05	0.04	0.04	0.01	0.30
Ethylbenzene	**0**	**100%**	**0.12**	**0.59**	**0.26**	**0.26**	**0.25**	**0.10**	**0.39**
Ethyl *tert*-butyl ether	30	0%	ND	ND	0.04	0.03	0.03	0.00	0.13
Methylene chloride	**6**	**80%**	**ND**	**0.47**	**0.14**	**0.15**	**0.12**	**0.09**	**0.64**
Methyl ethyl ketone	**3**	**90%**	**ND**	**3.40**	**1.03**	**1.13**	**0.83**	**0.78**	**0.69**
Methyl isobutyl ketone	25	17%	ND	0.25	0.04	0.05	0.04	0.05	0.96
Methyl methacrylate	25	17%	ND	0.17	0.04	0.05	0.04	0.04	0.79
Methyl *tert*-butyl ether	16	47%	ND	1.64	0.03	0.13	0.05	0.30	2.31
***n*-Octane**	**2**	**93%**	**ND**	**0.37**	**0.14**	**0.16**	**0.15**	**0.08**	**0.47**
Propylene	**0**	**100%**	**0.36**	**3.45**	**1.21**	**1.30**	**1.15**	**0.67**	**0.52**
Styrene	**0**	**100%**	**0.11**	**0.39**	**0.21**	**0.22**	**0.21**	**0.07**	**0.32**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-2 (Continued)
Summary Statistics for VOC Concentrations Measured at Baton Rouge, Louisiana (B2LA)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	29	3%	ND	0.04	0.04	0.03	0.03	0.00	0.06
1,1,2,2-Tetrachloroethane	30	0%	ND	ND	0.09	0.07	0.06	0.03	0.36
Tetrachloroethylene	**9**	**70%**	**ND**	**0.18**	**0.05**	**0.07**	**0.05**	**0.04**	**0.64**
Toluene	**0**	**100%**	**0.39**	**2.55**	**0.93**	**0.99**	**0.90**	**0.47**	**0.48**
1,1,1-Trichloroethane	**0**	**100%**	**0.05**	**0.28**	**0.13**	**0.13**	**0.12**	**0.06**	**0.42**
1,1,2-Trichloroethane	29	3%	ND	0.17	0.06	0.05	0.04	0.03	0.57
Trichloroethylene	22	27%	ND	0.17	0.02	0.03	0.03	0.04	1.04
Vinyl chloride	20	33%	ND	0.52	0.03	0.07	0.05	0.10	1.39
***m,p*-Xylene**	**0**	**100%**	**0.34**	**1.61**	**0.66**	**0.71**	**0.65**	**0.30**	**0.43**
***o*-Xylene**	**0**	**100%**	**0.18**	**0.80**	**0.33**	**0.35**	**0.33**	**0.14**	**0.39**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-3
Summary Statistics for VOC Concentrations Measured at Garyville, Louisiana (GALA)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	26	13%	ND	30.53	0.29	1.33	0.26	5.22	3.93
Acetylene	**0**	**100%**	**0.33**	**4.94**	**1.02**	**1.18**	**0.95**	**0.97**	**0.81**
Acrylonitrile	30	0%	ND	ND	0.11	0.07	0.06	0.04	0.54
Benzene	**0**	**100%**	**0.14**	**1.25**	**0.45**	**0.50**	**0.45**	**0.23**	**0.46**
Bromochloromethane	30	0%	ND	ND	0.05	0.03	0.03	0.01	0.38
Bromodichloromethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	30	0%	ND	ND	0.08	0.07	0.07	0.01	0.11
Bromomethane	30	0%	ND	ND	0.07	0.05	0.04	0.03	0.54
1,3-Butadiene	15	50%	ND	0.76	0.05	0.09	0.06	0.14	1.55
Carbon tetrachloride	**2**	**93%**	**ND**	**0.32**	**0.08**	**0.09**	**0.09**	**0.05**	**0.58**
Chlorobenzene	30	0%	ND	ND	0.04	0.03	0.03	0.01	0.27
Chloroethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	28	7%	ND	0.06	0.03	0.03	0.03	0.01	0.29
Chloromethane	**0**	**100%**	**0.30**	**4.01**	**0.89**	**1.07**	**0.89**	**0.75**	**0.70**
Chloroprene	20	33%	ND	2.94	0.05	0.39	0.09	0.71	1.83
Dibromochloromethane	30	0%	ND	ND	0.08	0.05	0.04	0.03	0.57
m-Dichlorobenzene	29	3%	ND	0.04	0.06	0.06	0.06	0.02	0.26
o-Dichlorobenzene	30	0%	ND	ND	0.08	0.07	0.06	0.02	0.23

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-3 (Continued)
Summary Statistics for VOC Concentrations Measured at Garyville, Louisiana (GALA)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	23	23%	ND	0.04	0.04	0.05	0.04	0.02	0.32
1,1-Dichloroethane	28	7%	ND	0.02	0.05	0.03	0.03	0.02	0.53
1,2-Dichloroethane	29	3%	ND	0.09	0.03	0.04	0.04	0.01	0.30
trans-1,2-Dichloroethylene	30	0%	ND	ND	0.06	0.04	0.04	0.02	0.41
1,2-Dichloropropane	30	0%	ND	ND	0.02	0.03	0.03	0.01	0.40
cis-1,3-Dichloropropylene	30	0%	ND	ND	0.03	0.02	0.02	0.01	0.33
trans-1,3-Dichloropropylene	30	0%	ND	ND	0.06	0.04	0.03	0.02	0.56
Ethyl acrylate	30	0%	ND	ND	0.05	0.04	0.03	0.02	0.42
Ethylbenzene	**0**	**100%**	**0.04**	**0.38**	**0.13**	**0.15**	**0.13**	**0.08**	**0.54**
Ethyl *tert*-butyl ether	30	0%	ND	ND	0.04	0.03	0.03	0.01	0.17
Methylene chloride	**11**	**63%**	**ND**	**7.16**	**0.06**	**0.48**	**0.12**	**1.39**	**2.89**
Methyl ethyl ketone	**2**	**93%**	**ND**	**33.33**	**0.62**	**1.79**	**0.60**	**5.97**	**3.33**
Methyl isobutyl ketone	29	3%	ND	0.11	0.04	0.04	0.04	0.01	0.35
Methyl methacrylate	30	0%	ND	ND	0.04	0.03	0.03	0.00	0.08
Methyl *tert*-butyl ether	28	7%	ND	0.11	0.03	0.03	0.02	0.02	0.70
***n*-Octane**	**6**	**80%**	**ND**	**0.70**	**0.12**	**0.15**	**0.11**	**0.12**	**0.85**
Propylene	**0**	**100%**	**0.24**	**2.41**	**0.83**	**0.91**	**0.79**	**0.48**	**0.53**
Styrene	**12**	**60%**	**ND**	**0.17**	**0.06**	**0.07**	**0.06**	**0.03**	**0.50**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-3 (Continued)
Summary Statistics for VOC Concentrations Measured at Garyville, Louisiana (GALA)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	30	0%	ND	ND	0.04	0.03	0.03	0.00	0.08
1,1,2,2-Tetrachloroethane	30	0%	ND	ND	0.09	0.06	0.05	0.03	0.53
Tetrachloroethylene	24	20%	ND	0.08	0.05	0.07	0.06	0.03	0.45
Toluene	**0**	**100%**	**0.22**	**10.23**	**0.70**	**1.18**	**0.78**	**1.82**	**1.54**
1,1,1-Trichloroethane	**0**	**100%**	**0.05**	**138.76**	**0.23**	**6.94**	**0.33**	**26.98**	**3.89**
1,1,2-Trichloroethane	30	0%	ND	ND	0.06	0.04	0.03	0.02	0.56
Trichloroethylene	29	3%	ND	0.13	0.03	0.03	0.03	0.02	0.70
Vinyl chloride	29	3%	ND	0.21	0.03	0.04	0.03	0.03	0.83
***m,p*-Xylene**	**0**	**100%**	**0.10**	**1.06**	**0.36**	**0.40**	**0.34**	**0.24**	**0.60**
***o*-Xylene**	**1**	**97%**	**ND**	**0.52**	**0.17**	**0.21**	**0.17**	**0.13**	**0.60**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-4
Summary Statistics for VOC Concentrations Measured at Hahnville, Louisiana (HALA)
(Based on 33 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	27	18%	ND	6.54	0.29	0.66	0.27	1.29	1.94
Acetylene	**0**	**100%**	**0.14**	**3.62**	**0.81**	**0.98**	**0.81**	**0.58**	**0.59**
Acrylonitrile	25	24%	ND	3.07	0.11	0.35	0.13	0.65	1.88
Benzene	**0**	**100%**	**0.07**	**1.21**	**0.45**	**0.50**	**0.40**	**0.29**	**0.58**
Bromochloromethane	33	0%	ND	ND	0.05	0.03	0.03	0.01	0.38
Bromodichloromethane	33	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	33	0%	ND	ND	0.08	0.07	0.07	0.01	0.11
Bromomethane	32	3%	ND	0.06	0.07	0.05	0.04	0.03	0.53
1,3-Butadiene	19	42%	ND	0.36	0.05	0.08	0.05	0.08	1.09
Carbon tetrachloride	**4**	**88%**	**ND**	**0.29**	**0.08**	**0.09**	**0.08**	**0.05**	**0.59**
Chlorobenzene	33	0%	ND	ND	0.04	0.03	0.03	0.01	0.27
Chloroethane	33	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	31	6%	ND	0.10	0.03	0.03	0.03	0.01	0.51
Chloromethane	**1**	**97%**	**ND**	**4.97**	**0.83**	**1.13**	**0.78**	**1.01**	**0.89**
Chloroprene	28	15%	ND	0.93	0.05	0.09	0.04	0.18	1.91
Dibromochloromethane	33	0%	ND	ND	0.08	0.05	0.04	0.03	0.56
m-Dichlorobenzene	33	0%	ND	ND	0.08	0.06	0.06	0.02	0.25
o-Dichlorobenzene	33	0%	ND	ND	0.08	0.07	0.06	0.02	0.23

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-4 (Continued)
Summary Statistics for VOC Concentrations Measured at Hahnville, Louisiana (HALA)
(Based on 33 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	29	12%	ND	0.03	0.04	0.05	0.05	0.02	0.32
1,1-Dichloroethane	32	3%	ND	0.01	0.05	0.03	0.03	0.02	0.52
1,2-Dichloroethane	29	12%	ND	0.16	0.03	0.04	0.04	0.02	0.60
trans-1,2-Dichloroethylene	33	0%	ND	ND	0.06	0.04	0.04	0.02	0.40
1,2-Dichloropropane	33	0%	ND	ND	0.02	0.03	0.03	0.01	0.40
cis-1,3-Dichloropropylene	33	0%	ND	ND	0.03	0.02	0.02	0.01	0.33
trans-1,3-Dichloropropylene	33	0%	ND	ND	0.06	0.04	0.03	0.02	0.55
Ethyl acrylate	33	0%	ND	ND	0.05	0.04	0.03	0.02	0.42
Ethylbenzene	**2**	**94%**	**ND**	**0.56**	**0.13**	**0.15**	**0.13**	**0.10**	**0.67**
Ethyl *tert*-butyl ether	32	3%	ND	0.81	0.04	0.05	0.03	0.14	2.52
Methylene chloride	**15**	**55%**	**ND**	**1.97**	**0.05**	**0.12**	**0.07**	**0.25**	**2.11**
Methyl ethyl ketone	**7**	**79%**	**ND**	**3.86**	**0.58**	**0.74**	**0.38**	**0.79**	**1.08**
Methyl isobutyl ketone	33	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl methacrylate	32	3%	ND	0.27	0.04	0.04	0.03	0.04	1.03
Methyl *tert*-butyl ether	28	15%	ND	0.24	0.03	0.04	0.03	0.05	1.21
***n*-Octane**	**3**	**91%**	**ND**	**1.36**	**0.13**	**0.20**	**0.14**	**0.27**	**1.33**
Propylene	**0**	**100%**	**0.24**	**8.04**	**0.93**	**1.52**	**1.05**	**1.80**	**1.19**
Styrene	**9**	**73%**	**ND**	**0.35**	**0.05**	**0.06**	**0.05**	**0.06**	**0.90**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-4 (Continued)
Summary Statistics for VOC Concentrations Measured at Hahnville, Louisiana (HALA)
(Based on 33 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	33	0%	ND	ND	0.04	0.03	0.03	0.00	0.08
1,1,2,2-Tetrachloroethane	33	0%	ND	ND	0.09	0.06	0.05	0.03	0.53
Tetrachloroethylene	25	24%	ND	0.15	0.05	0.07	0.06	0.03	0.48
Toluene	**0**	**100%**	**0.21**	**3.29**	**0.75**	**0.90**	**0.73**	**0.69**	**0.76**
1,1,1-Trichloroethane	**1**	**97%**	**ND**	**1.03**	**0.10**	**0.17**	**0.11**	**0.22**	**1.32**
1,1,2-Trichloroethane	33	0%	ND	ND	0.06	0.04	0.03	0.02	0.55
Trichloroethylene	32	3%	ND	0.08	0.02	0.03	0.02	0.01	0.42
Vinyl chloride	32	3%	ND	0.11	0.03	0.03	0.03	0.01	0.41
***m,p*-Xylene**	**0**	**100%**	**0.11**	**1.51**	**0.35**	**0.40**	**0.33**	**0.29**	**0.72**
***o*-Xylene**	**1**	**97%**	**ND**	**0.75**	**0.19**	**0.20**	**0.16**	**0.14**	**0.69**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-5
Geometric Mean Concentrations for the Most Prevalent VOC at B2LA, GALA, and HALA

Compound	Geometric Mean Concentration (ppbv), by Monitoring Station		
	B2LA	GALA	HALA
Acetylene	1.53	0.95	0.81
Benzene	0.54	0.45	0.40
Carbon tetrachloride	0.09	0.09	0.08
Chloromethane	0.58	0.89	0.78
Ethylbenzene	0.25	0.13	0.13
Methylene chloride	0.12	0.12	0.07
Methyl ethyl ketone	0.83	0.60	0.38
n-Octane	0.15	0.11	0.14
Propylene	1.15	0.79	1.05
Styrene	0.21	0.06	0.05
Toluene	0.90	0.78	0.73
1,1,1-Trichloroethane	0.12	0.33	0.11
m,*p*-Xylene	0.65	0.34	0.33
o-Xylene	0.33	0.17	0.16

Table 4-6
Summary Statistics for Carbonyl Concentrations Measured at Baton Rouge, Louisiana (B2LA)
(Based on 33 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.02**	**1.90**	**0.70**	**0.75**	**0.63**	**0.38**	**0.51**
Acetone	**1**	**97%**	**ND**	**2.04**	**1.02**	**0.96**	**0.61**	**0.60**	**0.62**
Acrolein	**3**	**91%**	**ND**	**0.22**	**0.02**	**0.03**	**0.02**	**0.04**	**1.34**
Benzaldehyde	**5**	**85%**	**ND**	**0.07**	**0.02**	**0.02**	**0.01**	**0.02**	**0.80**
Butyr/Isobutyraldehyde	**1**	**97%**	**ND**	**0.31**	**0.10**	**0.12**	**0.10**	**0.07**	**0.54**
Crotonaldehyde	24	27%	ND	0.03	0.00	0.01	0.00	0.01	1.31
2,5-Dimethylbenzaldehyde	32	3%	ND	0.02	0.00	0.00	0.00	0.00	1.10
Formaldehyde	**0**	**100%**	**0.02**	**8.08**	**1.46**	**1.83**	**1.39**	**1.45**	**0.79**
Hexanaldehyde	**1**	**97%**	**ND**	**0.19**	**0.02**	**0.04**	**0.03**	**0.04**	**0.98**
Isovaleraldehyde	19	42%	ND	0.03	0.01	0.01	0.01	0.01	0.78
Propionaldehyde	**1**	**97%**	**ND**	**0.28**	**0.08**	**0.10**	**0.08**	**0.06**	**0.60**
Tolualdehydes	21	36%	ND	0.07	0.00	0.02	0.01	0.02	1.19
Valeraldehyde	**2**	**94%**	**ND**	**0.09**	**0.02**	**0.03**	**0.02**	**0.02**	**0.78**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-7
Summary Statistics for Carbonyl Concentrations Measured at Garyville, Louisiana (GALA)
(Based on 33 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.53**	**1.78**	**0.81**	**0.95**	**0.89**	**0.36**	**0.38**
Acetone	**0**	**100%**	**0.14**	**4.44**	**0.50**	**0.87**	**0.60**	**0.92**	**1.05**
Acrolein	**0**	**100%**	**0.01**	**0.07**	**0.03**	**0.03**	**0.03**	**0.01**	**0.44**
Benzaldehyde	**6**	**82%**	**ND**	**0.15**	**0.03**	**0.04**	**0.02**	**0.03**	**0.86**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.08**	**0.36**	**0.17**	**0.18**	**0.17**	**0.08**	**0.43**
Crotonaldehyde	28	15%	ND	0.22	0.00	0.01	0.00	0.04	3.48
2,5-Dimethylbenzaldehyde	21	36%	ND	0.04	0.00	0.01	0.01	0.01	1.13
Formaldehyde	**0**	**100%**	**0.99**	**4.78**	**2.09**	**2.30**	**2.12**	**0.96**	**0.42**
Hexanaldehyde	**0**	**100%**	**0.04**	**1.02**	**0.09**	**0.15**	**0.10**	**0.19**	**1.30**
Isovaleraldehyde	**6**	**82%**	**ND**	**0.11**	**0.02**	**0.03**	**0.02**	**0.02**	**0.93**
Propionaldehyde	**0**	**100%**	**0.09**	**0.39**	**0.18**	**0.20**	**0.19**	**0.08**	**0.38**
Tolualdehydes	**6**	**82%**	**ND**	**0.14**	**0.03**	**0.03**	**0.02**	**0.03**	**0.85**
Valeraldehyde	**0**	**100%**	**0.02**	**0.36**	**0.16**	**0.17**	**0.15**	**0.09**	**0.50**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-8
Summary Statistics for Carbonyl Concentrations Measured at Hahnville, Louisiana (HALA)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.04**	**3.95**	**1.01**	**1.15**	**0.79**	**0.87**	**0.75**
Acetone	**0**	**100%**	**0.07**	**2.77**	**0.57**	**0.85**	**0.52**	**0.75**	**0.88**
Acrolein	**1**	**97%**	**ND**	**0.14**	**0.03**	**0.04**	**0.03**	**0.03**	**0.78**
Benzaldehyde	**1**	**97%**	**ND**	**0.39**	**0.03**	**0.05**	**0.03**	**0.08**	**1.61**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.02**	**1.34**	**0.20**	**0.23**	**0.16**	**0.24**	**1.06**
Crotonaldehyde	26	13%	ND	0.06	0.00	0.01	0.00	0.01	1.63
2,5-Dimethylbenzaldehyde	29	3%	ND	0.03	0.00	0.00	0.00	0.01	1.40
Formaldehyde	**0**	**100%**	**0.70**	**27.63**	**2.05**	**3.46**	**2.16**	**5.58**	**1.61**
Hexanaldehyde	**0**	**100%**	**0.02**	**4.78**	**0.07**	**0.29**	**0.08**	**0.88**	**3.08**
Isovaleraldehyde	**6**	**80%**	**ND**	**0.62**	**0.01**	**0.04**	**0.01**	**0.11**	**2.86**
Propionaldehyde	**0**	**100%**	**0.01**	**0.51**	**0.15**	**0.17**	**0.13**	**0.10**	**0.63**
Tolualdehydes	**10**	**67%**	**ND**	**0.21**	**0.02**	**0.04**	**0.02**	**0.04**	**1.14**
Valeraldehyde	**0**	**100%**	**0.01**	**1.30**	**0.07**	**0.15**	**0.08**	**0.25**	**1.68**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 4-9
Geometric Mean Concentrations for the Most Prevalent Carbonyls at B2LA, GALA, and HALA

Compound	Geometric Mean Concentration (ppbv), by Monitoring Station		
	B2LA	GALA	HALA
Acetaldehyde	0.63	0.89	0.79
Acetone	0.61	0.60	0.52
Acrolein	0.02	0.03	0.03
Benzaldehyde	0.01	0.02	0.03
Butyr/Isobutyraldehyde	0.10	0.17	0.16
Formaldehyde	1.39	2.12	2.16
Hexanaldehyde	0.03	0.10	0.08
Propionaldehyde	0.08	0.19	0.13
Valeraldehyde	0.02	0.15	0.08

5.0 Monitoring Results for Brattleboro, VT (BRVT)

This section summarizes ambient air monitoring data collected at the Brattleboro, Vermont (BRVT), monitoring station during the 1995, 1996, and 1997 UATMPs. Brattleboro is a small city located in a valley in southern Vermont. As Figure 5-1 shows, the monitoring station is located north of town in a vacant lot, next to a Farm & Garden Center (a store). The site is in a lightly industrial area. Except for Interstate highway 91 and U.S. highway 5, which both pass within 1 mile of the monitoring station, few heavily traveled roadways are in the immediate vicinity of BRVT. During the 1997 UATMP, the monitors at BRVT attempted to collect air samples on 32 days. Valid VOC samples were collected on 31 days, and valid carbonyl samples on 29 days. Thus, the completeness of the VOC and carbonyl sampling at BRVT was 97 percent and 91 percent, respectively.

The remainder of this section is divided into four parts: Section 5.1 summarizes the 1997 UATMP monitoring data collected at BRVT; Section 5.2 analyzes ambient air concentrations of selected nitriles and oxygenated compounds; Section 5.3 describes how concentrations of certain compounds have changed since the 1995 UATMP; and Section 5.4 briefly summarizes the most notable findings of the preceding subsections.

5.1 Data Summary Parameters for the 1997 UATMP

Using the data summary parameters defined in Section 3.1, Tables 5-1 and 5-2 summarize the data collected in Brattleboro, Vermont, during the 1997 UATMP. Table 5-1 presents data for VOC; Table 5-2 presents data for carbonyls. To facilitate comparisons between monitoring data from earlier UATMPs, the format used in these tables is the same as that used in previous reports.

5.1.1 Data Summary of VOC

The summary statistics in Table 5-1 reveal the following notable patterns among ambient air concentrations of VOC at Brattleboro, Vermont:

- *Prevalence*. According to Table 5-1, 18 of the 47 compounds that the VOC analytical method could identify were detected in more than half of the samples collected at BRVT. These compounds are: acetylene, benzene, 1,3-butadiene, carbon tetrachloride, chloromethane, ethylbenzene, methylene chloride, methyl ethyl ketone, methyl *tert*-butyl ether, *n*-octane, propylene, styrene, tetrachloroethylene, toluene, 1,1,1-trichloroethane, *m,p*-xylene, and *o*-xylene.

  Due to the frequent detections, summary statistics for these compounds are least affected by nondetect observations, which are replaced in the UATMP database with an estimated concentration of one-half the detection limit. Therefore, most of the discussion in this section focuses on the 18 most prevalent compounds. However, it should not be inferred that the VOC detected in fewer than half the samples are not present in ambient air at BRVT. They may be present at varying levels or consistently present at concentrations the VOC analytical method cannot measure. In either case, statistically meaningful air quality trends cannot be calculated for these compounds because of the high number of nondetects.

- *Concentration Range*. According to the concentration range data in Table 5-1, most VOC at BRVT never had 24-hour average concentrations greater than 1.0 ppbv. The exceptions are acetylene, methyl ethyl ketone, propylene, and toluene. Even for these compounds, the highest concentrations measured at BRVT are relatively modest compared to those measured at other monitoring stations. Ambient air concentrations of VOC at BRVT never reached 5.0 ppbv during the 1997 UATMP. Because samples were collected roughly biweekly, however, it is likely that concentrations of certain compounds reached levels higher than those shown in Table 5-1 on days when samples were not collected. Therefore, the concentration ranges in Table 5-1 only estimate the actual span of concentrations at BRVT.

- *Central Tendency*. Of the compounds shown in Table 5-1, only those shown in boldface were detected in more than half of the VOC samples. Central tendency values for all other compounds should be interpreted with caution, because these compounds' higher frequency of nondetects probably biased the central tendency calculations. Of the 18 compounds detected in more than half of the samples, the highest geometric mean concentrations were observed for acetylene (1.38 ppbv), propylene (0.75 ppbv), and toluene (0.95 ppbv). Geometric mean concentrations for all other VOC at BRVT were less than 0.50 ppbv.

  The graphs in Figure 3-1, which compare geometric mean concentrations observed at the 12 different UATMP monitoring stations, show that airborne levels of all but two VOC were not unusually higher or lower at BRVT than at the other monitoring stations. As the first exception, the BRVT monitoring station had the second highest geometric mean concentration of methylene chloride of the 1997

UATMP monitoring stations. The final report for the 1996 UATMP suggested that emissions from nearby industrial sources most likely accounted for the relatively high levels of methylene chloride at this station. According to TRI, an industrial facility in Brattleboro emitted 6,044 pounds of methylene chloride to the air in 1995, but it is not known how much this facility emitted during the 1997 UATMP. As the second exception, while geometric mean concentrations of methyl *tert*-butyl ether were less than 0.05 ppbv at most monitoring stations, the geometric mean concentration of this compound at Brattleboro (and at two other cities in Vermont) was greater than 0.15 ppbv. Section 5.2 identifies the most likely source of methyl *tert*-butyl ether in the Brattleboro air.

> *Note*: When interpreting the graphs in Figure 3-1, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within these areas. Since levels of air pollution vary significantly within cities, the figure should be interpreted as indicating ambient air concentrations specifically at the BRVT monitoring station. These concentrations may be dramatically different from those at other locations in Brattleboro.

- *Variability*. The coefficients of variation for all of the most prevalent VOC were less than 1.0, suggesting that ambient air concentrations of these compounds have comparable variability (i.e., concentration changes from one sampling date to the next are relatively similar for different VOC). Of the most prevalent VOC at Brattleboro, however, methylene chloride exhibited the greatest variability. The more variable concentrations of this compound are consistent with the assumption that methylene chloride was emitted primarily from sources at discrete locations in Brattleboro (e.g., industrial facilities), since the air monitor would probably detect the compound only when it was downwind from the emissions sources.

Section 5.2, which analyzes the air monitoring data for selected nitriles and oxygenated compounds, and Section 5.3, which evaluates how average concentrations of selected compounds have changed at BRVT since the 1995 UATMP, discuss air quality trends for VOC at Brattleboro in greater detail.

5.1.2 Data Summary of Carbonyls

Table 5-2 characterizes the ambient air monitoring data for carbonyls at BRVT as follows:

- *Prevalence*. Only two carbonyls (crotonaldehyde and 2,5-dimethylbenzaldehyde) were detected in fewer than half of the samples collected at BRVT. Therefore, summary statistics for all but these two carbonyls are expected to represent actual air quality trends in the Brattleboro area.

- *Concentration Range*. Only three carbonyls (acetaldehyde, acetone, and formaldehyde) had at least one 24-hour average concentration at BRVT greater than 1.0 ppbv during the 1997 UATMP, and no carbonyl was detected above 5.0 ppbv. As stated earlier, the concentration ranges shown in Table 5-2 only estimate the actual ranges, because concentrations may have reached higher and lower levels on days when sampling did not occur.

- *Central Tendency*. Of the 14 most prevalent carbonyls, geometric mean concentrations were highest for formaldehyde (1.81 ppbv), acetone (1.18 ppbv), and acetaldehyde (0.82 ppbv). These levels were all over six times greater than the next highest geometric mean concentration at this site (butyr/isobutyraldehyde, 0.12 ppbv). Therefore, ambient air concentrations of acetaldehyde, acetone, and formaldehyde account for a large portion of carbonyls in ambient air at Brattleboro.

  Figure 3-2, which compares geometric mean concentrations of the most prevalent carbonyls across all 12 monitoring stations, indicates that geometric mean concentrations at Brattleboro were about average compared to those measured at other monitoring stations. The geometric mean concentration of acetone at Brattleboro, however, was third highest among those at the 1997 UATMP monitoring stations. Other monitoring stations in Vermont also had relatively high geometric mean concentrations of acetone, but these concentrations were marginally lower than that at BRVT. The final report for the 1996 UATMP hypothesized that the relatively high levels of acetone in Vermont are due in part to both motor vehicle emissions and relatively weak photochemical reactivity during Vermont's short summer season.

  Note: As noted above, when reviewing the graphs in Figure 3-2, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within these areas. The information in Figure 3-2 should be interpreted accordingly.

- *Variability*. The coefficients of variation for the 14 most prevalent carbonyls at BRVT were all less than 1.0—a similarity suggesting that ambient air concentrations of these compounds have comparable variability. The relatively low coefficients of variation also suggest that carbonyls are consistently found in the Brattleboro air, regardless of changing wind directions. This trend is consistent with assumptions that carbonyls in the area possibly originated from many different emissions sources or as the product of photochemical reactions.

For further information on air quality trends for selected carbonyls, readers should refer to Section 5.3, which discusses annual variations in ambient air concentrations at BRVT, and to Section 12.1, which reviews carbonyl monitoring data from all 12 monitoring stations that participated in the 1997 UATMP.

5.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

As Section 2.2.1 described, the VOC analytical method used during the 1997 UATMP was capable of detecting nine compounds (all nitriles and oxygenated compounds) that could not be detected in earlier UATMPs. Most of these compounds were rarely detected at BRVT, except for methyl ethyl ketone and methyl *tert*-butyl ether. Detailed analyses of the ambient air monitoring data for the entire group of compounds follow:

- *Compounds that were rarely, if ever, detected.* Of the nine nitriles and oxygenated compounds measured during the 1997 UATMP, six—acetonitrile, ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, methyl methacrylate, and *tert*-amyl methyl ether—were never detected at BRVT, and one—acrylonitrile—was detected twice at this station. Not surprisingly, no industrial facilities in the vicinity of the BRVT monitoring station reported air releases of these seven compounds to the 1995 TRI. (Note: Facilities currently are not required to report releases of either ethyl *tert*-butyl ether or *tert*-amyl methyl ether to TRI.) Thus, few conclusions can be drawn about this subset of nitriles and oxygenated compounds, except that they consistently are not found at detectable levels in ambient air near the BRVT monitoring station.

- *Methyl ethyl ketone*. The geometric mean concentration of methyl ethyl ketone, which was detected during 28 sampling events, was 0.40 ppbv. Geometric mean concentrations of this compound at most of the other monitoring stations that participated in the 1997 UATMP were higher than this level. Even though methyl ethyl ketone has been found in motor vehicle exhaust, there is strong evidence that motor vehicles are not the predominant sources of methyl ethyl ketone at BRVT: concentrations of the compound were found to be weakly correlated, if not completely uncorrelated, with concentrations of compounds that are found primarily in motor vehicle exhaust (e.g., benzene, ethylbenzene, toluene, and the xylene isomers). Industrial emissions sources, on the other hand, probably account for a significant fraction of the levels of methyl ethyl ketone observed at BRVT (and at the other UATMP monitoring stations). However, according to the 1995 TRI, only one facility within 10 miles of the Brattleboro monitoring station reported releasing the compound, and that facility reported emitting less than 1,000 pounds of the compound to the air. This finding does not necessarily contradict the hypothesis that methyl ethyl ketone originated primarily from industrial sources, since not all industrial facilities are required to report chemical releases to TRI. Analyses of more recent TRI data, once available, and of local emissions inventories may identify other sources of methyl ethyl ketone in the area.

Concentrations of methyl ethyl ketone at most of the monitoring stations tended to be higher during the warmer summer months than during other months of the year. Consistent with this observation, the average concentration measured at Brattleboro from September 1997 to May 1998 (0.41 ppbv) was almost 40 percent lower than the average concentration measured between June and August of 1998 (0.65 ppbv). The higher concentrations during the warmer summer months may result from many factors, including greater evaporative losses of methyl ethyl ketone from industrial sources, seasonal changes in photochemical reactivity, and seasonal changes in prevailing wind patterns. Further study is needed to assess the extent to which these factors affect ambient air concentrations of methyl ethyl ketone in the Brattleboro area.

- *Methyl tert-butyl ether*. As Section 3.2 explained, methyl *tert*-butyl ether is added to gasoline in some states to reduce emissions of toxic chemicals from motor vehicles. Section 6.2 provides compelling evidence that the levels of methyl *tert*-butyl ether at the Vermont monitoring stations originate from the use of reformulated gasolines, even though Vermont does not require gas stations to sell reformulated fuels. Nonetheless, a small fraction of gasoline stations in the state are known to receive reformulated gasoline from their distributors (Scranton, 1999). Further, some motor vehicles operating in the state may run on fuel purchased in Massachusetts or other states that require motor vehicles to use only reformulated fuels.

  Since Brattleboro is within 10 miles of Massachusetts, it is possible that some methyl *tert*-butyl ether at BRVT may originate from emissions from motor vehicles traveling in the state of Massachusetts. However, the analyses in Section 6.2 suggest that the levels of methyl *tert*-butyl ether observed in other Vermont cities are likely not affected by transport of emissions from other states. A detailed inventory of the types of fuels sold at Brattleboro gas stations would help determine the extent to which local emissions and long-range transport of emissions affect levels of methyl *tert*-butyl ether at BRVT.

> For information on concentrations of methyl *tert*-butyl ether observed in an area where EPA requires all motor vehicles to use reformulated gasoline, readers should refer to the analyses for the Camden monitoring station in Section 7.2.

5.3 Annual Variations

Most of the compounds sampled for at BRVT during the 1997 UATMP were also sampled for during the 1995 and 1996 programs, allowing an analysis of annual trends in levels of air pollution. A complete set of monitoring data were not collected at BRVT during the 1995 UATMP. More specifically, valid VOC samples were collected on only four dates during the 1995 program, so representative annual average concentrations for that year are not available. Valid carbonyl samples, on the other hand, were collected on 13 dates during the 1995 program, but only between March and August of that year. This section considers the annual average concentrations of carbonyls for the 1995 UATMP, but these concentrations may be biased by seasonal changes in air quality.

Annual average concentrations of most air pollutants change, to a certain extent, from one year to the next, but these changes are not always statistically significant. As Section 3.3 explained, this report considers "significant" changes to occur only when the entire 95-percent confidence interval of an annual average concentration is higher or lower than that of another UATMP year. Statistically significant changes in air quality can occur for many different reasons, including changing emission rates from selected sources and changing meteorological conditions.

Figures 5-2 and 5-3 show how annual average concentrations (and corresponding confidence intervals) of the most prevalent VOC and carbonyls changed at BRVT during the last three UATMPs. Due to the effect of many nondetect observations on calculations of central tendency, this section does not consider annual variations for compounds detected in fewer than half of the samples collected during the 1997 UATMP.

When considering the following discussion of "annual" changes in average concentrations, it is important to note that the UATMP year does not correspond with the calendar year. The

UATMP year generally begins in September and ends in August of the following calendar year. Thus, a significant portion of the data reported for a given UATMP program year is actually collected during the following calendar year.

5.3.1 Annual Variations for VOC

According to Figure 5-2, average concentrations of almost all VOC did not change significantly from the 1996 to the 1997 UATMP. The exception was acetylene, for which the annual average concentration decreased by more than 40 percent over that period. More detailed analyses of the annual variations for different groups of compounds follow:

- *BTEX compounds*. The average concentration of benzene, ethylbenzene, toluene, and the xylene isomers—a group of compounds that is emitted primarily from mobile sources—either decreased slightly or did not change between the 1996 and 1997 program years. None of the averages decreased by more than 25 percent and no decrease appears to be statistically significant. The absence of notable annual variations suggests that local traffic patterns and motor vehicle fuels used in the Brattleboro area did not change significantly between the 1996 and 1997 UATMPs, but it is not certain whether these hypotheses are true.

- *Halogenated hydrocarbons*. Of the most prevalent VOC, five are halogenated hydrocarbons: carbon tetrachloride, chloromethane, methylene chloride, tetrachloroethylene, and 1,1,1-trichloroethane. Annual variations for these compounds are considered separately from those for the BTEX compounds, since previous UATMP reports have indicated that airborne halogenated hydrocarbons do not appear to originate from mobile source emissions. As Figure 5-3 shows, average concentrations of four of these compounds (carbon tetrachloride, chloromethane, tetrachloroethylene, and 1,1,1-trichloroethane) at BRVT changed by less than 0.05 ppbv from the 1996 to 1997 UATMPs. Besides the fact that none of these changes appear to be statistically significant, this level of change is too small to warrant discussion of potential causal factors.

  The average concentration of methylene chloride, in contrast, fell from 0.77 ppbv to 0.41 ppbv from the 1996 UATMP to the 1997 UATMP—a decline of almost 50 percent. Since the 95-percent confidence intervals of the average concentrations in program years 1996 and 1997 overlap, it is not clear whether the apparent decline in concentrations is statistically significant. As noted previously, local industrial sources (including one that reportedly emitted 6,044 pounds of the compound to the air in 1995) probably account for the levels of methylene chloride observed at

BRVT. Since TRI data are not available for 1996, 1997, or 1998, the effect of changing emissions from industrial sources on ambient air concentrations of methylene chloride cannot be evaluated. Further research is encouraged to determine why concentrations of methylene chloride decreased at this station, and further monitoring is encouraged to confirm whether the decreasing concentrations were anomalous or part of a long term trend.

- *Other compounds*. Of the five remaining prevalent VOC, ambient air concentrations for four changed little from the 1996 to 1997 programs and the changes did not appear to be statistically significant: the average concentrations of 1,3-butadiene, *n*-octane, and styrene changed by 0.03 ppbv or less from program year 1996 to the following year; and the average concentration of propylene fell by a greater amount (from 0.90 ppbv to 0.79 ppbv), but this change amounted to only a 12-percent decrease.

  Only one of the five remaining VOC—acetylene—changed significantly over time: the average concentration was 2.60 ppbv during the 1996 UATMP, and 1.52 ppbv the next year—a decline of over 40 percent. The annual variations for acetylene at BRVT differ from those for the BTEX compounds, even though motor vehicle emissions reportedly account for a large fraction of airborne acetylene and BTEX compounds in urban environments. Ambient air concentrations of acetylene decreased by 30–50 percent between the 1996 and 1997 programs at all five UATMP monitoring stations in Vermont. Though the similar trends at these different locations suggest that regional factors (e.g., photochemical reactions, long-range transport of emissions) might have a significant impact on ambient levels of acetylene, further research is needed to explain the annual variations for this compound.

5.3.2 Annual Variations for Carbonyls

Figure 5-3 shows average concentrations of carbonyls measured at Brattleboro during the 1995, 1996, and 1997 UATMPs. As noted earlier in this section, the average concentrations for the 1995 program may be influenced by seasonal effects, since these averages are based on only 6 months of sampling. Like those of the VOC, annual average concentrations of carbonyls at BRVT tended to either decrease or stay the same over the past 3 years. A discussion of the annual variations for the most prevalent carbonyls follows:

- *Compounds with decreasing annual average concentrations*. Of the 14 carbonyls considered in Figure 5-3, 10 exhibited similar annual variations: their annual average concentrations during the 1995 UATMP were higher than those during the 1996 UATMP, which were higher still than those during the 1997 UATMP. This trend was observed for acetaldehyde, butyr/isobutyraldehyde, hexanaldehyde, isovaleraldehyde, propionaldehyde, the three tolualdehyde isomers, and valeraldehyde. For all of these compounds, the annual average concentration decreased by between 40 and 80 percent from the 1995 to the 1997 programs. Though the downward trend for many of these compounds appears to be statistically significant, the primary cause of the decreasing concentrations is not known. As Sections 6 and 10 note, ambient air concentrations of many of the same compounds also decreased in three other cities in Vermont (Burlington, Rutland, and Winooski). Further monitoring is needed to determine whether the similar annual variations across these cities are coincidental or part of a regional data trend.

- *Compounds with unchanging levels or no apparent annual trends*. For the remaining four carbonyls shown in Figure 5-3 (acetone, acrolein, benzaldehyde, and formaldehyde), annual average concentrations increased from the 1995 to the 1996 UATMP and then decreased from the 1996 UATMP to the 1997 UATMP. With one exception, the annual variations observed for these compounds do not appear to be statistically significant. For acetone, however, the annual average concentrations during the 1996 and 1997 programs are at least twice as high as that during the 1995 program, and these differences appear to be statistically significant. Identifying the causes of these annual variations is difficult because emissions data are not readily available for these carbonyls. Further, without ambient air monitoring data for VOC from 1995, it is uncertain whether the annual variations for carbonyls parallel those for selected VOC. (Similarities between ambient air concentrations of different compounds help provide insight into what factors affect annual variations in air quality.) Results from additional monitoring studies and detailed emissions inventories may provide better explanations for the subtle air quality trends for these carbonyls.

5.4 Summary

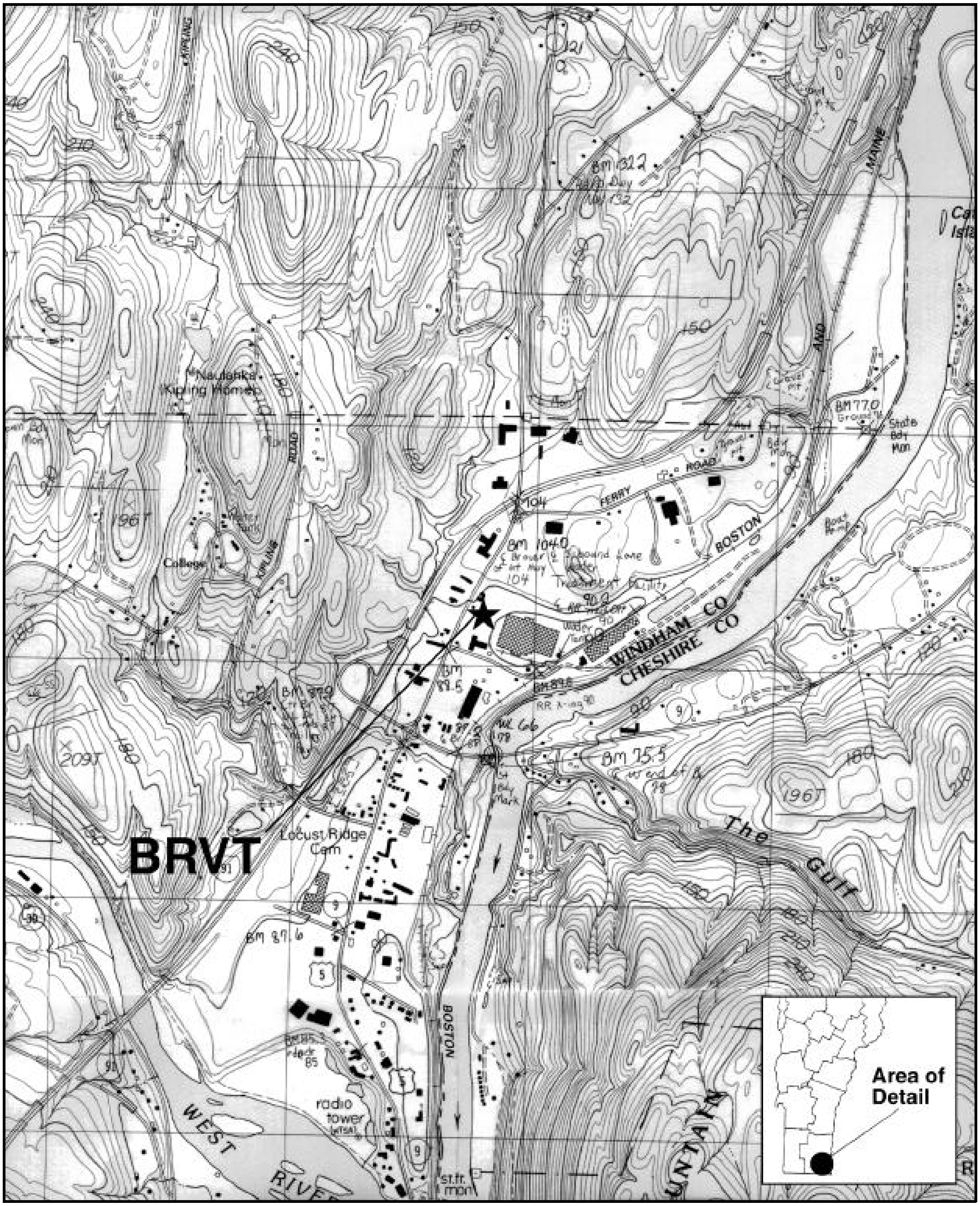
The 1997 UATMP monitoring data collected at Brattleboro, Vermont, were in many ways similar to the data collected during previous UATMPs at the same site. For example, about half of the compounds identified by the sampling and analytical methods (i.e., 18 VOC and 12 carbonyls) were detected in over half of the ambient air samples taken at BRVT. Of these compounds, ambient air concentrations of acetaldehyde, acetone, acetylene, formaldehyde, propylene, and toluene were consistently higher than those of other compounds. With the possible exception of methylene chloride, the geometric mean concentrations of most pollutants at

Brattleboro were neither notably higher nor lower than levels measured at the other monitoring stations participating in the 1997 UATMP. Consistent with findings from the 1996 UATMP, the relatively high levels of methylene chloride at BRVT appear to originate from nearby industrial emissions sources.

The 1997 UATMP was the first year in which air samples were analyzed for concentrations of nine nitriles and oxygenated compounds. Of these, only methyl ethyl ketone and methyl *tert*-butyl ether were detected in more than half of the samples collected at BRVT. The UATMP data from BRVT (and other stations) indicate that emissions from industrial sources probably account for much of the methyl ethyl ketone found in the air. Concentrations of methyl *tert*-butyl ether, on the other hand, seem to result primarily from emissions from motor vehicles that use reformulated gasoline. While Vermont does not require that gasoline sold in the state contain methyl *tert*-butyl ether, some gas stations in the state sell fuels containing the compound, and all gasoline sold in nearby Massachusetts contains it.

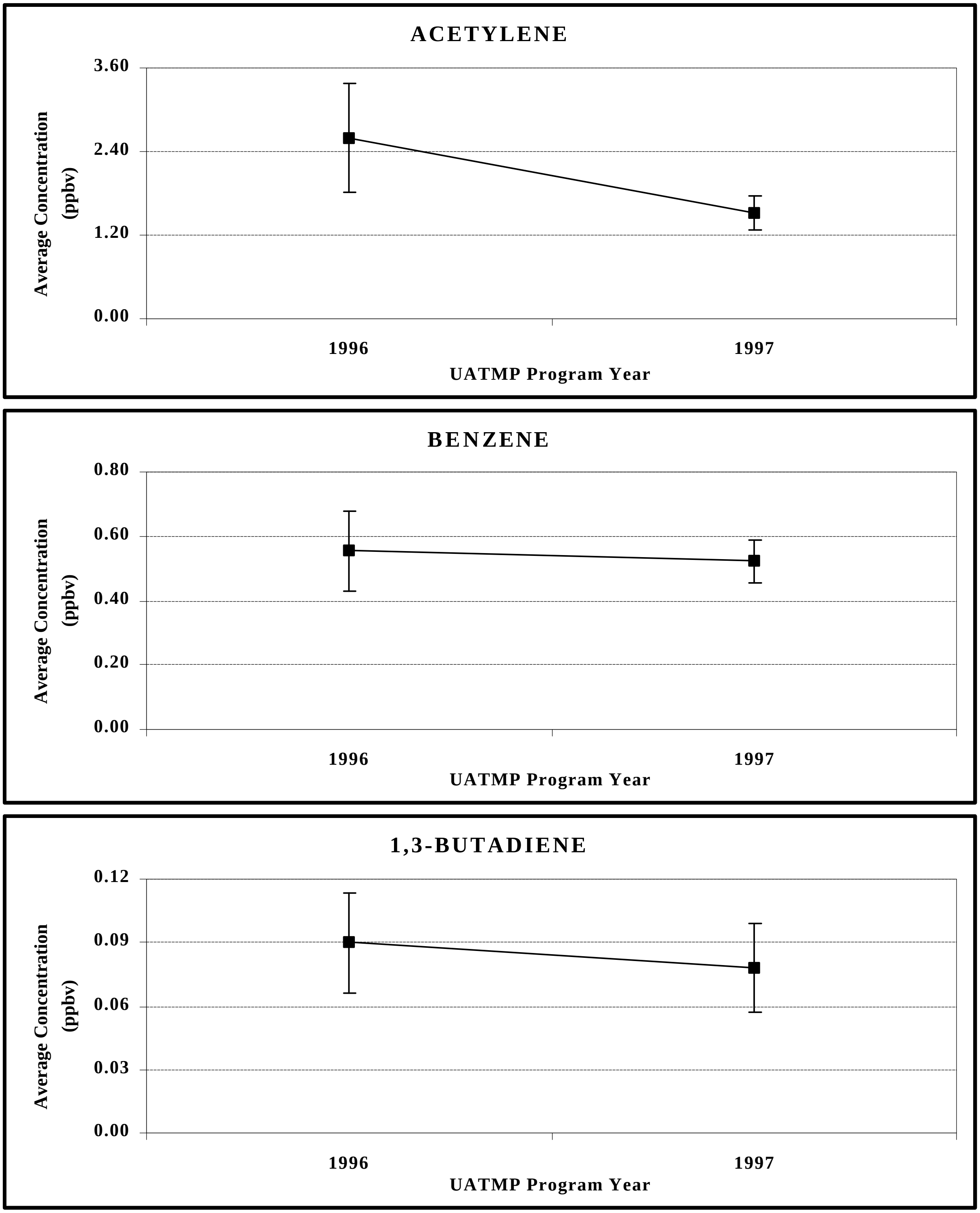
With one exception, the annual average concentrations of the most prevalent VOC did not change significantly between the 1996 and the 1997 UATMPs. The average concentration of acetylene, however, decreased by 40 percent over that time. The reason for the decreasing concentrations of acetylene is not known. Annual average concentrations of carbonyls from the 1995 to the 1997 UATMP also tended to stay the same or decrease, but the average concentration of acetone increased significantly during that period. The varying magnitudes and directions (increasing or decreasing) of annual variations of different compounds suggests that many different factors affect ambient air concentrations of the selected pollutants in the Brattleboro air.

Figure 5-1
Brattleboro, Vermont (BRVT), Monitoring Station



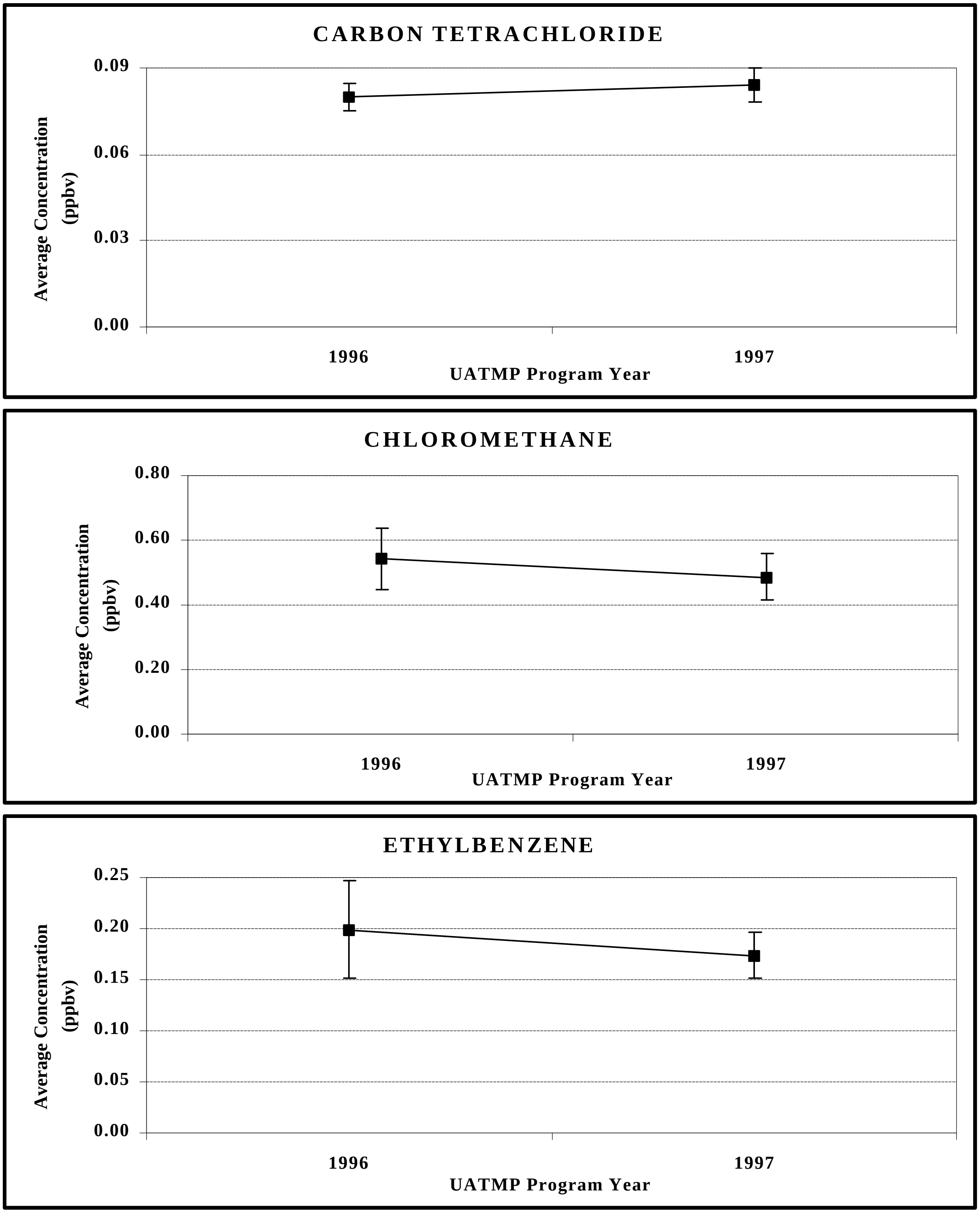
Source: USGS 7.5 X 15 Minute Series (metric). Map Scale: 1:25,000.

Figure 5-2 (Page 1 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BRVT



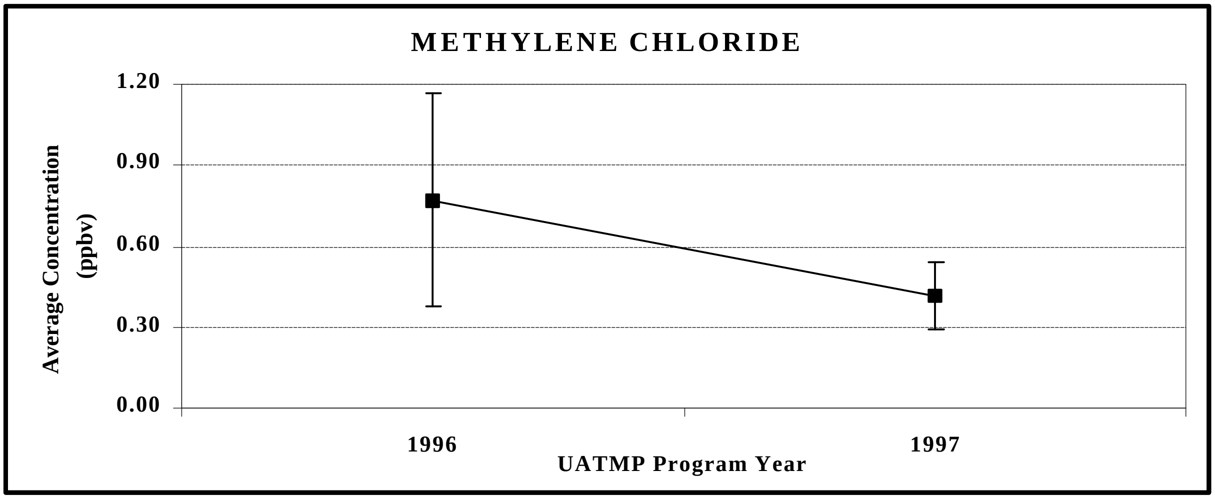
Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
Not enough samples were collected during the 1995 UATMP to calculate representative annual average concentrations.

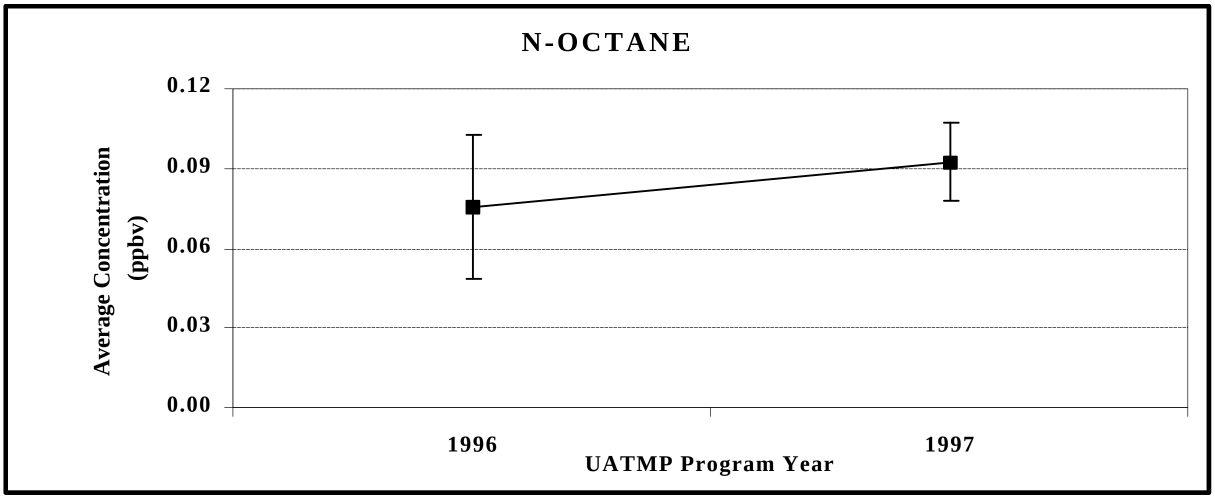
Figure 5-2 (Page 2 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BRVT

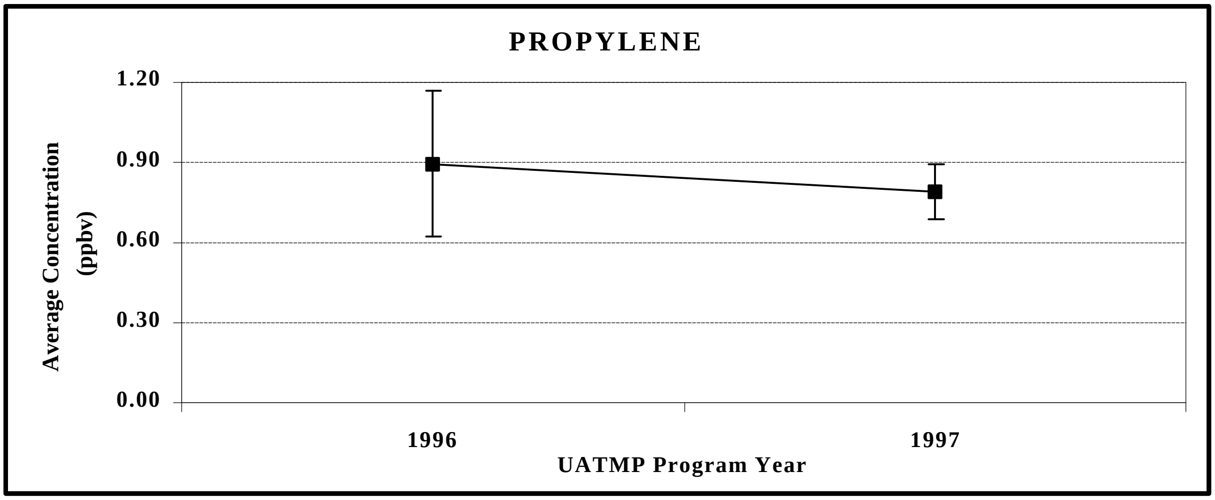


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
Not enough samples were collected during the 1995 UATMP to calculate representative annual average concentrations.

Figure 5-2 (Page 3 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BRVT

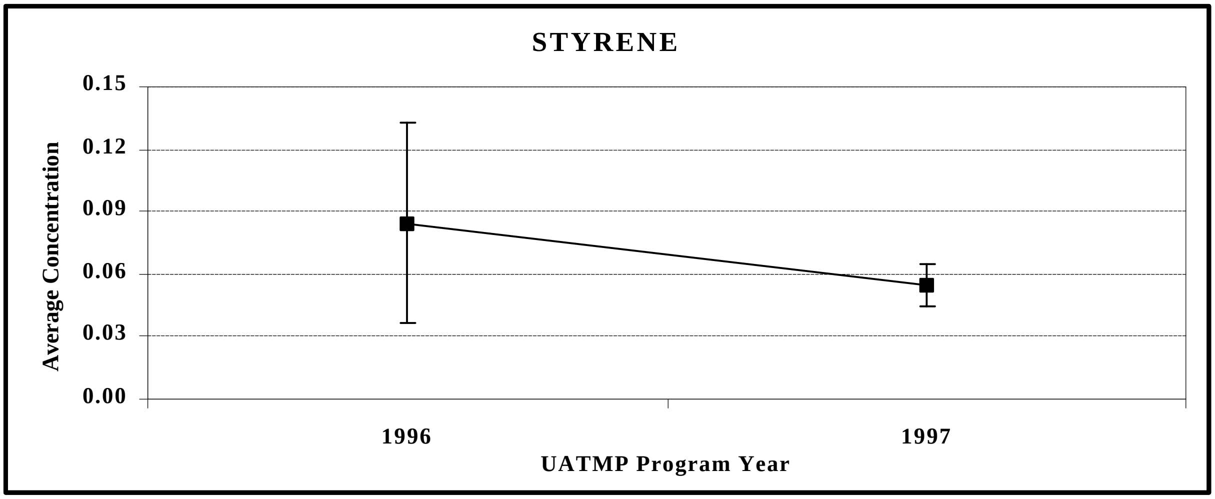


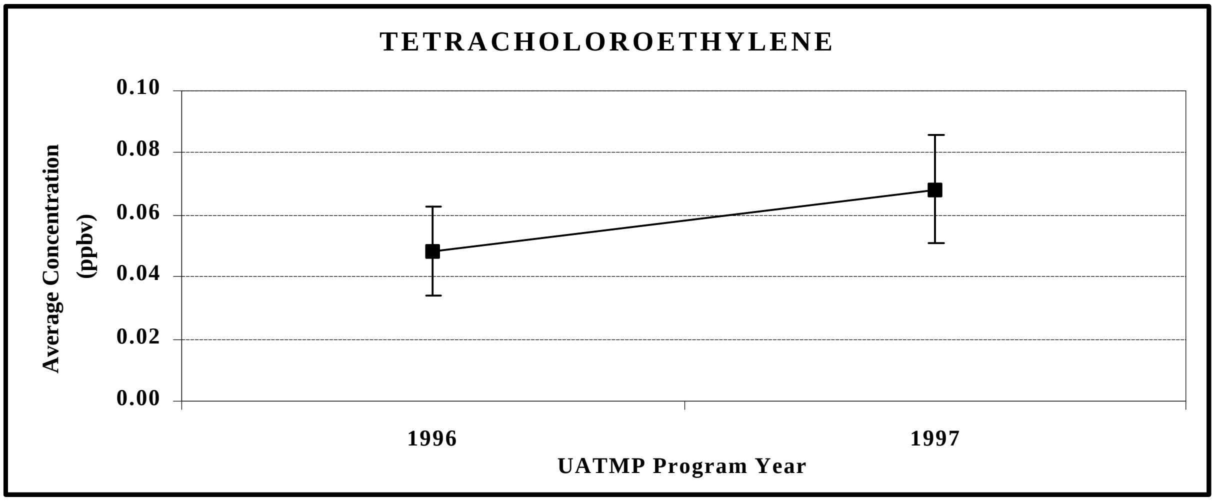


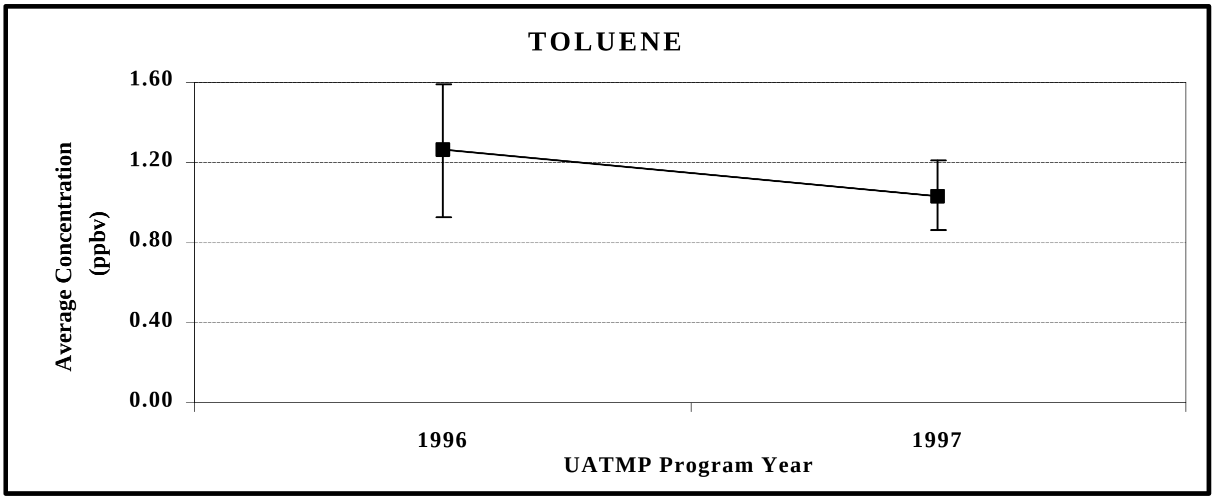


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
Not enough samples were collected during the 1995 UATMP to calculate representative annual average concentrations.

Figure 5-2 (Page 4 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BRVT

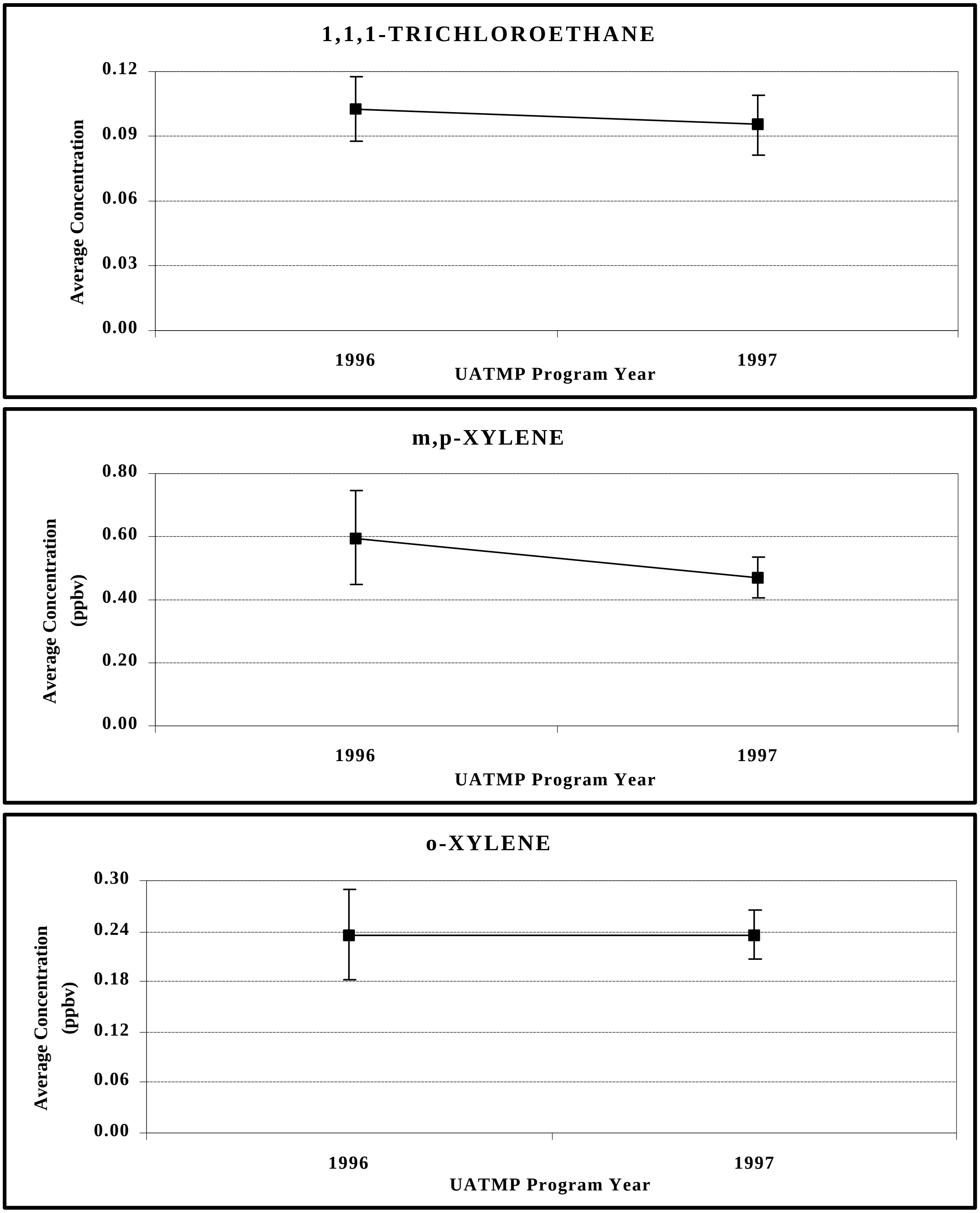






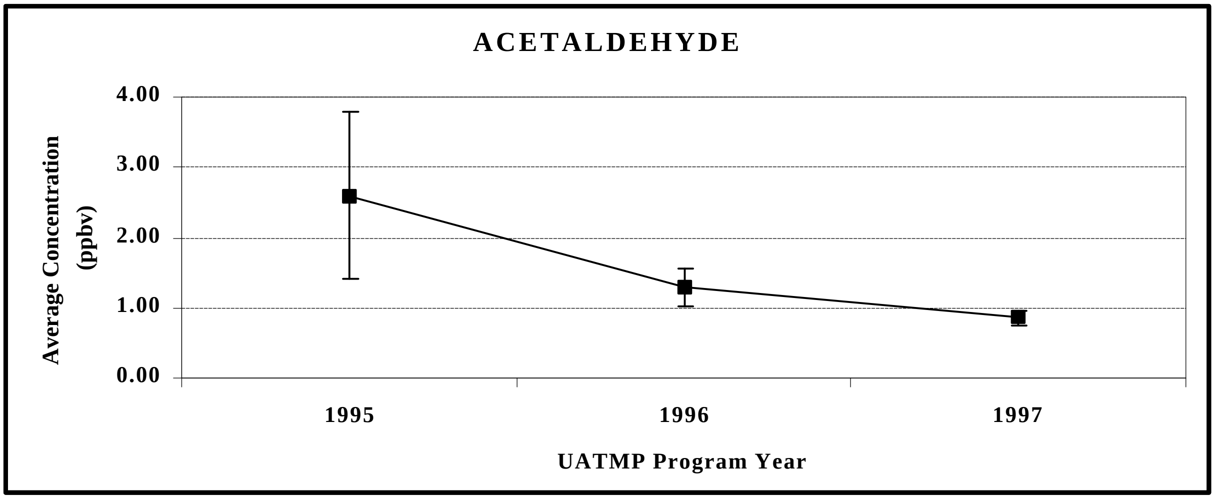
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
Not enough samples were collected during the 1995 UATMP to calculate representative annual average concentrations.

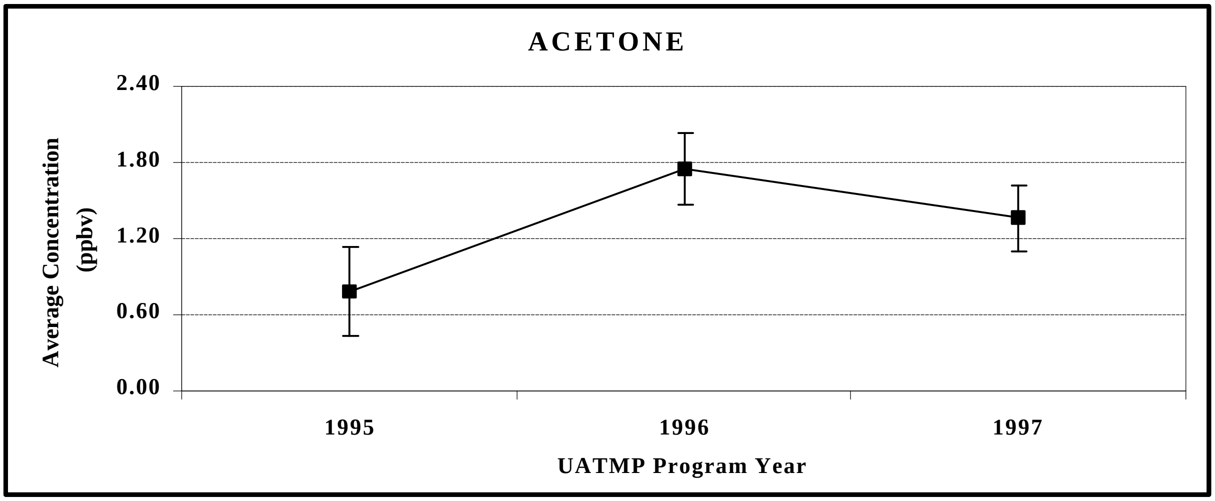
Figure 5-2 (Page 5 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BRVT

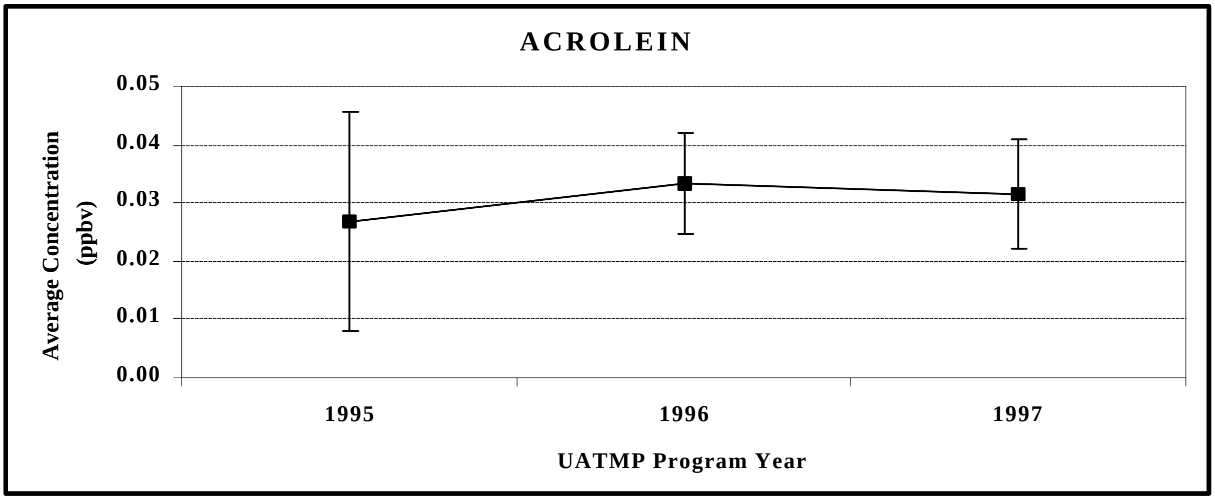


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
Not enough samples were collected during the 1995 UATMP to calculate representative annual average concentrations.

Figure 5-3 (Page 1 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BRVT



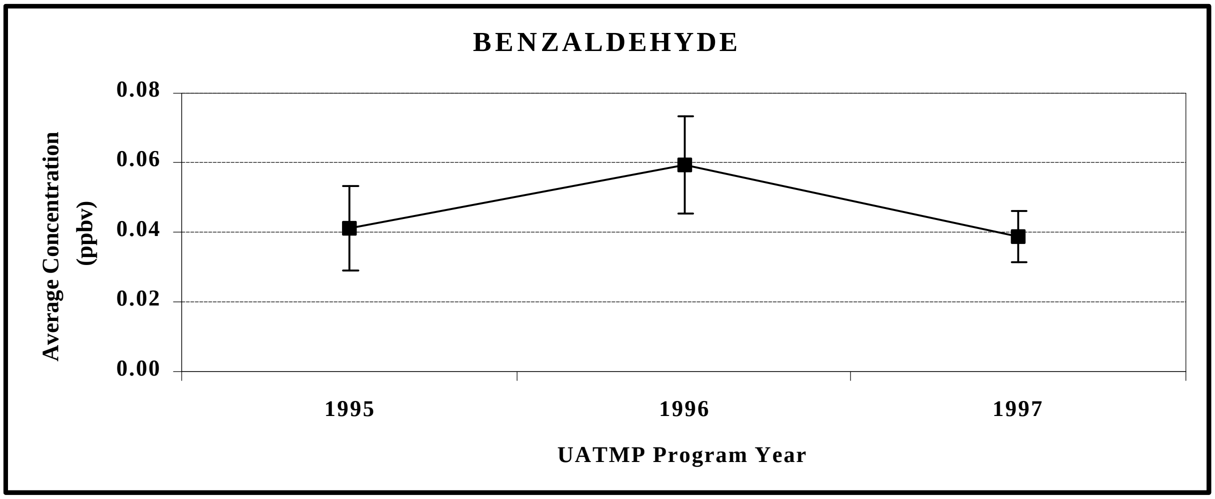


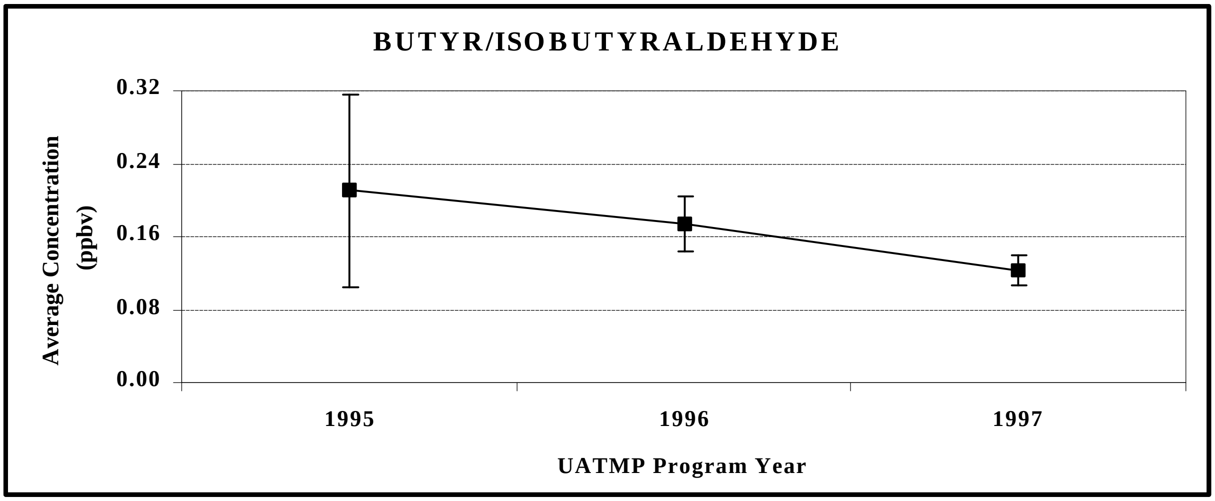


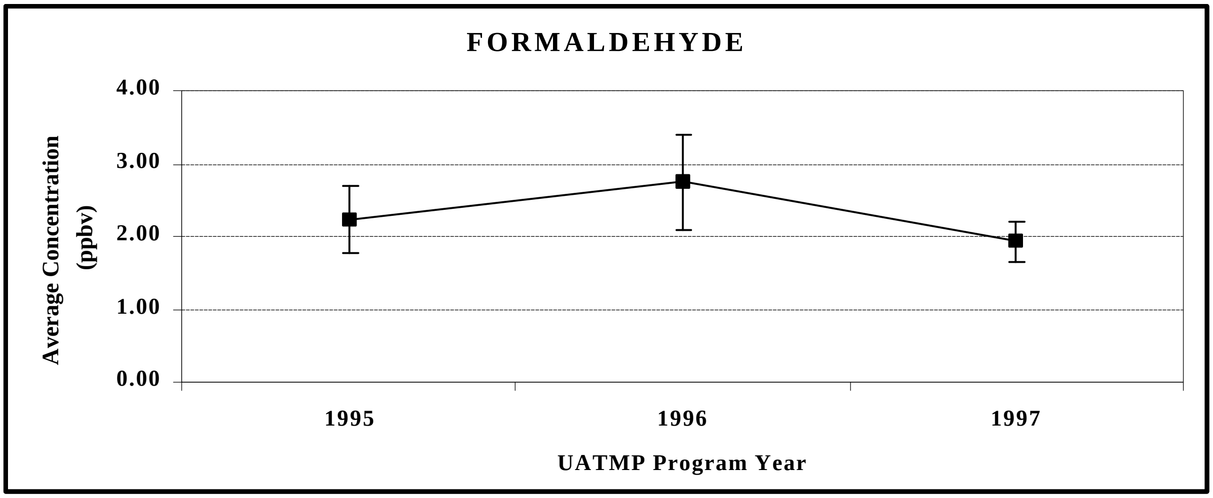
Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

The annual average concentrations shown for the 1995 UATMP are based on 6 months of sampling and, therefore, may be biased by seasonal changes in air quality.

Figure 5-3 (Page 2 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BRVT

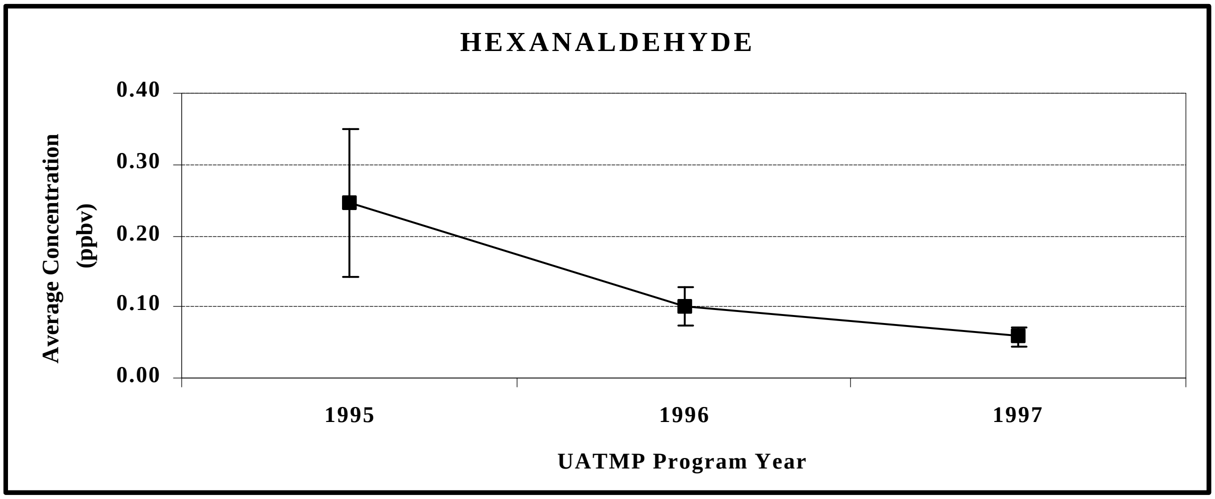


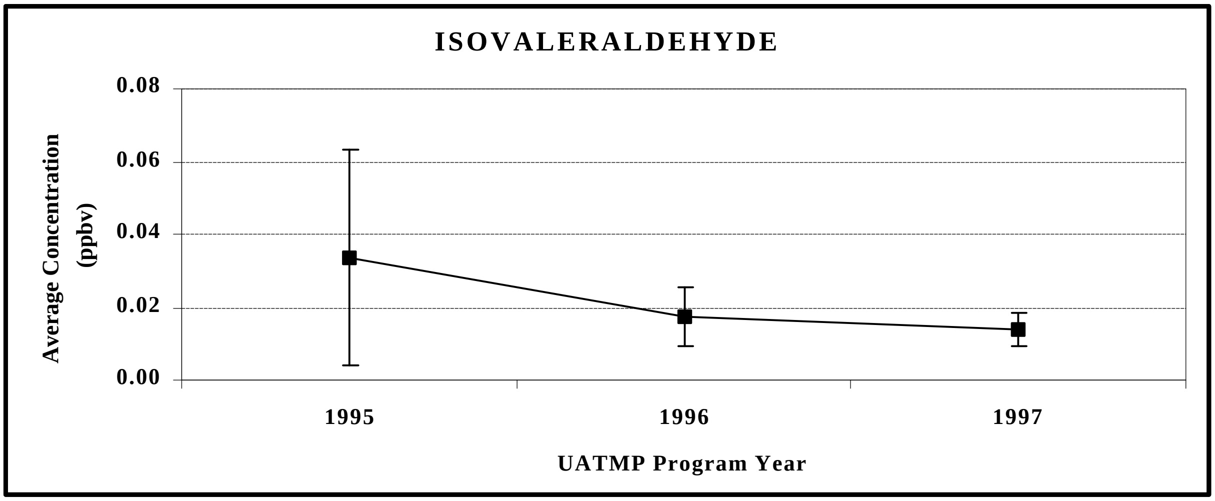


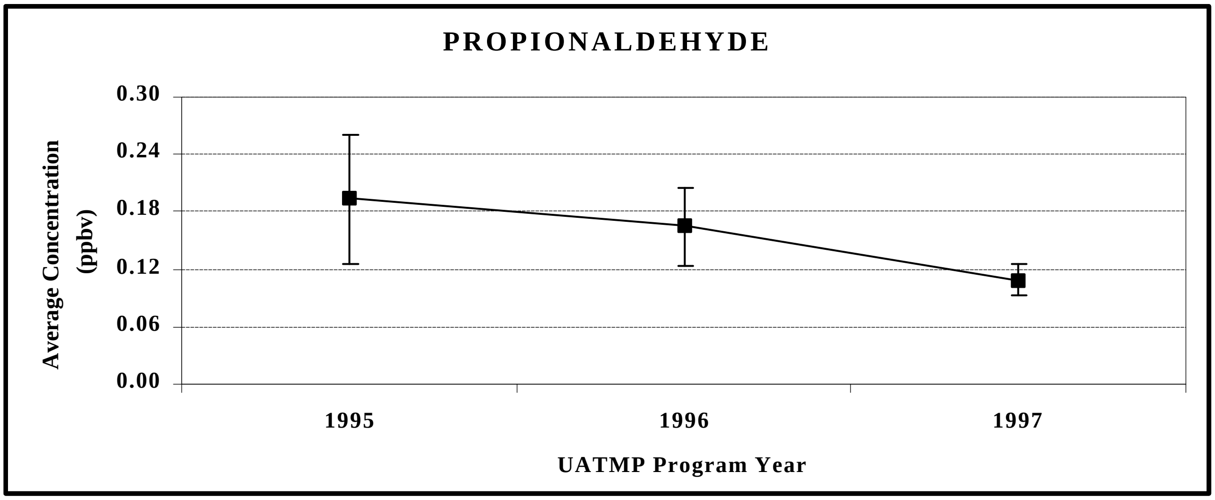


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The annual average concentrations shown for the 1995 UATMP are based on 6 months of sampling and, therefore, may be biased by seasonal changes in air quality.

Figure 5-3 (Page 3 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BRVT

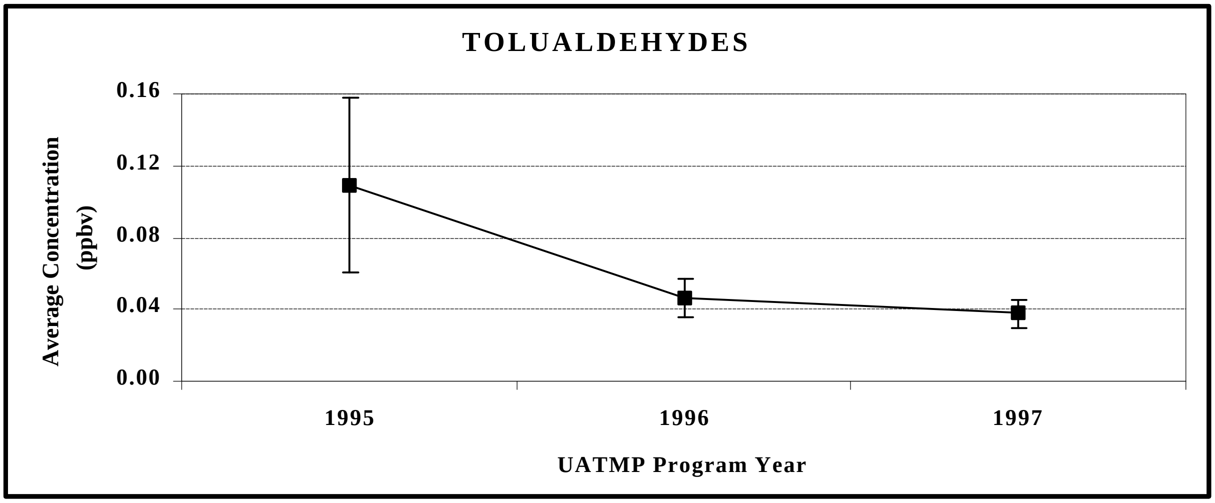


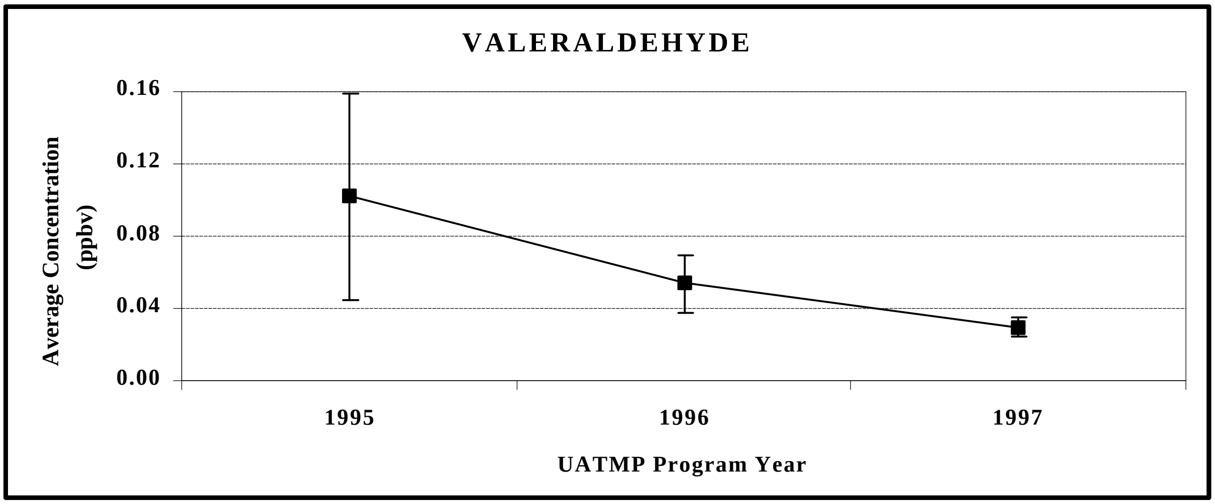




Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The annual average concentrations shown for the 1995 UATMP are based on 6 months of sampling and, therefore, may be biased by seasonal changes in air quality.

Figure 5-3 (Page 4 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BRVT





Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The annual average concentrations shown for the 1995 UATMP are based on 6 months of sampling and, therefore, may be biased by seasonal changes in air quality.

Table 5-1
Summary Statistics for VOC Concentrations Measured at Brattleboro, Vermont (BRVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	31	0%	ND	ND	0.29	0.24	0.22	0.08	0.34
Acetylene	**0**	**100%**	**0.54**	**3.09**	**1.41**	**1.52**	**1.38**	**0.66**	**0.43**
Acrylonitrile	29	6%	ND	0.28	0.11	0.09	0.08	0.05	0.50
Benzene	**0**	**100%**	**0.22**	**0.97**	**0.55**	**0.52**	**0.49**	**0.19**	**0.36**
Bromochloromethane	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.29
Bromodichloromethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.09
Bromomethane	29	6%	ND	0.03	0.07	0.05	0.05	0.02	0.43
1,3-Butadiene	**14**	**55%**	**ND**	**0.22**	**0.05**	**0.08**	**0.06**	**0.06**	**0.73**
Carbon tetrachloride	**0**	**100%**	**0.05**	**0.12**	**0.08**	**0.08**	**0.08**	**0.02**	**0.19**
Chlorobenzene	31	0%	ND	ND	0.04	0.03	0.03	0.01	0.21
Chloroethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	26	16%	ND	0.08	0.03	0.03	0.03	0.01	0.41
Chloromethane	**1**	**97%**	**ND**	**0.82**	**0.56**	**0.49**	**0.42**	**0.19**	**0.39**
Chloroprene	31	0%	ND	ND	0.05	0.04	0.04	0.02	0.38
Dibromochloromethane	31	0%	ND	ND	0.08	0.06	0.05	0.02	0.40
m-Dichlorobenzene	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.20
o-Dichlorobenzene	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.18

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 5-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Brattleboro, Vermont (BRVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	31	0%	ND	ND	0.07	0.06	0.06	0.01	0.19
1,1-Dichloroethane	31	0%	ND	ND	0.05	0.04	0.04	0.02	0.38
1,2-Dichloroethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.14
trans-1,2-Dichloroethylene	31	0%	ND	ND	0.06	0.05	0.05	0.02	0.31
1,2-Dichloropropane	31	0%	ND	ND	0.02	0.03	0.02	0.01	0.42
cis-1,3-Dichloropropylene	31	0%	ND	ND	0.03	0.03	0.03	0.01	0.26
trans-1,3-Dichloropropylene	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.40
Ethyl acrylate	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.32
Ethylbenzene	**1**	**97%**	**ND**	**0.28**	**0.17**	**0.17**	**0.16**	**0.06**	**0.35**
Ethyl *tert*-butyl ether	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.14
Methylene chloride	**5**	**84%**	**ND**	**0.99**	**0.27**	**0.41**	**0.25**	**0.34**	**0.82**
Methyl ethyl ketone	**3**	**90%**	**ND**	**1.05**	**0.42**	**0.46**	**0.40**	**0.23**	**0.50**
Methyl isobutyl ketone	31	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl methacrylate	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.07
Methyl *tert*-butyl ether	**2**	**94%**	**ND**	**0.79**	**0.22**	**0.30**	**0.23**	**0.21**	**0.68**
***n*-Octane**	**5**	**84%**	**ND**	**0.20**	**0.09**	**0.09**	**0.08**	**0.04**	**0.43**
Propylene	**0**	**100%**	**0.45**	**1.74**	**0.70**	**0.79**	**0.75**	**0.28**	**0.36**
Styrene	**11**	**65%**	**ND**	**0.18**	**0.05**	**0.05**	**0.05**	**0.03**	**0.49**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 5-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Brattleboro, Vermont (BRVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.07
1,1,2,2-Tetrachloroethane	31	0%	ND	ND	0.09	0.07	0.06	0.03	0.38
Tetrachloroethylene	**14**	**55%**	**ND**	**0.24**	**0.05**	**0.07**	**0.06**	**0.05**	**0.69**
Toluene	**0**	**100%**	**0.37**	**2.60**	**1.02**	**1.04**	**0.95**	**0.46**	**0.45**
1,1,1-Trichloroethane	**0**	**100%**	**0.04**	**0.19**	**0.09**	**0.10**	**0.09**	**0.04**	**0.39**
1,1,2-Trichloroethane	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.40
Trichloroethylene	29	6%	ND	0.26	0.02	0.03	0.02	0.04	1.43
Vinyl chloride	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.07
***m,p*-Xylene**	**0**	**100%**	**0.23**	**0.89**	**0.47**	**0.47**	**0.44**	**0.17**	**0.37**
***o*-Xylene**	**0**	**100%**	**0.12**	**0.41**	**0.22**	**0.24**	**0.22**	**0.08**	**0.34**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 5-2
Summary Statistics for Carbonyl Concentrations Measured at Brattleboro, Vermont (BRVT)
(Based on 29 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.38**	**1.60**	**0.82**	**0.86**	**0.82**	**0.29**	**0.33**
Acetone	**0**	**100%**	**0.14**	**3.12**	**1.13**	**1.36**	**1.18**	**0.67**	**0.49**
Acrolein	**0**	**100%**	**0.00**	**0.14**	**0.03**	**0.03**	**0.03**	**0.03**	**0.79**
Benzaldehyde	**3**	**90%**	**ND**	**0.07**	**0.04**	**0.04**	**0.03**	**0.02**	**0.49**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.05**	**0.24**	**0.12**	**0.12**	**0.12**	**0.04**	**0.35**
Crotonaldehyde	20	31%	ND	0.10	0.00	0.01	0.00	0.02	1.90
2,5-Dimethylbenzaldehyde	23	21%	ND	0.01	0.00	0.00	0.00	0.00	0.45
Formaldehyde	**0**	**100%**	**1.03**	**4.14**	**1.72**	**1.93**	**1.81**	**0.74**	**0.38**
Hexanaldehyde	**0**	**100%**	**0.02**	**0.15**	**0.05**	**0.06**	**0.05**	**0.03**	**0.57**
Isovaleraldehyde	**7**	**76%**	**ND**	**0.05**	**0.01**	**0.01**	**0.01**	**0.01**	**0.86**
Propionaldehyde	**0**	**100%**	**0.04**	**0.22**	**0.11**	**0.11**	**0.10**	**0.04**	**0.41**
Tolualdehydes	**1**	**97%**	**ND**	**0.10**	**0.03**	**0.04**	**0.03**	**0.02**	**0.53**
Valeraldehyde	**0**	**100%**	**0.01**	**0.06**	**0.03**	**0.03**	**0.03**	**0.01**	**0.48**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

6.0 Monitoring Results for Burlington, VT (BUVT), Underhill, VT (UNVT), and Winooski, VT (WIVT)

This section summarizes and interprets ambient air monitoring data collected over the last 3 years in the cities of Burlington, Underhill, and Winooski, Vermont. Because the air monitoring stations in these cities are located within 20 miles of each other, air quality at the three locations may be influenced, to a certain extent, by the same factors. For this reason, results from the three stations are presented in this one section, instead of in three separate sections.

Figures 6-1, 6-2, and 6-3 indicate the land use in the immediate vicinity of the Burlington, Underhill, and Winooski monitoring stations, respectively. The BUVT monitoring station is located near several heavily traveled roadways and two gas stations in the downtown area of Burlington, which is Vermont’s largest city. Located roughly 3 miles northeast of the BUVT monitoring station, the WIVT monitors are on the grounds of a high school in a suburb, across the Winooski River from Burlington. The UNVT monitoring station is located in a remote field surrounded by forest, about 15 to 20 miles east of Burlington. Approximately 100,000 people live within 10 miles of the BUVT and WIVT monitoring stations, but the population density in the vicinity of the UNVT is notably lower (i.e., fewer than 20,000 people reside within 10 miles of the monitors). In short, the monitors in Burlington, Winooski, and Underhill can be loosely classified as being in urban, suburban, and rural areas, respectively.

Table 6-1 presents completeness data for the BUVT, UNVT, and WIVT monitors, indicating that only one sampling event (a carbonyl sample at the Burlington station) was unsuccessful during the 1997 program. Thus, the completeness of VOC and carbonyl sampling was at least 97 percent at all three stations. Also shown in Table 6-1 is the fact that the Winooski monitoring station collected air samples only from September to December during the 1997 program. Because this station sampled air for only 4 months, the 1997 UATMP monitoring data for WIVT better represent air quality for the fall season than air quality for the entire year—an important distinction reiterated throughout this section.

The remainder of this section summarizes the 1997 UATMP monitoring data for BUVT, UNVT, and WIVT (Section 6.1), analyzes in detail ambient air concentrations of selected nitriles and oxygenated compounds at these three stations (Section 6.2), and illustrates how ambient air concentrations of certain compounds have changed in the Burlington area since the 1995 UATMP (Section 6.3). For quick reference, the section concludes with a brief summary that highlights the most notable air quality trends observed for this area (Section 6.4).

6.1 Data Summary Parameters for the 1997 UATMP

Tables 6-2 through 6-4 and 6-6 through 6-8 use the data summary parameters defined in Section 3.1 to provide an extensive, yet succinct, account of the ambient air monitoring data collected at the Burlington, Underhill, and Winooski monitoring stations. The format used in these tables is the same as that used in earlier reports, thus facilitating comparisons of selected summary statistics from one year to the next.

6.1.1 Data Summary of VOC

Tables 6-2, 6-3, and 6-4 reveal the following notable trends regarding ambient air concentrations of VOC at BUVT, UNVT, and WIVT, respectively:

- *Prevalence.* According to the data summary tables, only the following 13 compounds were detected in more than half of the ambient air samples collected at the monitoring stations in Burlington, Underhill, and Winooski:

  Acetylene
  Benzene
  Carbon tetrachloride
  Chloromethane
  Ethylbenzene
  Methylene chloride
  Methyl ethyl ketone
  Propylene
  Toluene
  1,1,1-Trichloroethane
  m,p-Xylene
  o-Xylene

  In addition, some compounds were detected in more than half of the samples at one or two of the monitoring stations, but not at all three. For example, *n*-octane was detected in more than half of the samples at Burlington and Winooski, but not at Underhill. Similarly, 1,3-butadiene, methyl *tert*-butyl ether, and styrene were detected in more than half of the samples at Burlington, but in half or fewer of the samples at Underhill and Winooski. Finally, tetrachloroethylene was notably more prevalent at Winooski (70 percent) than at Burlington (39 percent) and Underhill

(3 percent). As noted previously, most of the analyses in this report focus on the compounds with highest prevalence, because their summary statistics are least affected by nondetect observations, which are replaced in the UATMP database with an estimated concentration of one-half the detection limit. Except for methyl *tert*-butyl ether, there were no compounds that had notably higher prevalence at the BUVT, UNVT, and WIVT monitoring stations than at the other UATMP monitoring stations. Section 6.2 discusses air quality trends for this compound in greater detail.

Despite the emphasis this section places on the most prevalent compounds, it should not be inferred that the other compounds are not present in ambient air in the Burlington metropolitan area. Rather, the least prevalent compounds may be present in the air, but consistently at levels that the VOC analytical method cannot measure. Therefore, statistically meaningful air quality trends cannot be calculated for these compounds, due to their large number of nondetects. Nonetheless, Section 6.2 presents a brief analyses of air quality trends for acetonitrile and acrylonitrile—both of which were detected in fewer than half of the samples, but were more prevalent at the remote Underhill site than at the more heavily populated Burlington and Winooski sites.

- *Concentration range.* As the summary tables show, eight compounds (acetonitrile, acetylene, benzene, propylene, toluene, *m,p*-xylene, and *o*-xylene) had at least one 24-hour average concentration higher than 1.0 ppbv at Burlington; two compounds (acetonitrile and acetylene) had at least one concentration higher than this level at Underhill; and three compounds (acetylene, methylene chloride, and toluene) had at least one concentration higher than this level at Winooski. This observation indicates that ambient air concentrations of many VOC, particularly those found in motor vehicle exhaust, reach higher levels in Burlington than they do in either Winooski or Underhill. As an exception, concentrations of methylene chloride reached higher levels at Winooski. The following bullet item discusses the spatial variations in concentrations of methylene chloride in greater detail. Section 6.2 offers insight into why peak levels of acetonitrile were observed at the remote Underhill site.

  When interpreting data on highest concentrations, it is important to note that the UATMP monitors did not collect samples daily. Thus, the concentration ranges in the summary tables do not represent the actual span of ambient air concentrations in the Burlington area; ambient air concentrations probably rose to higher levels on days when samples were not collected. This observation is particularly true for the Winooski data, because samples were only collected there for 4 months.

- *Central tendency.* Table 6-5 lists the geometric mean concentrations of the 13 most prevalent compounds detected at the BUVT, UNVT, and WIVT monitoring stations. The spatial variations in geometric mean concentrations can be classified into three different categories: compounds with no notable spatial variations, compounds with highest levels at Burlington, and compounds with highest levels at Winooski. The following discussion characterizes each category in detail.

Of the 13 most prevalent compounds, three—carbon tetrachloride, chloromethane, and 1,1,1-trichloroethane—have geometric mean concentrations that are not notably different at the BUVT, UNVT, and WIVT monitoring stations. The final report for the 1996 UATMP also noted an absence of significant spatial variations for these halogenated hydrocarbons. The previous report hypothesized that historical releases from sources across the country probably account for the levels of carbon tetrachloride detected and natural emissions sources may contribute most to levels of chloromethane. Though factors affecting levels of 1,1,1-trichloroethane were not identified in the previous UATMP reports, Section 6.3.1 of this report provides evidence that industrial emissions sources in the Burlington area, especially those near the WIVT monitoring station, may best explain why the compound is found in the air at BUVT, UNVT, and WIVT.

As Table 6-5 shows, acetylene, benzene, ethylbenzene, methyl ethyl ketone, propylene, toluene, *m,p*-xylene, and *o*-xylene all exhibit similar spatial variations: geometric mean concentrations are highest at Burlington, second highest at Winooski (except for methyl ethyl ketone), and lowest at Underhill. Section 6.2 describes the unique spatial variations for methyl ethyl ketone in greater detail. All other compounds that had higher concentrations at BUVT than at UNVT and WIVT are hydrocarbons that are typically found in motor vehicle exhaust. The measured levels of these hydrocarbons undoubtedly originate, to a certain extent, from motor vehicles traveling in the immediate vicinity of the monitoring stations. However, there is evidence that hydrocarbons detected at the UNVT and WIVT monitoring stations may have transported from other areas, most likely Burlington.

To assess the age of air masses (an indicator of long-range transport), Figure 6-4 indicates how concentration ratios of toluene to ethylbenzene and total xylenes to benzene vary among the monitoring stations in the Burlington area. These concentration ratios gradually change as air masses move, primarily because toluene is much more reactive in photochemical smog than ethylbenzene and xylenes are much more reactive than benzene (USEPA, 1996). As a result, the toluene:ethylbenzene and xylenes:benzene ratios typically decrease as an air mass travels from emissions sources to downwind locations. The graphs in Figure 6-4 clearly illustrate that the two concentration ratios are highest in Burlington, second highest in Winooski, and lowest in Underhill. Given what is known about the reactivity of these aromatic compounds, the different concentration ratios suggest that airborne hydrocarbons in Underhill and, to a lesser extent, in Winooski may originate from distant sources, most likely motor vehicles in the Burlington area. A detailed emissions inventory of all pollution sources in this area can confirm this trend.

Of the most prevalent compounds identified by the VOC analytical method, only methylene chloride had a geometric mean concentration that was notably higher at the Winooski monitoring station (0.19 ppbv) than at the Burlington (0.10 ppbv) and Underhill (0.06 ppbv) monitoring stations. Because this trend differs from that for compounds emitted by motor vehicles, the relatively higher concentrations of methylene chloride in Winooski most likely originate from nearby industrial sources. According to the TRI, no facilities in the Burlington metropolitan area reported releases of methylene chloride in reporting years 1989 through 1995; however, one facility in Essex Junction, a small town outside of Winooski, reported releases of this compound for reporting years 1987 and 1988. It is unknown whether this facility no longer uses methylene chloride or continues to use the compound, but presumably at levels below the reporting threshold. Emissions from industrial facilities not subject to the TRI reporting requirements also may explain the relatively high concentrations of methylene chloride observed at the WIVT monitoring station during the 1997 UATMP.

To show how ambient air concentrations of VOC in the Burlington area compare to those at other UATMP monitoring stations, Figure 3-1 presents geometric mean concentrations of VOC that were most prevalent during the 1997 program. The figure indicates three important air quality trends for the monitors in the Burlington area. First, for nine hydrocarbons typically found in motor vehicle exhaust (acetylene, benzene, 1,3-butadiene, ethylbenzene, propylene, toluene, and the xylene isomers), geometric mean concentrations at BUVT ranked second highest among the UATMP monitoring stations. Second, for this same group of hydrocarbons, levels at UNVT ranked last or second to last among the stations. Third, Figure 3-1 suggests that concentrations of tetrachloroethylene were highest at the remote Underhill site, but this finding is actually an artifact of the data processing algorithms. More specifically, tetrachloroethylene was measured at concentrations lower than one-half the detection limit several times at every monitoring station except at Underhill, where it was detected only once. Because nondetect observations were replaced with concentrations of one-half the detection limit and measured concentrations below this level are considered valid results (see Section 3.1), the calculated geometric mean concentration for tetrachloroethylene at Underhill is higher than that for other stations, even though the compound was detected more often at the other monitoring stations. If nondetects are omitted from the data analysis, geometric mean concentrations at UNVT would be the lowest of the UATMP monitoring stations.

Note: When interpreting the graphs in Figure 3-1, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within these areas. Even though ambient air concentrations of many compounds were second highest at Burlington and lowest at Underhill, it is likely that average concentrations of these same compounds are higher (and lower) in many urban areas that did not participate in the 1997 program. It is also likely that concentrations of some pollutants in many parts of Burlington are not as high as those that were measured in the busy downtown area.

- *Variability.* With one exception, coefficients of variation for the most prevalent VOC at the three monitoring stations in the Burlington area were less than 1.0. The similarity in these coefficients of variation suggests that ambient air concentrations of these VOC have comparable variability. As the exception, the coefficients of variation for methylene chloride were 1.00 at BUVT, 1.25 at UNVT, and 1.63 at WIVT. The relatively higher variability for this compound suggests that the concentration changes significantly from one day to the next. This observation is consistent with the assumption that methylene chloride originated predominantly from sources found at discrete locations (e.g., industrial emissions sources), because the monitors would probably detect the compound only when emissions from these specific locations blew toward the stations. This finding supports the hypothesis, stated earlier, that an industrial emissions source (or sources) most likely explains the spatial variations observed for methylene chloride.

For more information on trends and patterns among VOC monitoring data in the Burlington area, Section 6.2 describes in detail the monitoring data for nitriles and oxygenated compounds and Section 6.3 comments on annual variations.

6.1.2 Data Summary of Carbonyls

Tables 6-6, 6-7, and 6-8 reveal the following notable trends regarding ambient air concentrations of carbonyls at BUVT, UNVT, and WIVT, respectively:

- *Prevalence.* The prevalence data in Tables 6-6 through 6-8 indicate that all but three of the carbonyl compounds (crotonaldehyde, 2,5-dimethylbenzaldehyde, and isovaleraldehyde) were detected in at least half of the samples collected at the BUVT, UNVT, and WIVT monitoring stations. Thus, summary statistics for most of the carbonyls are not influenced by large numbers of nondetect observations and therefore are expected to represent actual air quality trends in the Burlington area.

- *Concentration range.* According to the data summary tables, acetaldehyde, acetone, and formaldehyde were the only carbonyls that were measured at all three monitoring stations at levels higher than 1.0 ppbv. One concentration of hexanaldehyde also exceeded this threshold at UNVT, but not at the other two monitoring stations in the Burlington area. Though the highest concentrations of carbonyls at these monitoring stations were generally of the same order of magnitude, the highest concentrations of formaldehyde at UNVT were significantly higher than those at BUVT and WIVT. On three occasions, concentrations of formaldehyde at the remote Underhill site exceeded 20 ppbv—a level more than three times higher than the highest concentration observed at both BUVT and WIVT. The reasons for the notably higher concentrations of formaldehyde at Underhill are not known. As noted earlier, the concentration ranges shown in Tables 6-6 to 6-8 only estimate the actual ranges, because concentrations may have reached higher levels and lower levels on days when samples were not collected.

- *Central tendency.* At all three stations, geometric mean concentrations of acetaldehyde, acetone, and formaldehyde combined accounted for over 90 percent of the concentration of total carbonyls measured during the 1997 UATMP. To highlight spatial variations in concentrations of carbonyls, Table 6-9 lists the geometric mean concentrations of the 13 most prevalent compounds detected at the BUVT, UNVT, and WIVT monitoring stations. The most striking trend in this table is the similarity of geometric mean concentrations across all three stations, as opposed to the notable differences highlighted in Table 6-5 for VOC. For instance, geometric mean concentrations of the VOC typically found in motor vehicle exhaust were at least five times higher at BUVT than at UNVT. Except for benzaldehyde, geometric mean concentrations of the most prevalent carbonyls at BUVT were no more than twice as high as those at UNVT. This distinctly different spatial variation strongly suggests that the factors affecting ambient levels of carbonyls in the Burlington area differ from those affecting concentrations of VOC. Further research is needed to determine the extent to which different factors (such as emissions from residential wood combustion, emissions from natural sources, emissions from motor vehicles, and photochemical reactions) explain the notably weaker spatial variations for carbonyls.

  As Figure 3-2 shows, geometric mean concentrations of the most prevalent carbonyls at BUVT were not unusually higher or lower than those at any other UATMP monitoring station. Concentrations at UNVT and WIVT, on the other hand, were generally among the lowest observed at the UATMP monitors.

Section 12.1 comments further on what these spatial variations indicate about the sources of carbonyls in urban ambient air.

- *Variability*. According to Tables 6-6 through 6-8, coefficients of variation for the most prevalent carbonyls at Burlington and Winooski were all less than 1.0. The similar and relatively low coefficients of variation suggest that these carbonyls are consistently found in ambient air and their concentrations do not change dramatically from one sample to the next, regardless of changing wind directions and seasons. According to Table 6-9, however, coefficients of variation for about half of the most prevalent carbonyls at Underhill were greater than 1.0—a trend that is also indicated in data summary tables in the 1996 UATMP final report. The greater variability observed at this site may result from many different factors, such as specific meteorological conditions that favor transport of pollutants to Underhill on certain days and emissions from nearby sources that reach the UNVT monitors only when winds blow in certain directions. Detailed analyses of meteorological conditions are needed to understand why ambient air concentrations of carbonyls are more variable at the remote Underhill site.

For further information on air quality trends for carbonyls, readers should refer to Section 6.3.2 for an overview of how levels have changed in the Burlington area since 1995 and to Section 12.1 for a general summary of carbonyl monitoring data collected at all 12 monitoring stations that participated in the 1997 monitoring program.

6.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

During the 1997 UATMP, the VOC analytical method was capable of identifying nine nitriles and oxygenated compounds that were not identified during previous UATMPs. The following discussion summarizes air monitoring data collected at BUVT, UNVT, and WIVT for these compounds:

- *Compounds that were rarely, if ever, detected.* Of the nine nitriles and oxygenated compounds measured in the Burlington area, five—ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, methyl methacrylate, and *tert*-amyl methyl ether—were detected in 3 or fewer valid VOC sampling events at each of the monitoring stations. Not surprisingly, the TRI for 1995 indicates that no industrial facilities within 10 miles of these monitoring stations reported releasing ethyl acrylate, methyl isobutyl ketone, or methyl methacrylate to the air. Though facilities currently are not required to report releases of ethyl *tert*-butyl ether or *tert*-amyl methyl ether to TRI, the fact that they were rarely detected in the Burlington ambient air suggests that industrial emissions for these compounds are probably insignificant. In short, few conclusions can be drawn for the five compounds that were rarely, if ever, detected.

- *Acetonitrile and acrylonitrile.* Although not detected in a majority of samples at any of the monitoring stations in the Burlington area, acetonitrile and acrylonitrile were found at measurable levels most often at the remote Underhill site. In fact, acrylonitrile was detected more often at Underhill (prevalence of 29 percent) than at any other UATMP monitoring station. Emissions from mobile sources cannot explain the higher prevalence of these compounds at Underhill, mainly because the compounds were rarely, if ever, detected in the heavily traveled area surrounding the BUVT monitor. According to the most recent TRI data, no industrial facilities located in the entire Burlington metropolitan area reported emitting either compound to the air. Therefore, the primary source of these nitriles at UNVT is most likely neither motor vehicles or large industrial facilities, but may be due to natural emissions sources or releases from small businesses near the Underhill station. Additional monitoring data are needed (1) to confirm that the higher prevalence of acetonitrile and acrylonitrile at UNVT is an actual air quality trend and not an anomalous artifact of the 1997 UATMP data and (2) to identify the primary source of nitriles at this remote monitoring location.

- *Methyl ethyl ketone.* According to the data summary tables, methyl ethyl ketone was detected in a majority of air samples at all three monitoring stations in the Burlington area. The geometric mean concentrations of this compound were no more than 40 percent different for each of the three stations (0.33 ppbv at BUVT, 0.28 ppbv at UNVT, and 0.21 ppbv at WIVT), and the concentrations at the three stations were essentially uncorrelated. As Figure 3-1 shows, ambient air concentrations of methyl ethyl ketone at these three monitoring stations were lower than those at every other UATMP monitoring station. The lower levels near Burlington are consistent with the TRI data for reporting year 1995, which indicate that no industrial facilities within 10 miles of the three monitoring stations in the Burlington area reported emitting methyl ethyl ketone to the air. Emissions from many different sources (e.g., solvent usage, paint, motor vehicles, home heating) probably best explain the levels of methyl ethyl ketone at BUVT, UNVT, and WIVT.

- *Methyl tert-butyl ether.* Of the nine nitriles and oxygenated compounds that the VOC analytical method could identify, methyl *tert*-butyl ether exhibited the most significant spatial variations in the Burlington area. As Figure 6-5 shows, the geometric mean concentration of methyl *tert*-butyl ether at BUVT (0.23 ppbv) was over five times higher than that at UNVT (0.03 ppbv) and at WIVT (0.04 ppbv). With no industrial facilities in the entire state of Vermont reporting releases of this compound to TRI, the spatial variations of methyl *tert*-butyl ether in Burlington probably result from emissions associated with reformulated gasoline.

The state of Vermont does not require, and has never required, motor vehicles within its jurisdiction to use reformulated gasoline. Nonetheless, a small fraction of gasoline stations in the state are known to receive reformulated gasoline from their distributors (Scranton, 1999), and a small fraction of motor vehicles driving through the state may run on fuels purchased in neighboring states where reformulated gasolines are sold (e.g., Massachusetts). Since the entire fleet of motor vehicles driving in Vermont does not use reformulated fuels, concentrations of methyl *tert*-butyl ether in the Burlington area are not expected to exhibit air quality trends similar to the compounds typically associated with motor vehicle exhaust. Table 6-10, which shows that concentrations of methyl *tert*-butyl ether at BUVT were essentially uncorrelated with concentrations of compounds typically emitted by motor vehicles, supports this hypothesis. The table also provides an example of how levels of benzene are highly correlated with other hydrocarbons known to be emitted by cars. Three other observations provide additional insight into the factors that most affect concentrations of methyl *tert*-butyl ether in the Burlington area:

(1) Since methyl *tert*-butyl ether is found in low concentrations in conventional gasoline, some might argue that emissions from cars using conventional gasoline (as opposed to reformulated gasoline) explain airborne levels of this compound in Burlington. However, as Section 8 describes in detail, the monitors at EPTX rarely detected methyl *tert*-butyl ether, even though they are located near several heavily traveled roadways where cars use only conventional gasoline. Further, the monitors in Arkansas and Louisiana also rarely detected this compound, despite the fact that motor vehicles in these states also use only conventional gasoline. Therefore, the levels of methyl *tert*-butyl ether observed in the Burlington area are inconsistent with the use of conventional gasolines.

(2) Because Massachusetts and other nearby states require motor vehicles to use reformulated gasolines, some might argue that long-range transport of mobile source emissions in other states may explain the levels of methyl *tert*-butyl ether observed in Burlington. If this compound indeed transported over such long distances (as opposed to having local emissions sources), one would expect airborne levels of methyl *tert*-butyl ether in the entire Burlington metropolitan area to be relatively constant because airborne levels of pollutants in the immediate vicinity of emissions sources tend to exhibit significant concentration gradients, and levels at locations far from emissions sources do not vary much at all (though the magnitude

of the concentrations is substantially lower at locations further from the source). Figure 6-5 clearly shows that ambient air concentrations of methyl *tert*-butyl ether vary significantly throughout the Burlington area, thus ruling out the possibility that emissions from other states alone account for the levels detected during the 1997 UATMP.[1]

(3) Though not apparent from the summary statistics, ambient air concentrations of methyl *tert*-butyl ether during the 1997 UATMP showed notable seasonal trends: ambient air concentrations of the compound measured at BUVT in June, July, and August were (on average) nearly three times higher than those measured in other months of the year. This seasonal trend, which was not observed at BUVT for those hydrocarbons typically found in motor vehicle exhaust, may be explained by several factors: evaporative losses of methyl *tert*-butyl ether, possibly from the two gasoline stations located near the BUVT monitors, are expected to be highest during the warmer summer months; the composition of gasoline sold in the area may change during the year (see Section 3.2); and motor vehicles from other states may drive in the Burlington area more frequently during the summer. Further research is needed to confirm which combination of factors best explains the seasonal trends in concentrations of methyl *tert*-butyl ether at BUVT.

For information on air quality trends of methyl *tert*-butyl ether in an area where EPA requires motor vehicles to use reformulated gasoline, readers should refer to the analyses in Section 7.2 for the Camden monitoring station.

6.3 Annual Variations

The BUVT, UNVT, and WIVT monitoring stations have participated in the 1995, 1996, and 1997 UATMPs. Comparing annual average concentrations of the most prevalent compounds across the different program years can provide insight into how air quality in the Burlington area has changed over this 3-year period. Although the BUVT monitoring station has collected ambient air monitoring data during previous UATMP procurements, this section does not consider those earlier data, because important features of the monitoring program (e.g., detection

---

[1] It should be noted that many hydrocarbons and carbonyls also exhibit significant spatial variations among the BUVT, UNVT, and WIVT monitors. For the same reason as listed in the text for methyl *tert*-butyl ether, the presence of notable spatial variations rules out the possibility that transport of emissions from other states has a significant impact on ambient air concentrations for many hydrocarbons in the Burlington area. Nonetheless, it is certainly possible that state-to-state transport of other pollutants *not identified by the UATMP* may affect air quality in many areas of Vermont.

limits, measurement precision) have likely changed. This section also does not consider annual variations for the least prevalent compounds, since their summary statistics are highly uncertain due to the many nondetect observations.

The annual variations for the most prevalent VOC (Section 6.3.1) and carbonyls (Section 6.3.2) have three important data limitations. First, as Section 3.3 explained, not every change in annual average concentrations from one year to the next is statistically significant; the following analyses indicate which variations appear to be statistically significant and which do not. Second, the analyses of long-term variations for the Winooski monitoring station consider annual average concentrations for the 1995, 1996, and 1997 monitoring programs, even though this site collected only 4 months of monitoring data during the 1997 program. As a result, trends presented for 1997 for WIVT should be interpreted with caution. Third, all annual variations are presented for the UATMP year, which typically begins in September and ends in August of the following calendar year. Thus, average concentrations presented in Figures 6-6 and 6-7 may differ from annual average concentrations calculated for the 1995, 1996, and 1997 calendar years.

6.3.1 Annual Variations for VOC

Figure 6-6 shows how concentrations of the 12 most prevalent VOC changed at the three monitoring stations in the Burlington area from the 1995 UATMP to the 1997 UATMP. (Note: Section 6.1.1 identified 13 VOC as being present in more than half of the samples collected at these stations, but one of these compounds is methyl ethyl ketone. Because this compound was not measured in earlier UATMPs, annual variations for methyl ethyl ketone cannot be evaluated.) As the diagrams in Figure 6-6 indicate, there is no uniform trend that explains annual variations for VOC in the Burlington area: average concentrations of some compounds increased at two sites but decreased at the other, levels of some compounds at one site increased but levels of other compounds at that site decreased, and so on. Detailed analyses of the annual variations for different groups of compounds follow:

- *BTEX compounds*. As Figure 6-6 illustrates, ambient air concentrations of benzene, toluene, ethylbenzene, and xylene isomers exhibited some consistent trends between the 1995 and 1997 UATMP. For example, average levels of these compounds increased by 20 to 40 percent at BUVT and WIVT from 1995 to 1997, except for levels of *m,p*-xylene, which were essentially the same over this period. Of these increases, however, only that for benzene appeared to be statistically significant, based on the 95-percent upper confidence intervals. Contrary to the findings for the BUVT and WIVT monitors, average levels of some BTEX compounds at UNVT increased, but average levels of others decreased. More specifically, the average concentration of benzene at Underhill during the 1997 UATMP was over 50 percent higher than the average concentration during the 1995 UATMP. On the other hand, average levels of ethylbenzene, toluene, and the xylene isomers in 1997 at Underhill were all lower than they were in 1995. The annual variations for benzene, ethylbenzene, and *m,p*-xylene at Underhill all appear to be statistically significant.

  The relative increases in ambient air concentrations at Burlington and Winooski and the relative decreases at Underhill do not necessarily contradict the hypothesis raised earlier that BTEX compounds in these areas originate from the same group of sources (i.e., mostly motor vehicles). Motor vehicle emissions in the downtown Burlington area may have increased between 1995 and 1997, thus explaining the relative increases of BTEX compounds at both BUVT and WIVT. However, it does not necessarily follow that average concentrations at Underhill should also increase over this period, because (1) motor vehicle emissions in the immediate vicinity of the Underhill station may have declined over this period, even though they increased in Burlington, (2) meteorological conditions favoring the transport of emissions from the Burlington area to the Underhill area (e.g., westerly winds, no precipitation) may not have been as prevalent during the 1997 UATMP, and (3) contributions from other sources in the Underhill area, such as emissions from home heating, may have decreased from 1995 to 1997. More detailed analyses of these other factors are needed to explain the different annual variations for BTEX compounds in the Burlington area.

- *Halogenated hydrocarbons*. Of the most prevalent VOC, four (carbon tetrachloride, chloromethane, methylene chloride, and 1,1,1-trichloroethane) are halogenated hydrocarbons. Previous UATMP reports have shown that factors other than motor vehicle emissions affect ambient air concentrations of this group of compounds most significantly. According to Figure 6-6, average concentrations of carbon tetrachloride and chloromethane changed little from the 1995 program to the 1997 program, and none of the annual changes were statistically significant. Further, the magnitudes of the average concentrations at BUVT, UNVT, and WIVT are nearly identical. The absence of notable spatial variations and temporal variations are consistent with the assumption that these compounds were not emitted in large quantities by local sources.

The annual variations for methylene chloride at the three monitoring stations also were not statistically significant. However, there is a notable difference between the average concentrations of this compound at the three stations: regardless of the monitoring year, average levels of methylene chloride at WIVT were over twice as high as those at BUVT and UNVT. This observation confirms the hypothesis, raised earlier, that the most significant source of methylene chloride in the Burlington metropolitan area is most likely closer to the WIVT monitoring station than to the BUVT or UNVT stations.

Of the halogenated hydrocarbons, only 1,1,1-trichloroethane had statistically significant annual variations in the Burlington area: at all three monitoring stations, average concentrations of this compound decreased by a factor of two or more from the 1995 UATMP to the 1996 UATMP, and then remained unchanged between the 1996 and 1997 programs. The notable decrease probably resulted from decreased emissions from industrial sources over the same time frame. Because concentrations of this compound at the WIVT monitoring station are approximately twice as high as those at the BUVT and UNVT stations, the primary sources of this compound in the area are probably closest to the Winooski area. The TRI data confirm that two industrial facilities in close proximity to the WIVT monitors reportedly used more than 10,000 pounds of 1,1,1-trichloroethane in 1995: one facility is located less than one-half mile northwest of the monitoring station (but the TRI database does not indicate any air emissions for this facility) and the other facility is located just over 1 mile north of the monitoring station (and reported releasing 343 pounds of 1,1,1-trichloroethane to the air in 1995). No other industrial facilities in the entire state of Vermont reported use of 1,1,1-trichloroethane to TRI in 1995. Though changing emissions from these two facilities may have caused the decreasing concentrations, emissions from other sources—especially those not required to report to TRI—may have also contributed to the lower levels of 1,1,1-trichloroethane in the Burlington area.

- *Other compounds*. The two remaining prevalent VOC, acetylene and propylene, exhibited different air quality trends, even though both are found, to a certain extent, in motor vehicle exhaust and emissions from other combustion sources. According to Figure 6-6, ambient air concentrations of acetylene at BUVT, UNVT, and WIVT were 30 percent to 40 percent lower during the 1997 UATMP than during the 1995 UATMP, but this difference appears to be statistically significant only for the BUVT monitoring station. The decrease in concentrations of acetylene at BUVT is difficult to explain, especially because levels of BTEX compounds, which are also found in motor vehicle exhaust, generally increased at this station over the same period.

In the case of propylene, average concentrations at the BUVT monitoring station were essentially unchanged from the 1995 to the 1997 UATMP, but statistically significant increases were observed for both the Winooski and Underhill stations. In fact, the average concentration of propylene at UNVT in 1997 was over three times higher than that during 1995—an increase much greater than that for any other VOC at the remote Underhill station. The reason for the notable increases in concentrations of propylene at every station but BUVT is not known, but should be confirmed with additional monitoring to verify whether the increase is a trend or simply part of a longer-term fluctuation cycle.

6.3.2 Annual Variations for Carbonyls

Figure 6-7 shows how concentrations of the 13 most prevalent carbonyls have changed in the Burlington area since the 1995 UATMP. Unlike the annual variations for VOC, which did not exhibit any uniform trends, ambient air concentrations of the most prevalent carbonyls at the Burlington and Winooski sites either all decreased or stayed the same and concentrations at Underhill either all increased or stayed the same. The following discussion examines these two trends in greater detail:

- *Annual variations at Burlington and Winooski*. The average concentrations of all of the most prevalent carbonyls, except for acrolein, during the 1997 UATMP at both BUVT and WIVT were between 25 percent and 95 percent lower than their levels during the 1995 program. According to Figure 6-7, most of these changes appear to be statistically significant. Concentrations of acrolein, on the other hand, changed little at Burlington and gradually declined at Winooski over this same time frame, but the decrease in acrolein at Winooski does not appear to be statistically significant. Interestingly, the levels of most carbonyls have steadily decreased at BUVT and WIVT over the last 3 years, while levels of VOC at these stations have increased (see Section 6.3.1). These opposite trends suggest that the factors that most significantly affect ambient air concentrations of carbonyls in the Burlington area may differ from those that most significantly affect concentrations of VOC. Though motor vehicle emissions undoubtedly contribute to the airborne levels of carbonyls in this area, the difference in trends suggests that other factors (most likely photochemical reactions) also impact ambient air concentrations of carbonyls.

- *Annual variations at Underhill*. Contrary to the trends observed for Burlington and Winooski, ambient air concentrations of the most prevalent carbonyls at the remote Underhill site tended to increase between the 1995 UATMP and the 1997 UATMP. Only the tolualdehyde isomers had decreasing concentrations at UNVT over this time frame (but their decrease does not appear to be statistically significant). The exact reason, or reasons, for the increasing concentrations of carbonyls at Underhill is not known; this trend warrants further research. Analyses of additional monitoring data can help determine whether the increasing concentrations at UNVT are part of a continuing trend or whether they are merely fluctuations that typically occur over multi-year cycles.

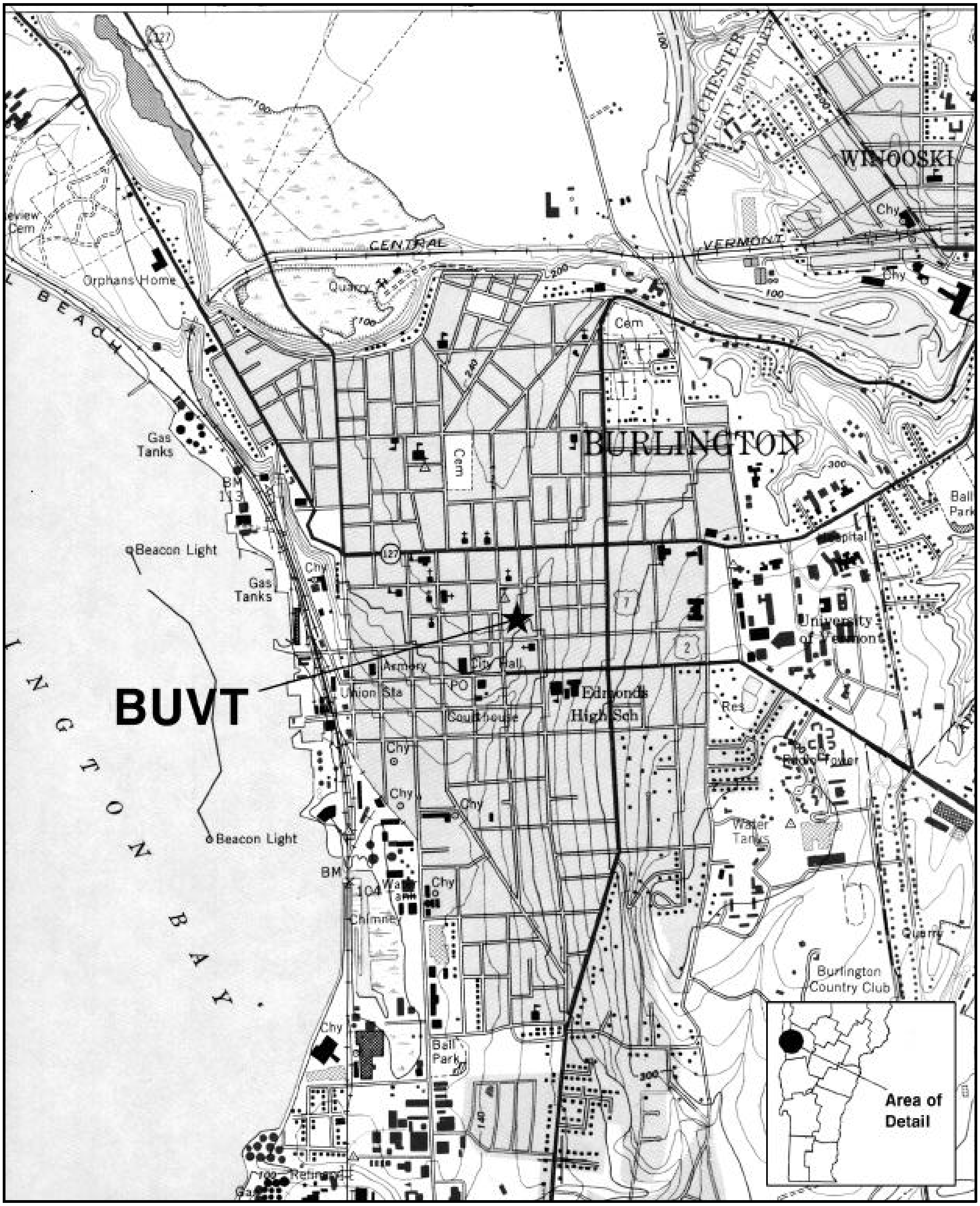
6.4 Summary

The 1997 UATMP monitoring data for BUVT, UNVT, and WIVT characterize how ambient air concentrations of selected VOC and carbonyls vary throughout the Burlington, Vermont, metropolitan area. Consistent with monitoring data from other urban areas, the three VOC with the highest geometric mean concentrations at the Burlington and Winooski monitors were, in order of decreasing geometric mean concentration, acetylene, toluene, and propylene; the three VOC with highest levels at the rural Underhill site were chloromethane, acetylene, and methyl ethyl ketone. At all three stations, the three carbonyls with the highest geometric mean concentrations were acetaldehyde, acetone, and formaldehyde (though not necessarily in this order). The average composition of hydrocarbons in the samples suggested that the air masses at Underhill and, to a much lesser extent, in Winooski were “older” than the air mass at Burlington. This observation, coupled with the fact that concentrations of hydrocarbons were notably higher at Burlington, indicated that a significant portion of the hydrocarbons measured at Winooski and especially at Underhill may have originated from mobile source emissions near downtown Burlington.

Due to recent improvements to the laboratory analytical method for VOC, the 1997 UATMP measured concentrations of nine nitriles and oxygenated compounds. Though most of these compounds were rarely, if ever, detected at the three monitoring stations near Burlington, methyl ethyl ketone and methyl *tert*-butyl ether were found to be quite prevalent in the ambient air throughout this area. The observed levels of methyl ethyl ketone were assumed to be linked to many different emissions sources, such as solvents, paints, and motor vehicles; and the levels of methyl *tert*-butyl ether were shown to be related to use of reformulated gasoline, even though the state of Vermont does not require vehicles to use these fuels.

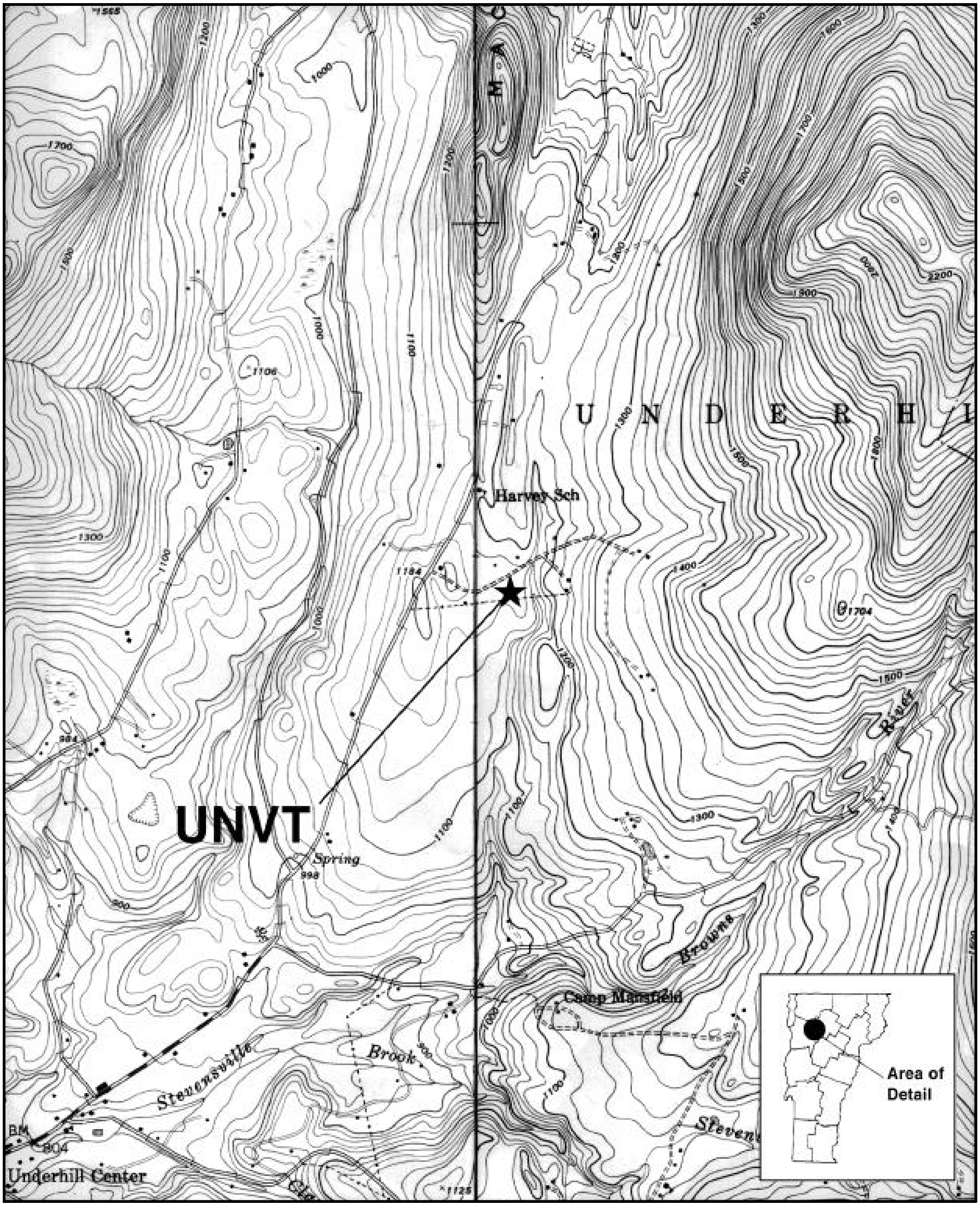
The analyses of annual variations showed that concentrations of some components of air pollution increased at certain monitors (but not necessarily at all three) between 1995 and 1997, while concentrations of other components of air pollution decreased over this same time frame. Many of the increases and decreases in ambient air concentrations over time were apparently statistically significant. Though some of the annual variations appeared to be closely linked to variations in emissions from industrial facilities (e.g., 1,1,1-trichloroethane), the exact reasons for most of the annual variations are not known. Analyses of additional monitoring data are needed to differentiate those annual variations that are part of long-term increases or decreases in air quality from those that are simply fluctuations about a concentration that does not change significantly over the longer term.

Figure 6-1
Burlington, Vermont (BUVT), Monitoring Station



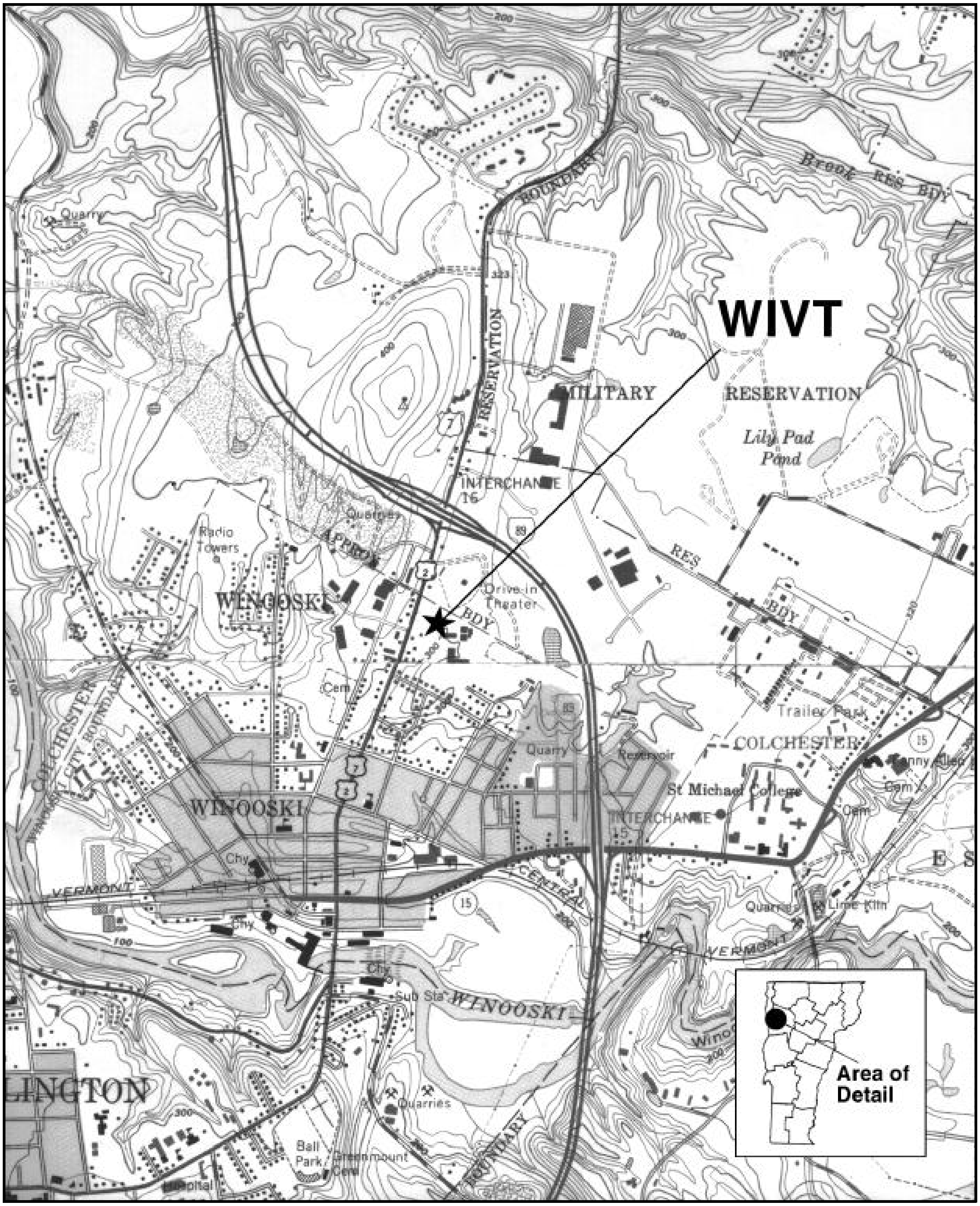
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 6-2
Underhill, Vermont (UNVT), Monitoring Station



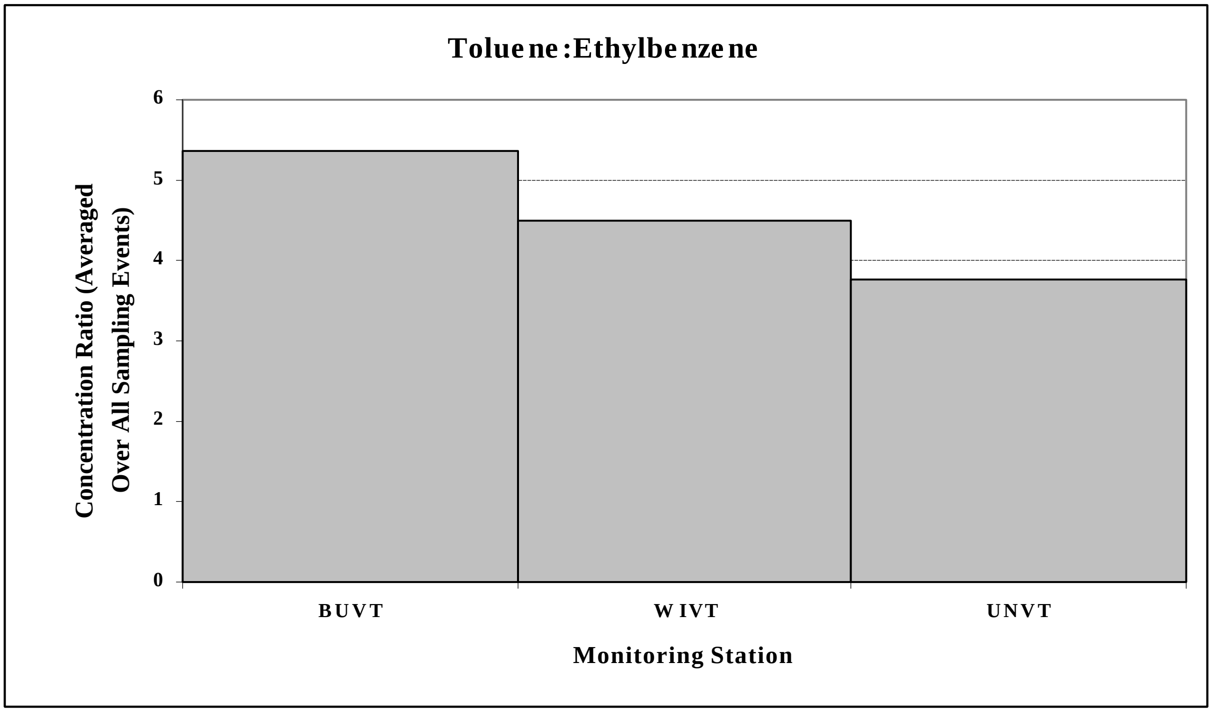
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 6-3
Winooski, Vermont (WIVT), Monitoring Station



Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 6-4
Concentrations Ratios for Selected Aromatic Hydrocarbons



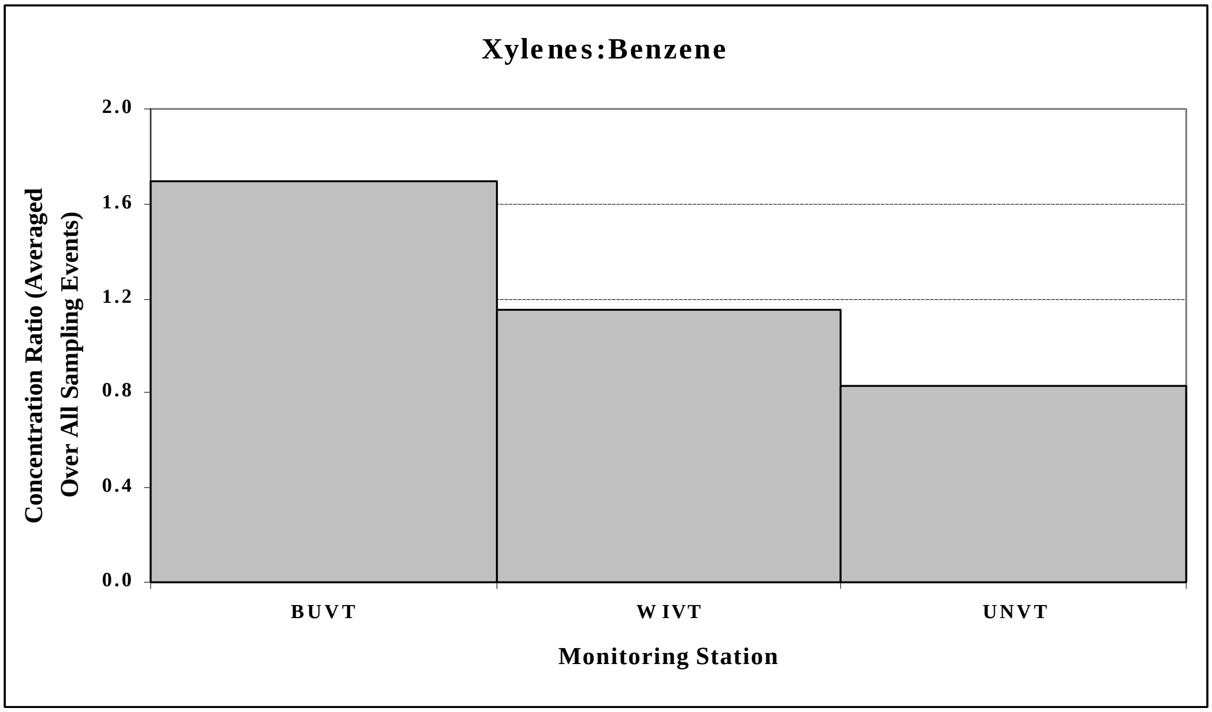
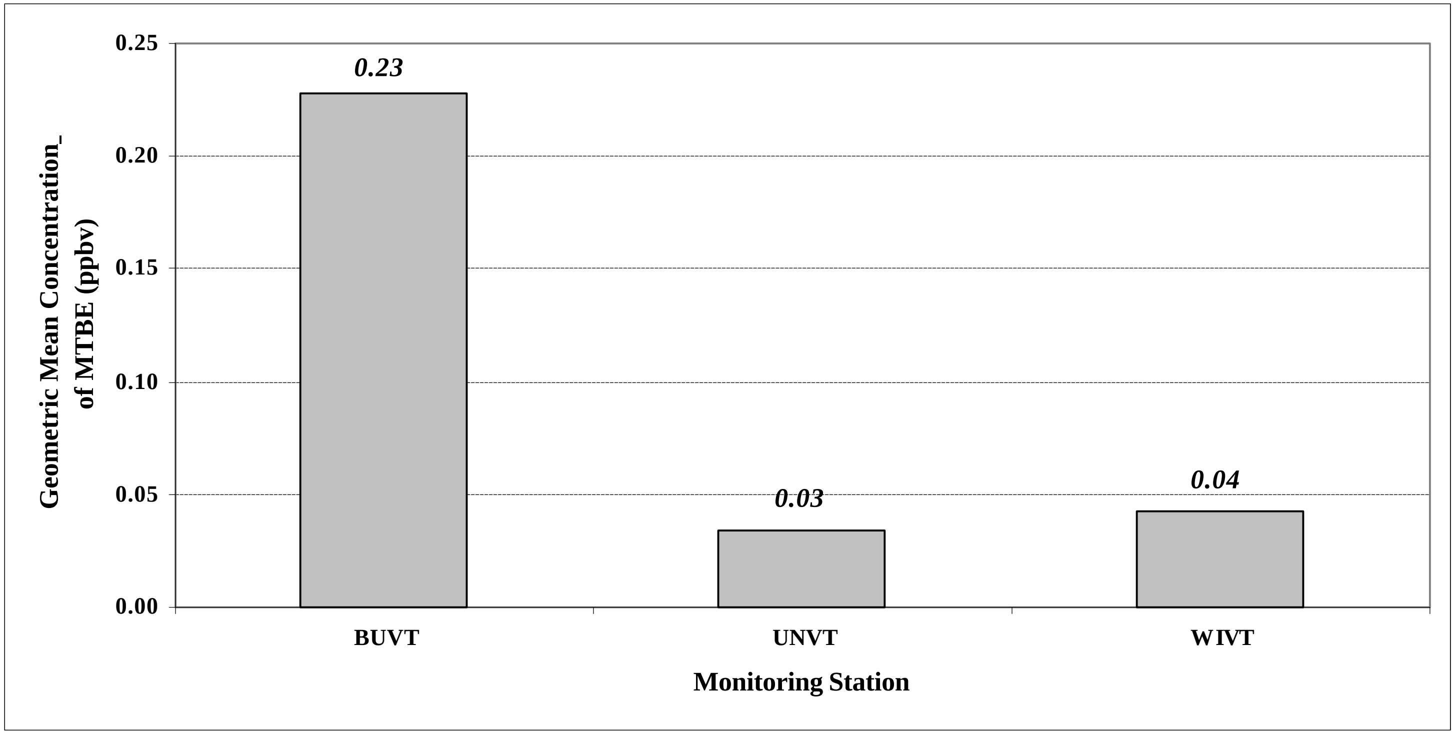
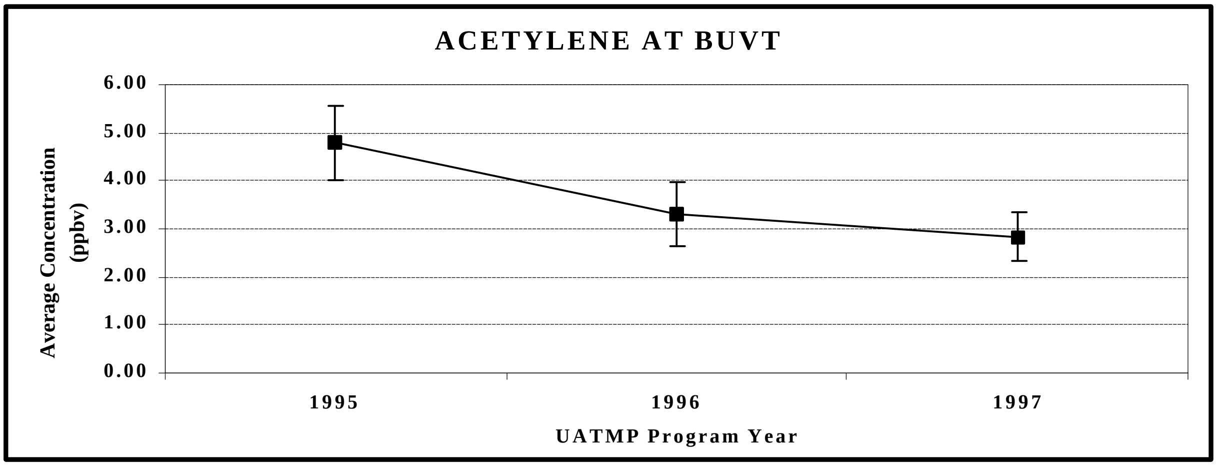


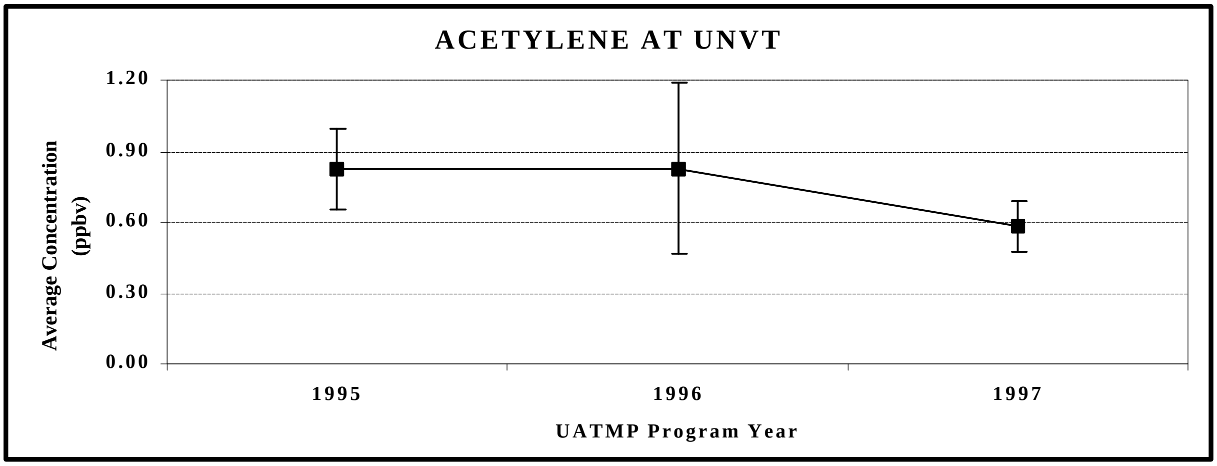
Figure 6-5
Geometric Mean Concentrations of Methyl *tert*-Butyl Ether in the Burlington Area

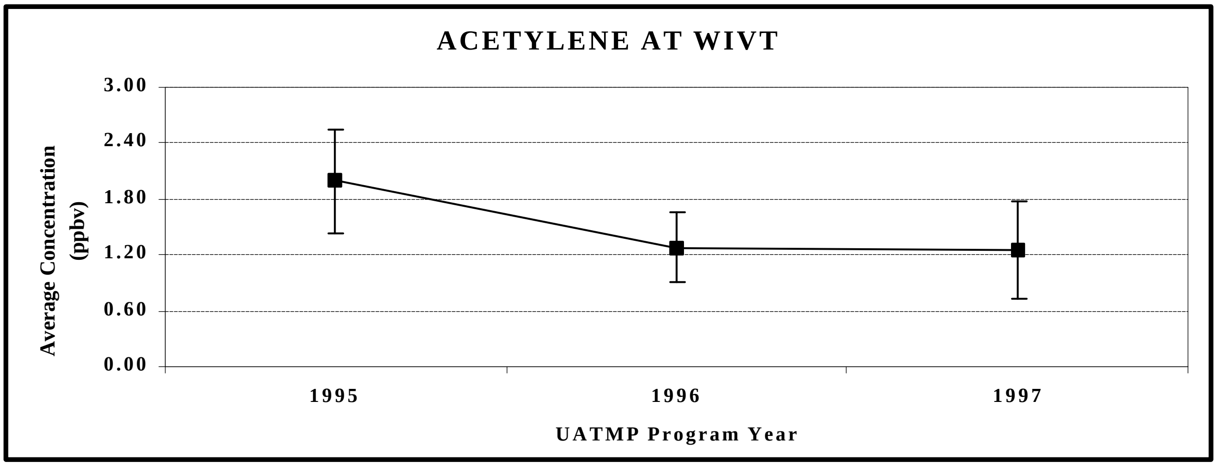


Note: The geometric mean concentration for WIVT may not represent the actual central tendency for the entire 1997 UATMP, because the monitoring station collected air samples only from September, 1997, to December, 1997.

Figure 6-6 (Page 1 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT

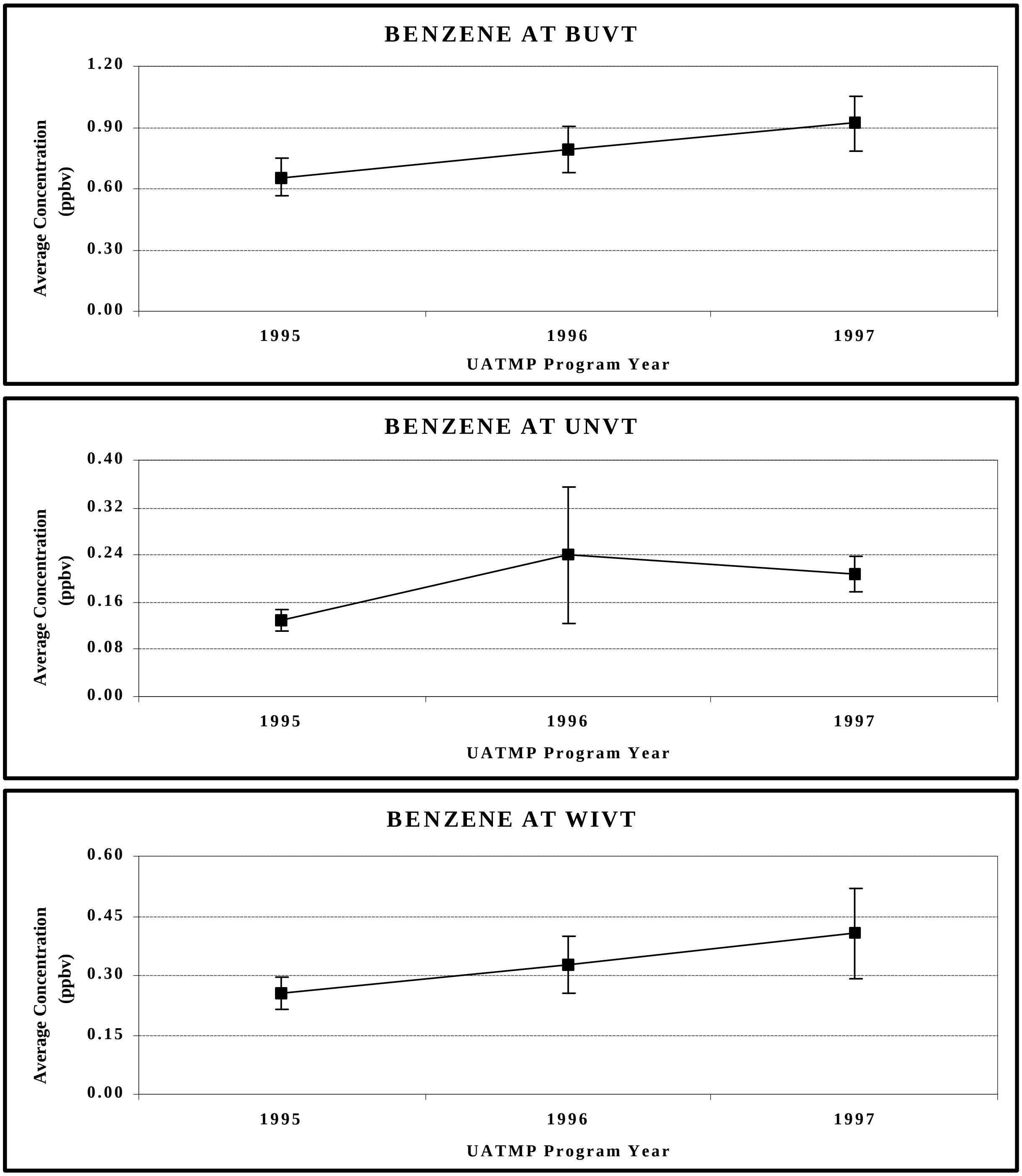






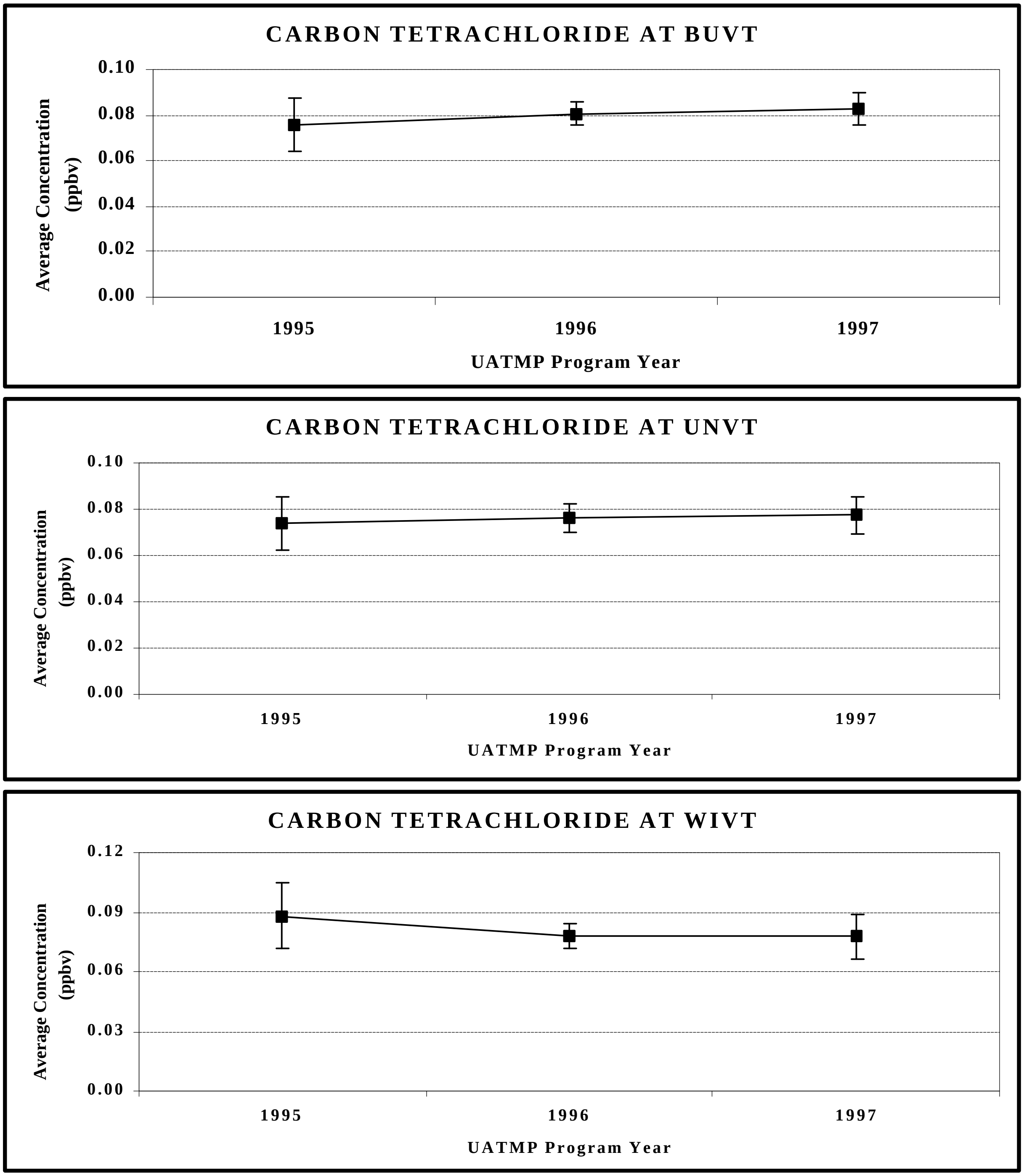
Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-6 (Page 2 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT



Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

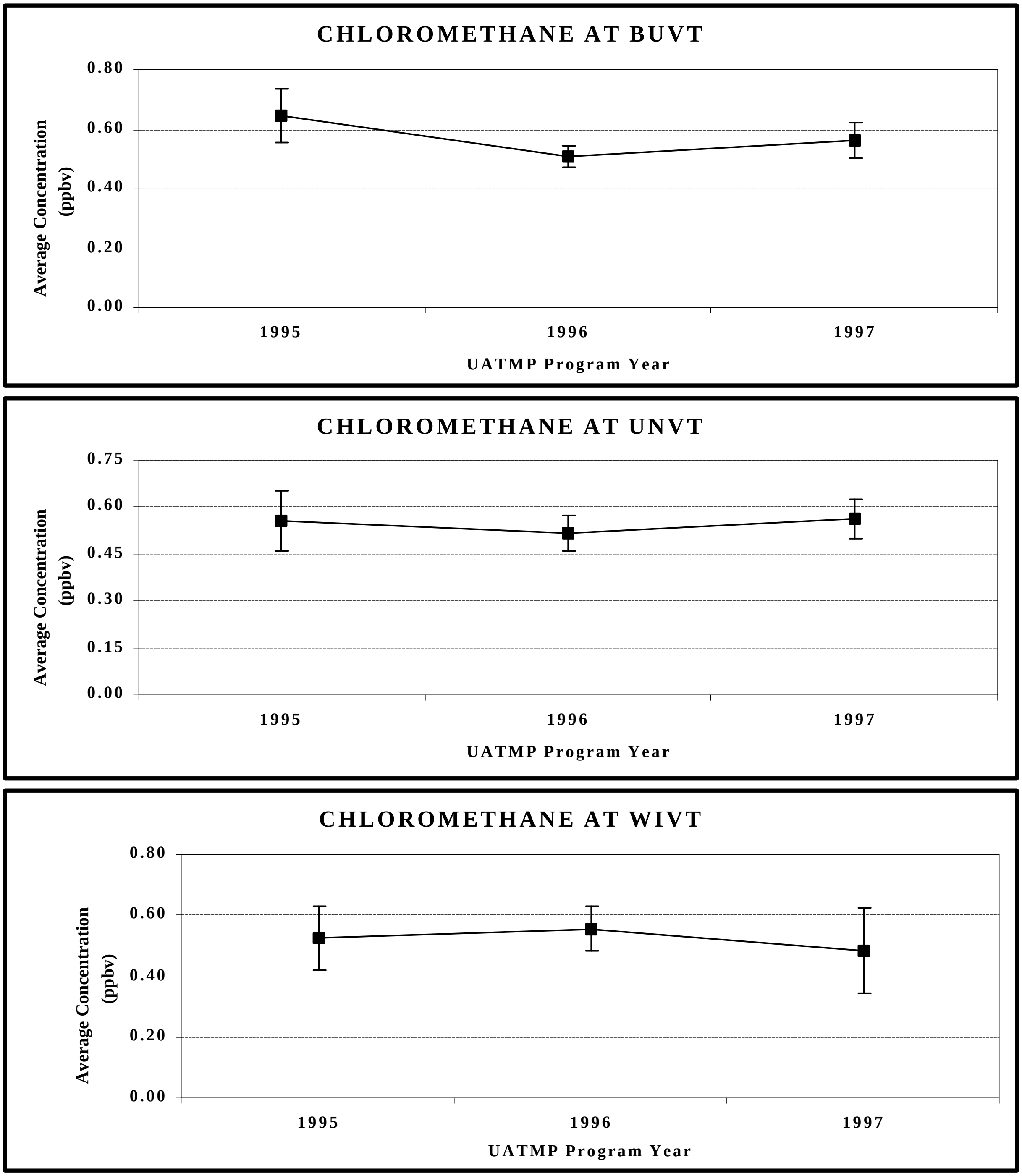
Figure 6-6 (Page 3 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT



Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

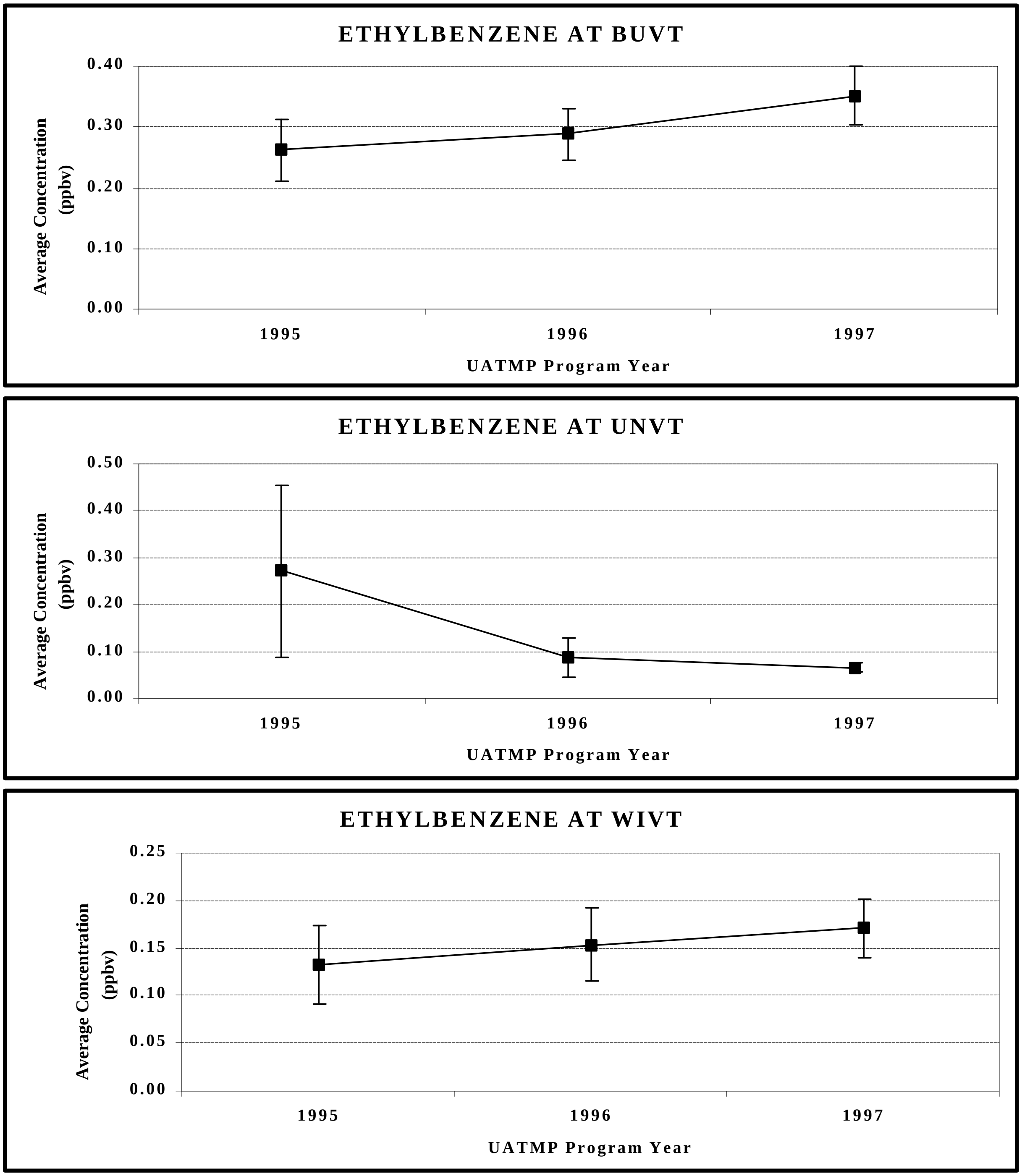
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-6 (Page 4 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC
at BUVT, UNVT, and WIVT



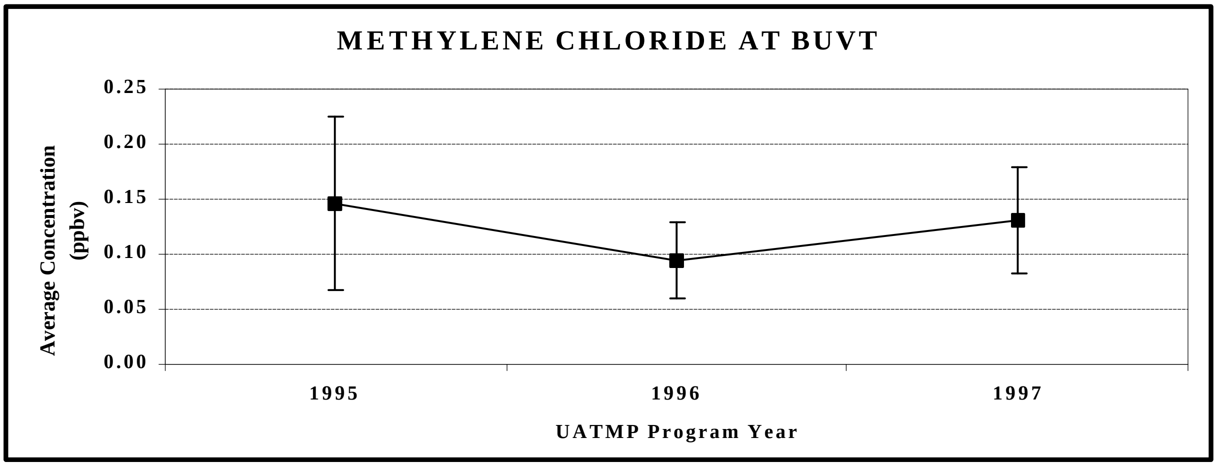
Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

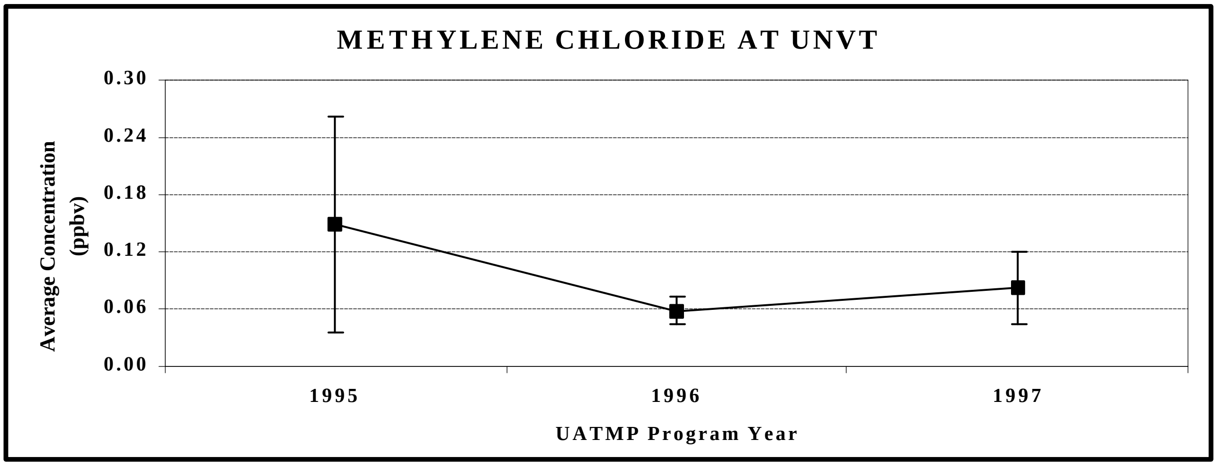
Figure 6-6 (Page 5 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT

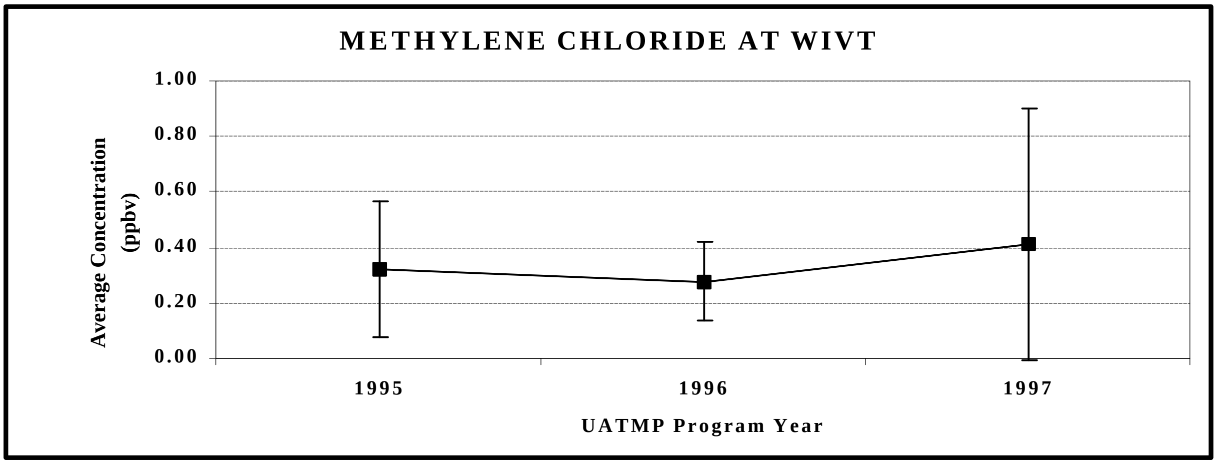


Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-6 (Page 6 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT

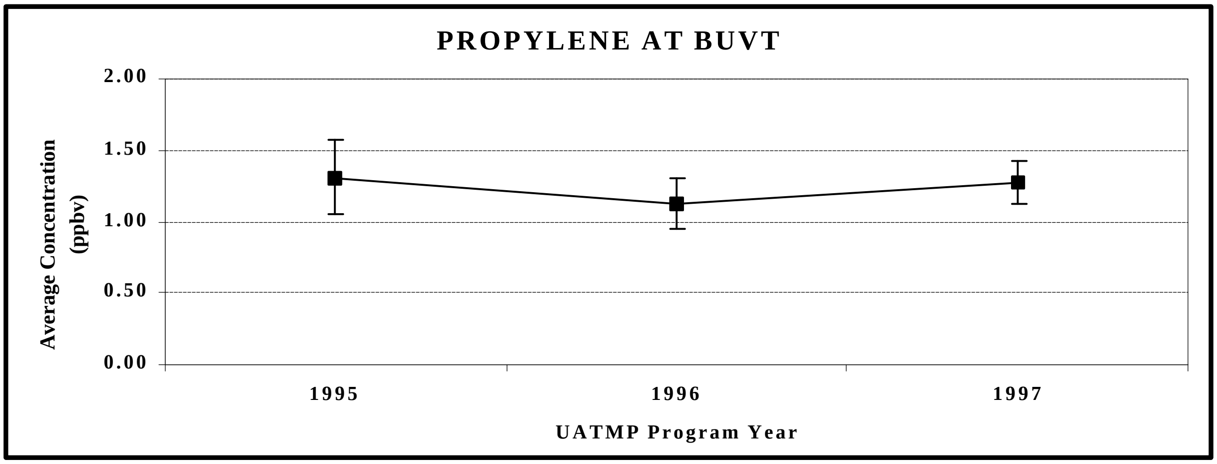


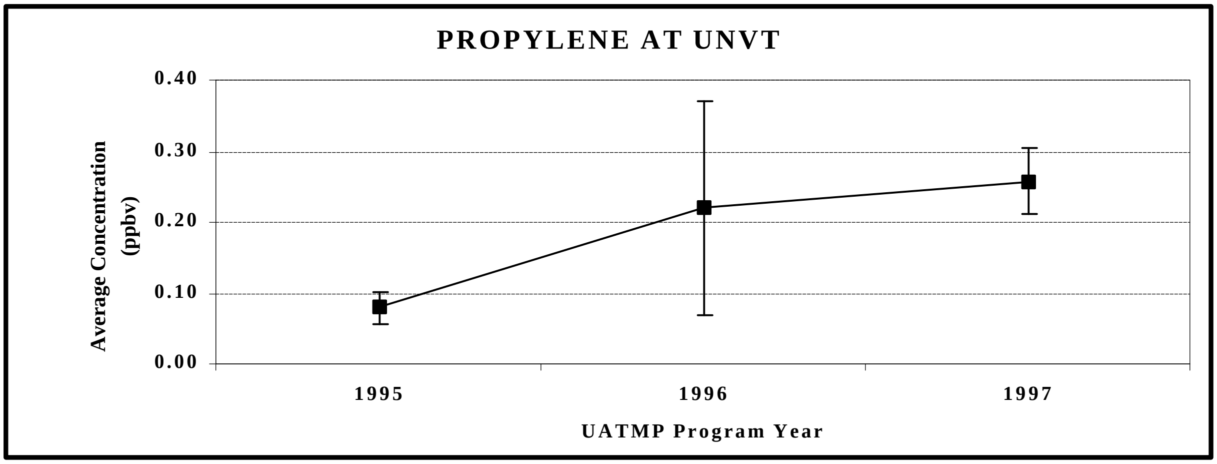


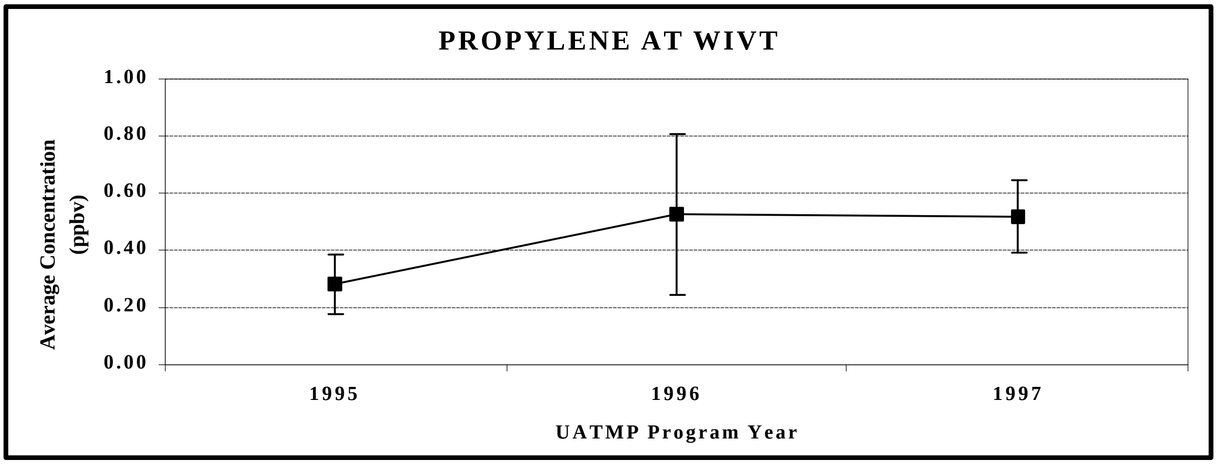


Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-6 (Page 7 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT

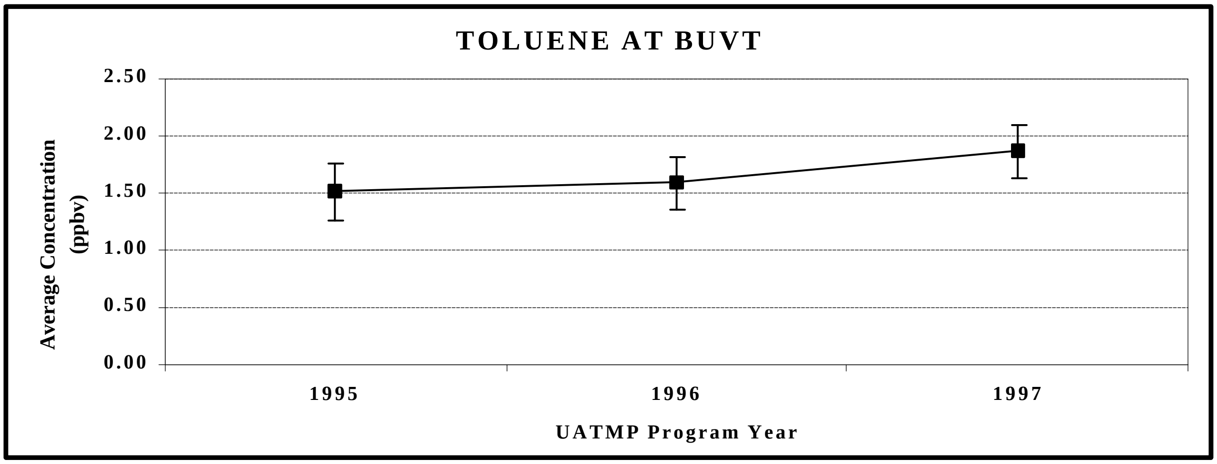


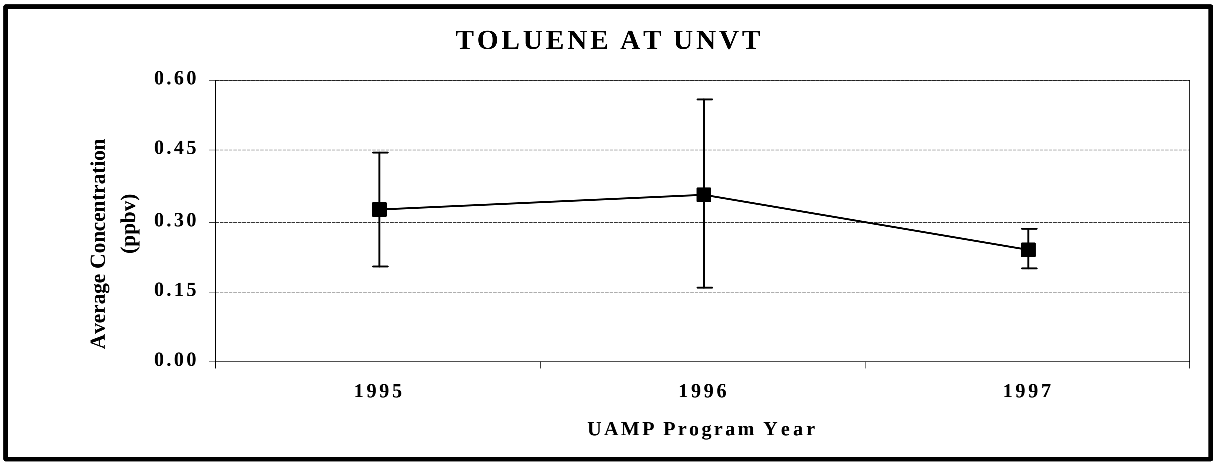


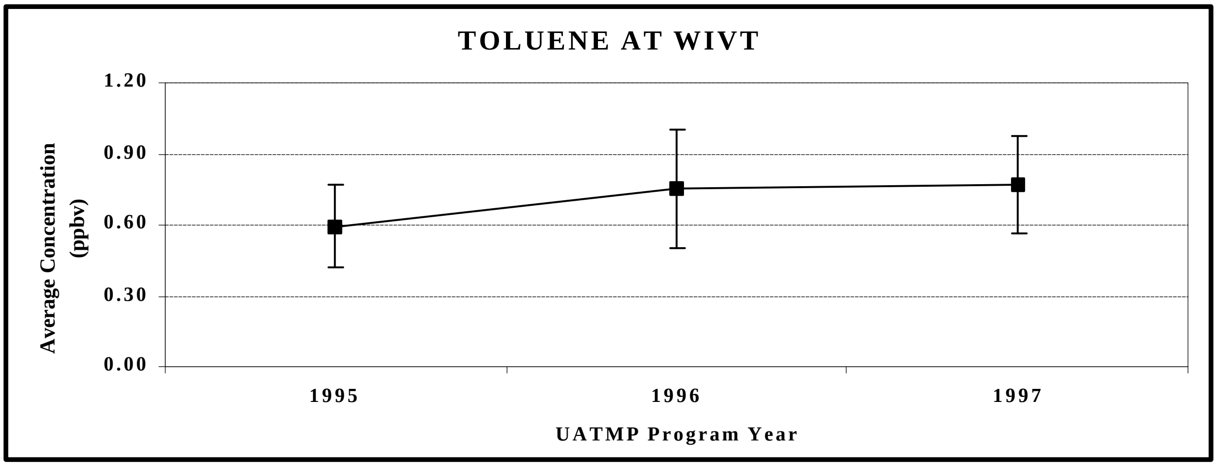


Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-6 (Page 8 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT

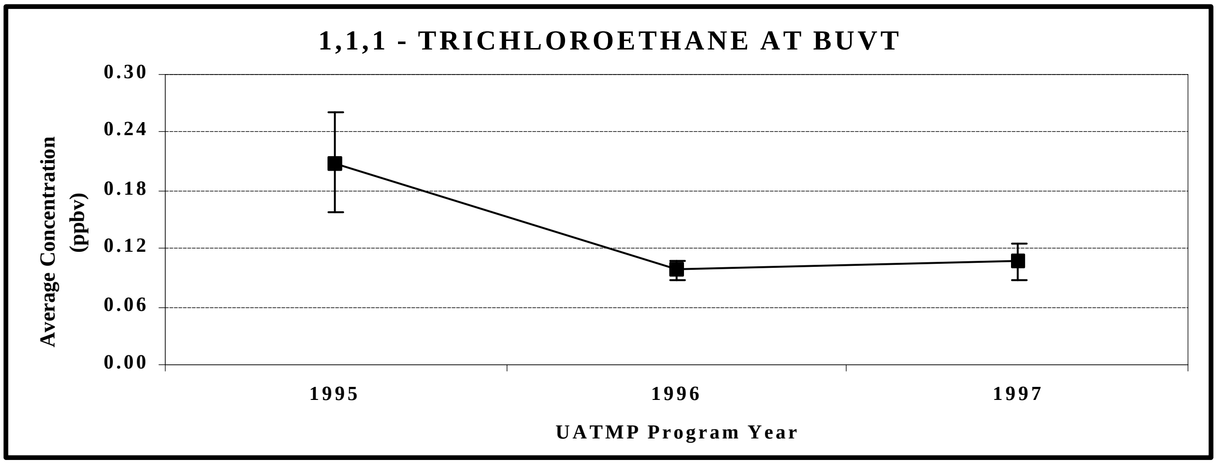


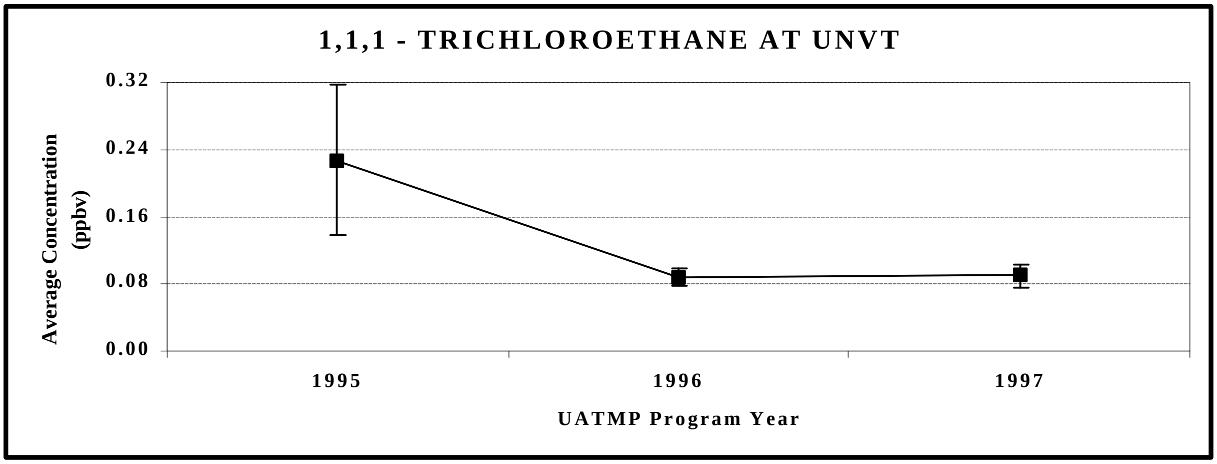


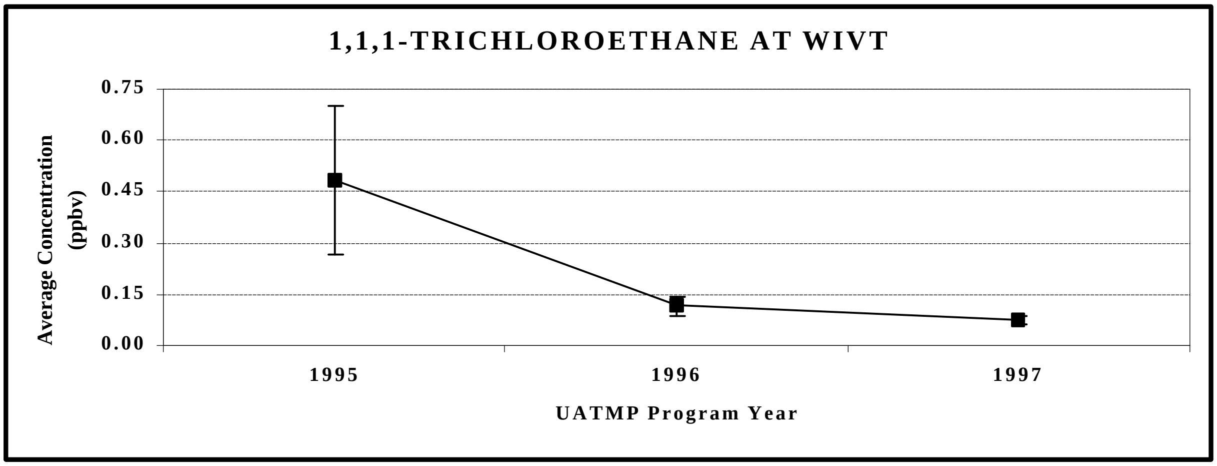


Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-6 (Page 9 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT

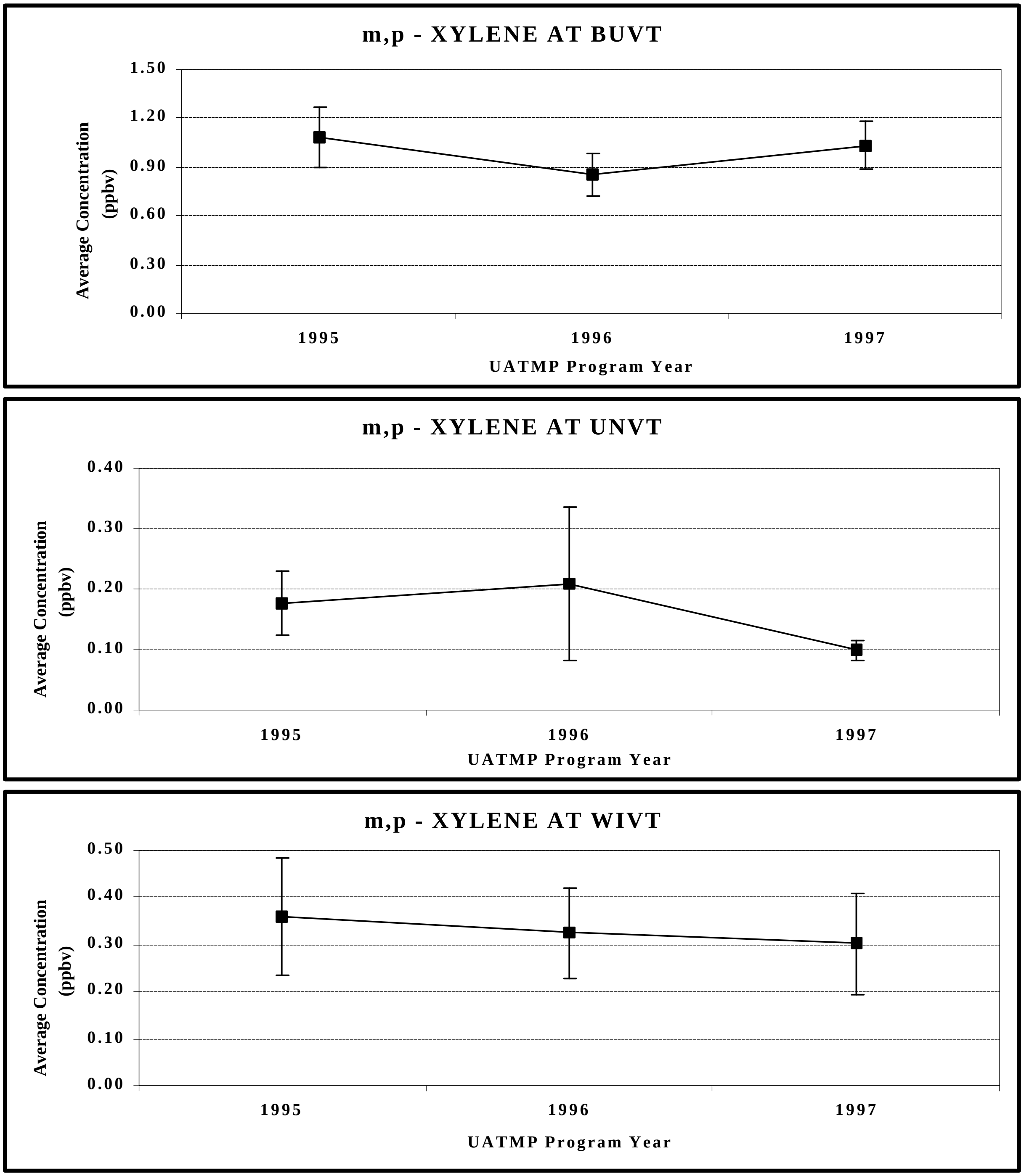






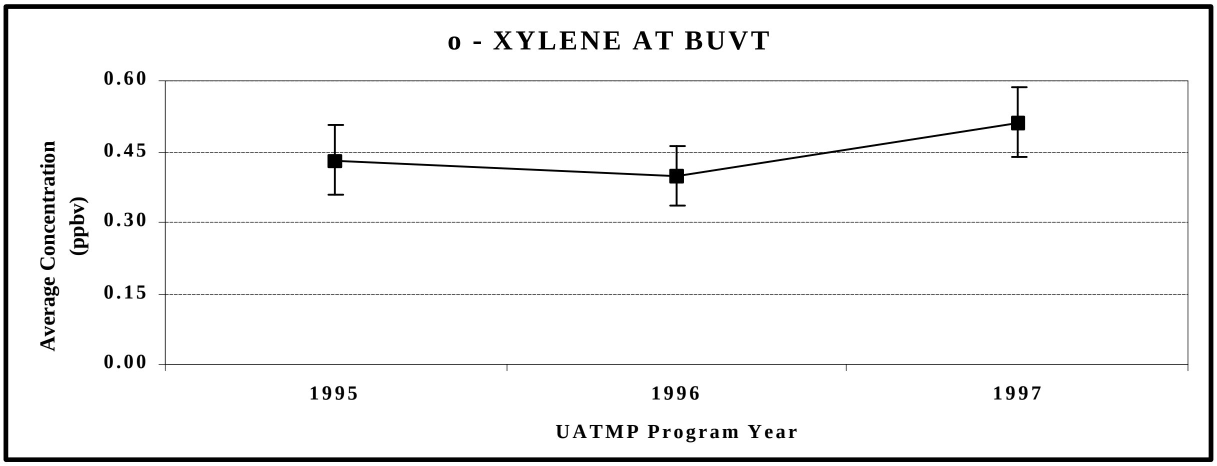
Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

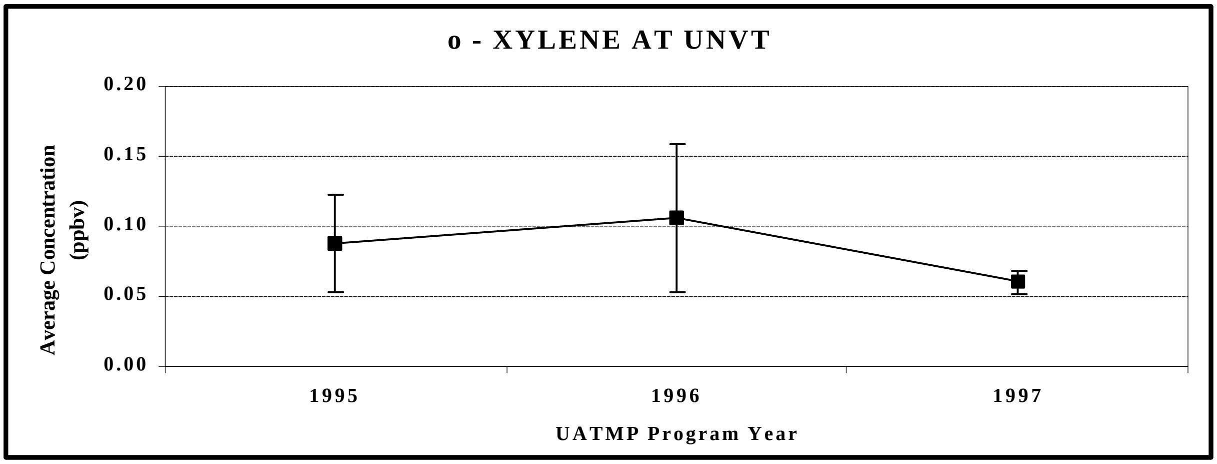
Figure 6-6 (Page 10 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC
at BUVT, UNVT, and WIVT

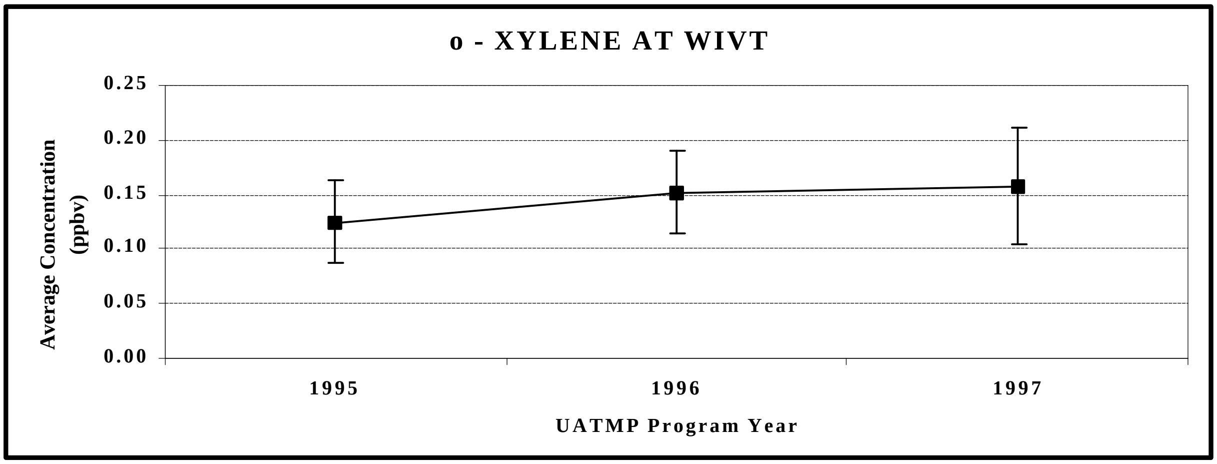


Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-6 (Page 11 of 11)
Annual Variations in Average Concentrations of the Most Prevalent VOC at BUVT, UNVT, and WIVT

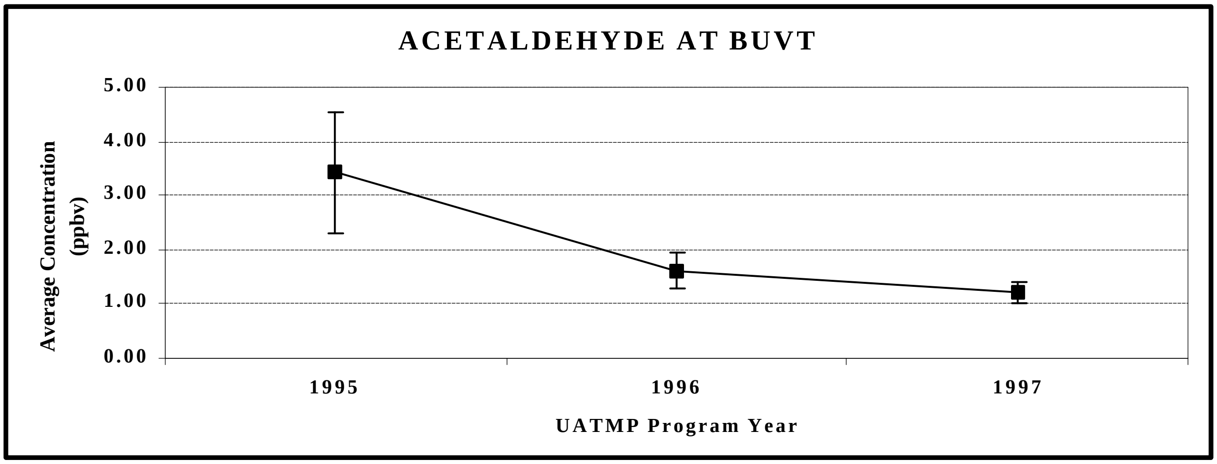


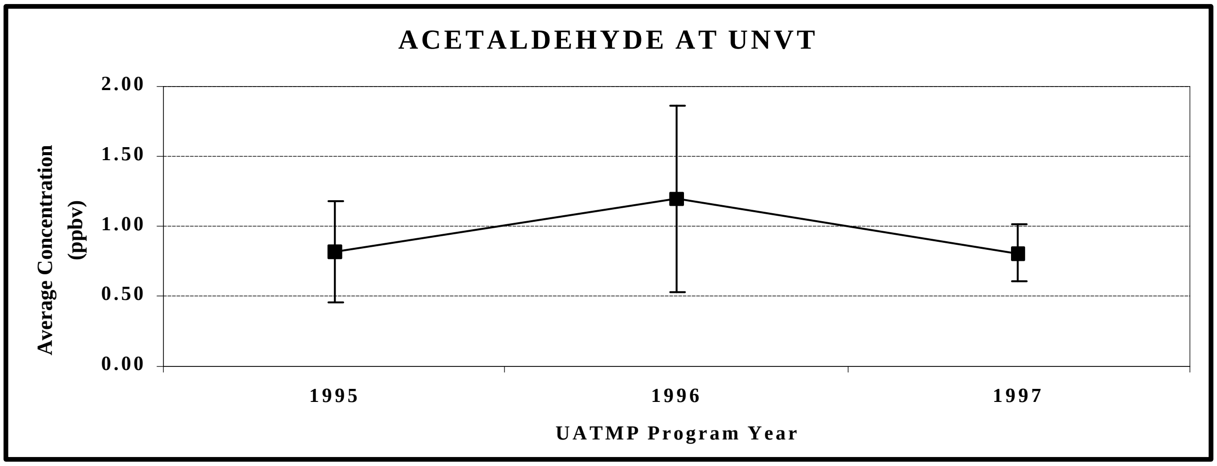


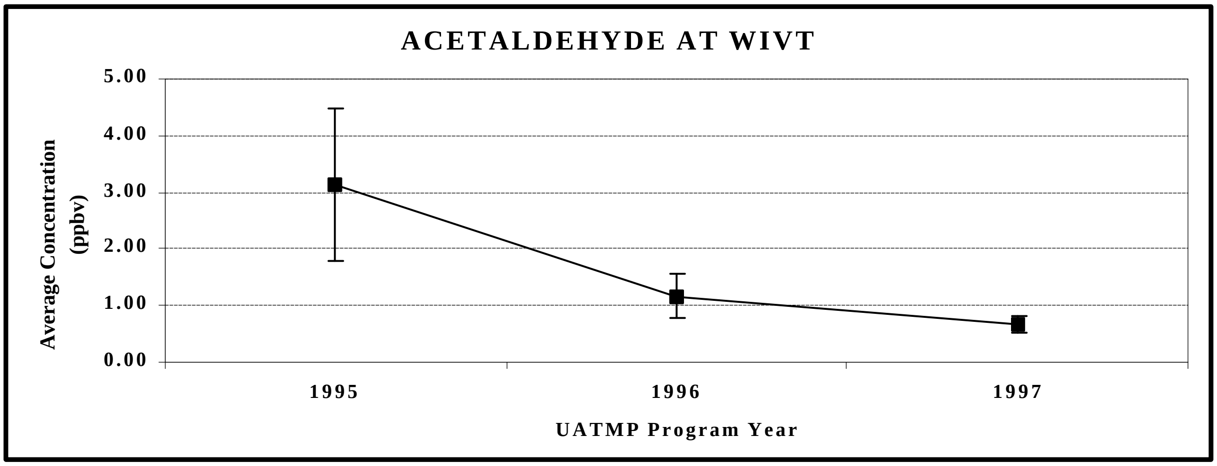


Notes: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-7 (Page 1 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT



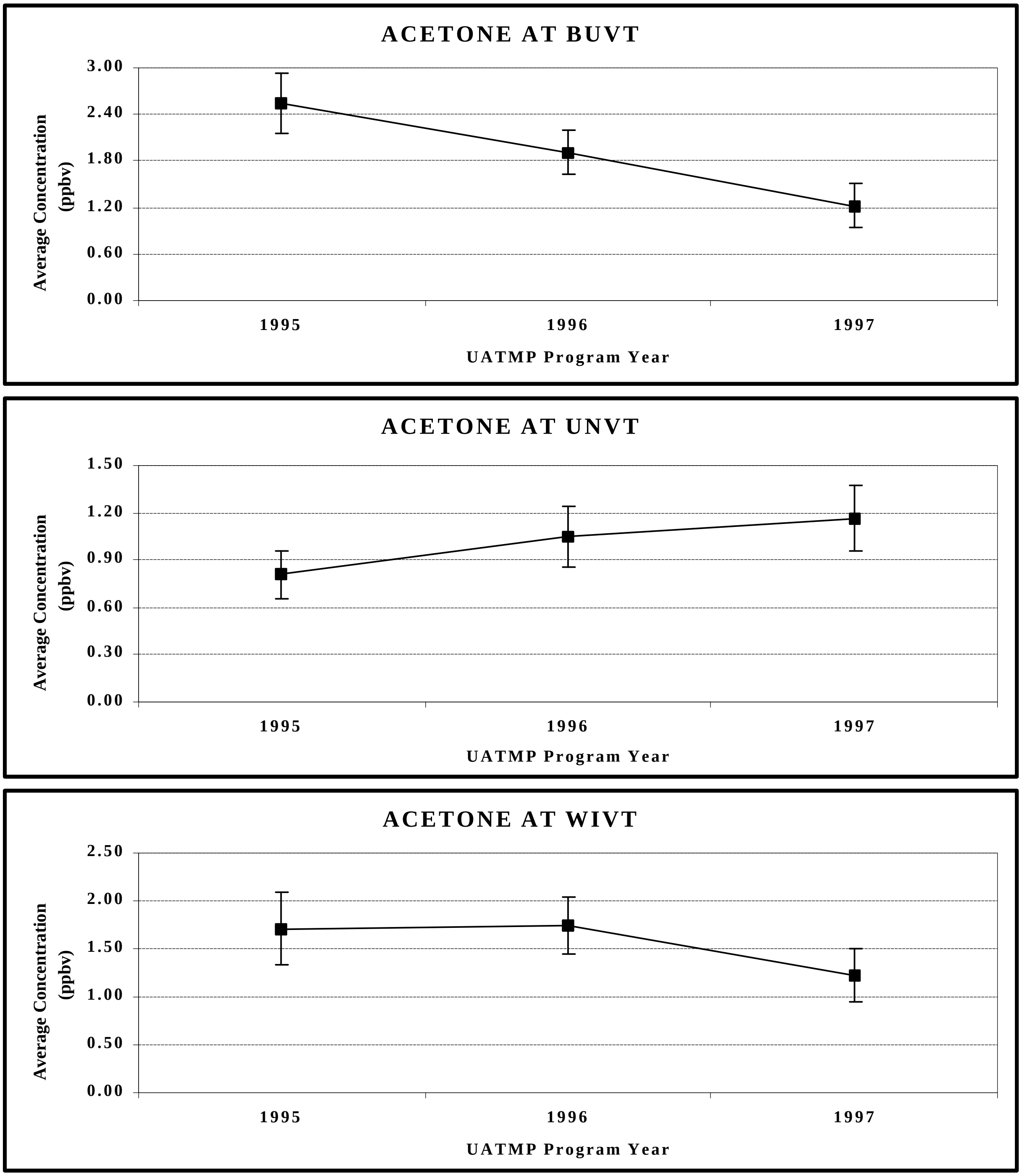




Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

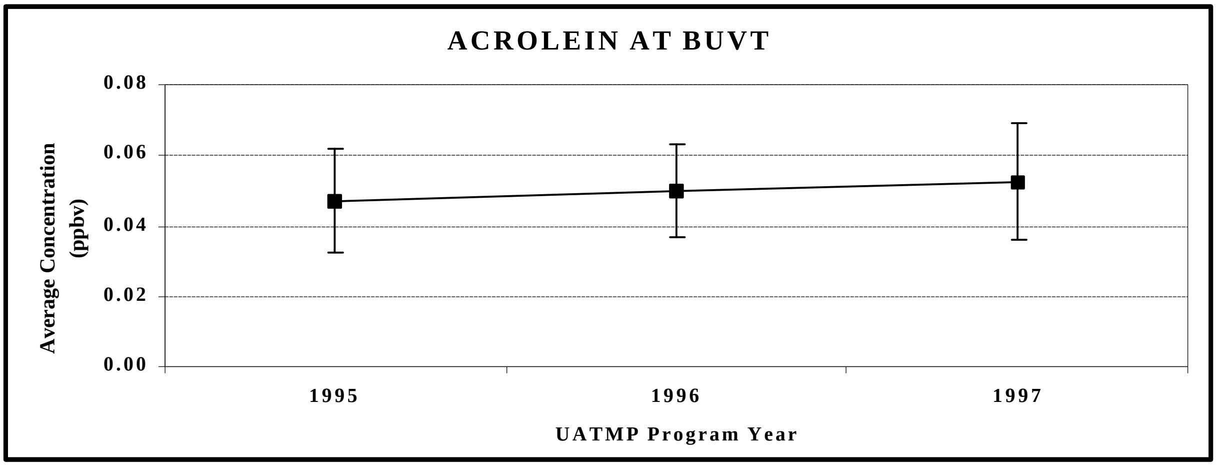
Figure 6-7 (Page 2 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT

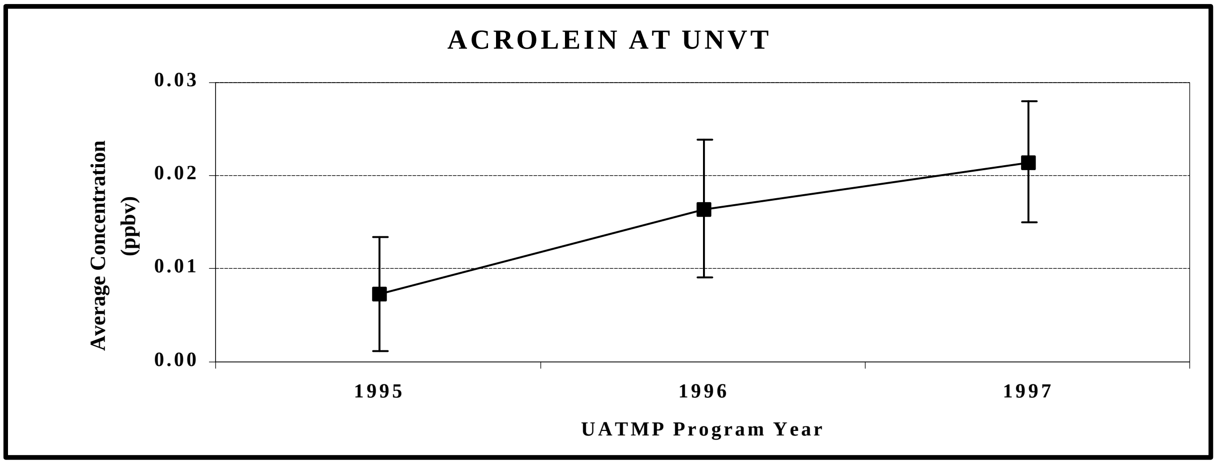


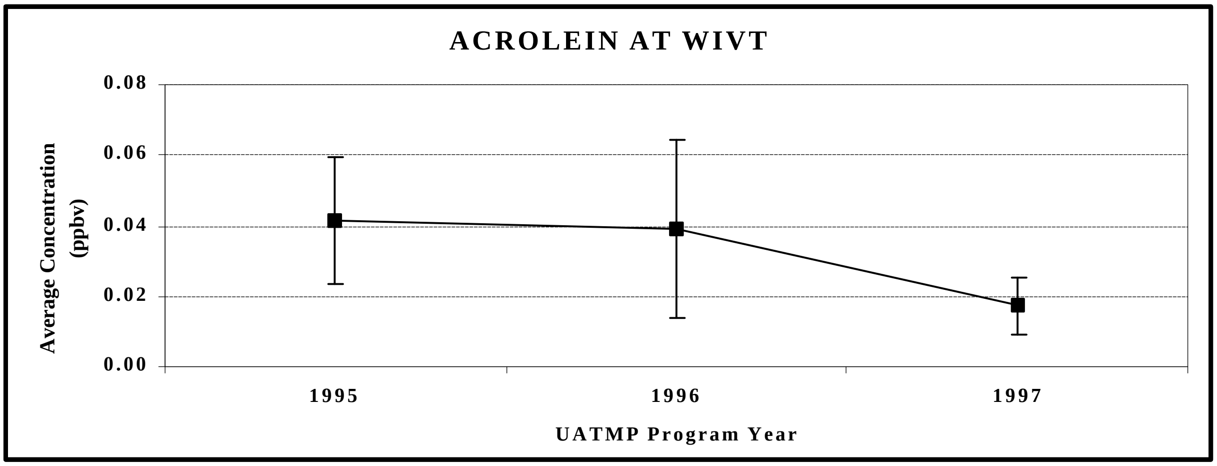
Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-7 (Page 3 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT

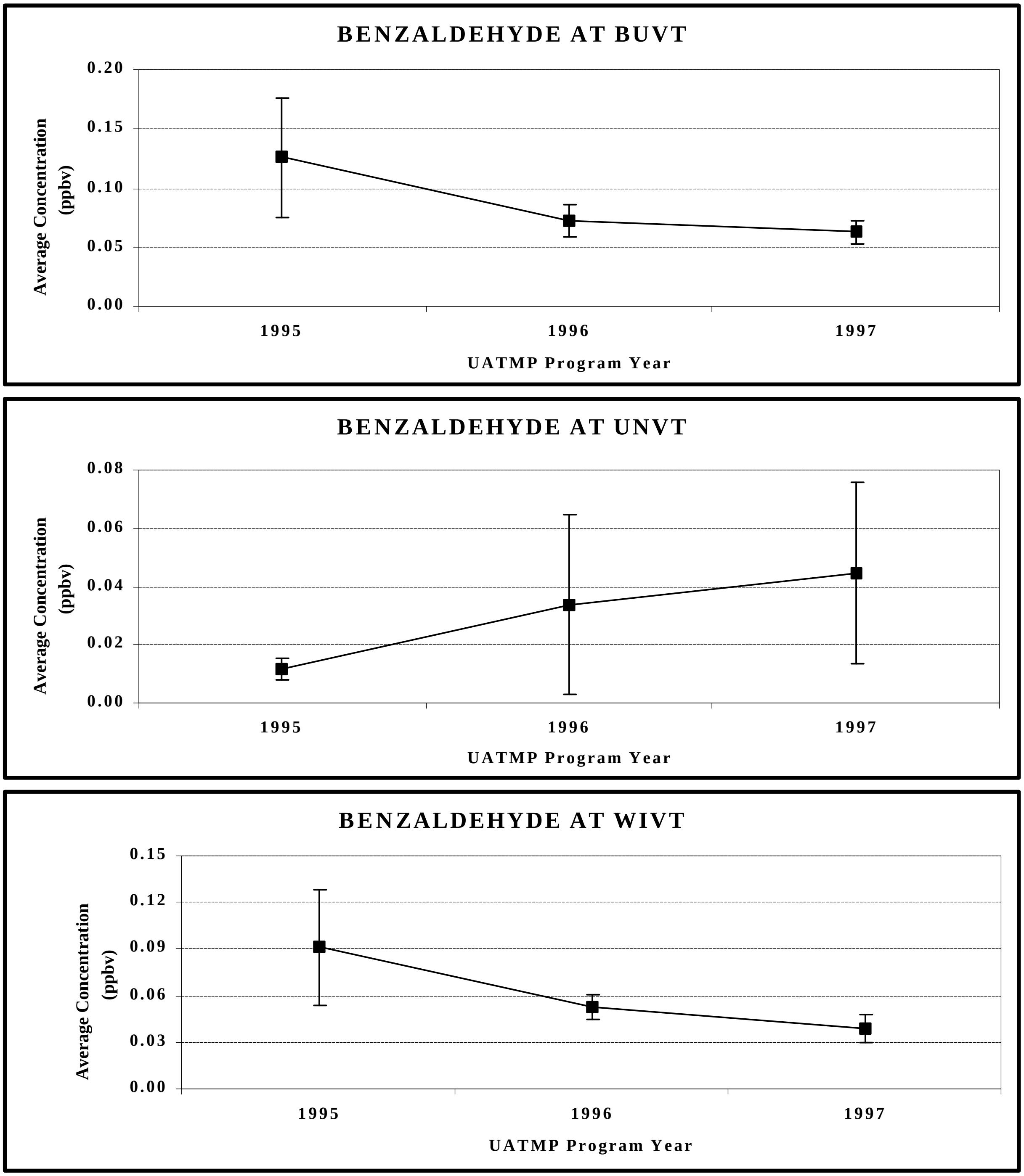






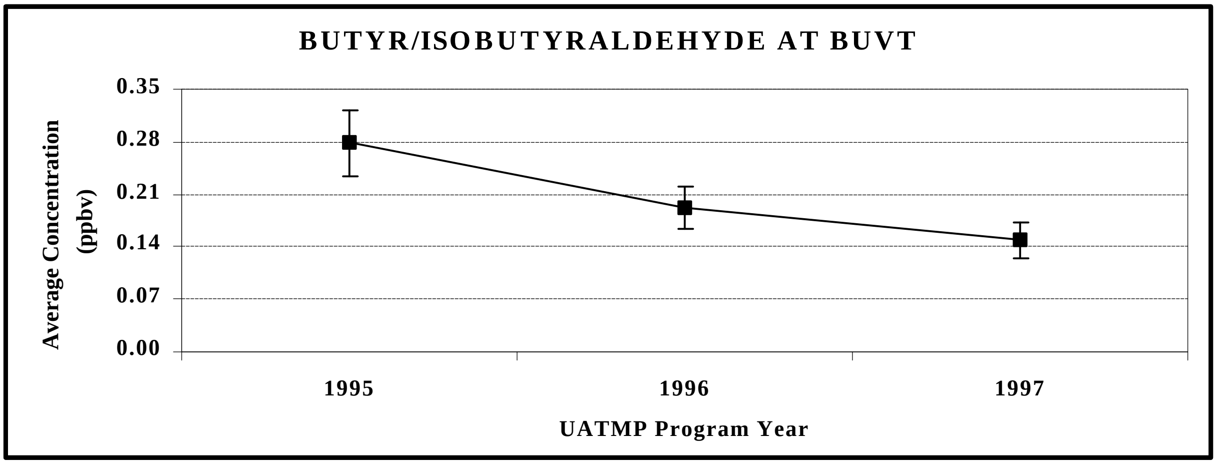
Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

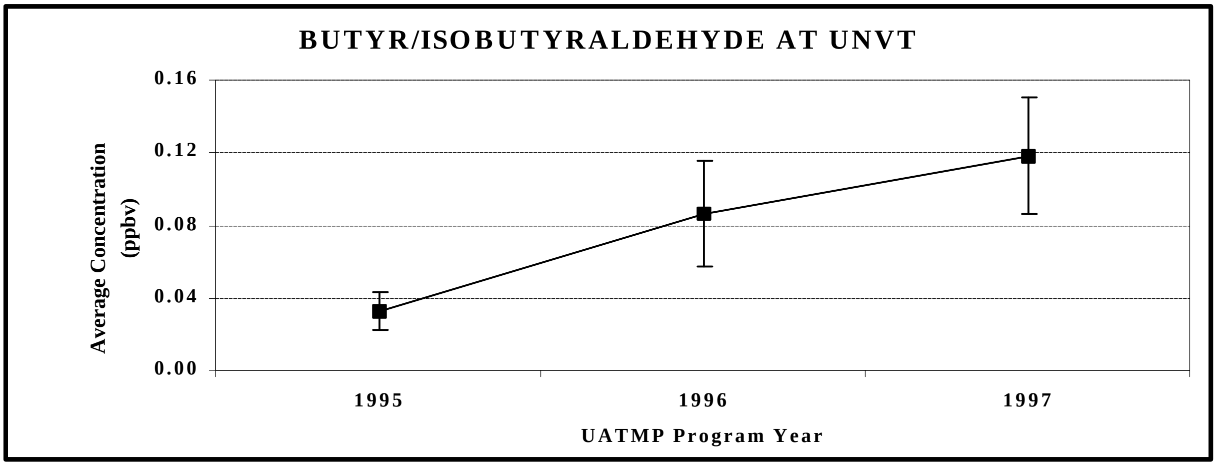
Figure 6-7 (Page 4 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT

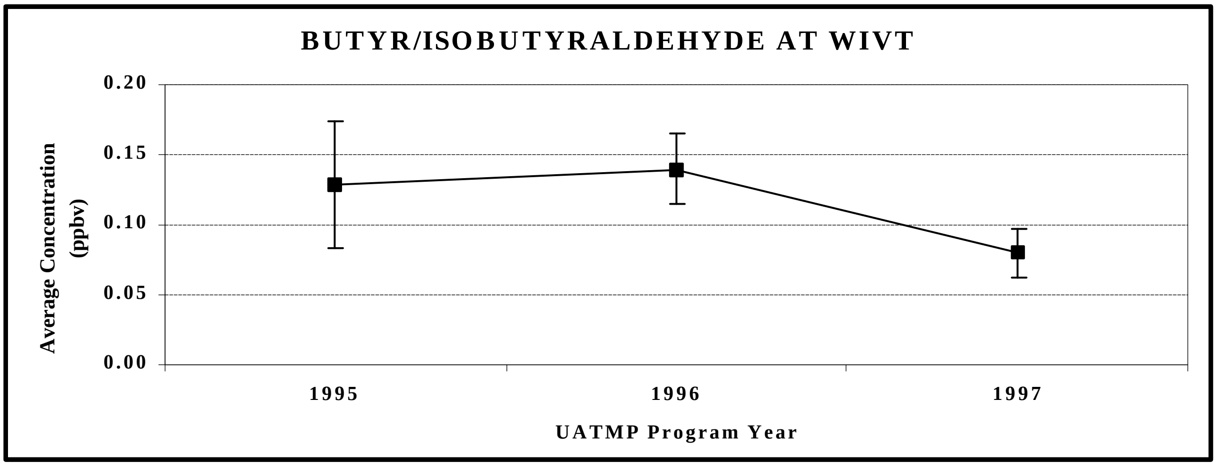


Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-7 (Page 5 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT

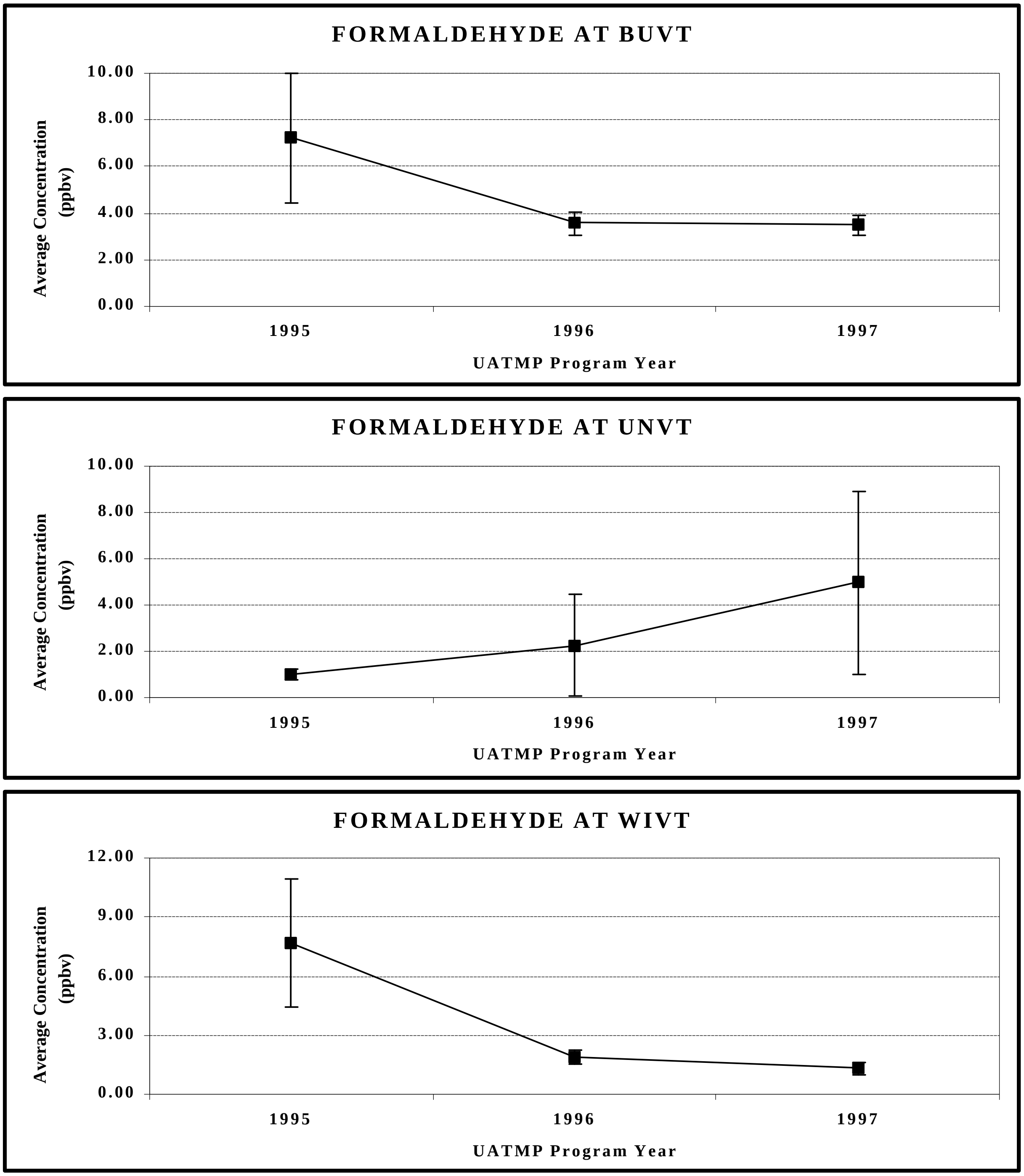






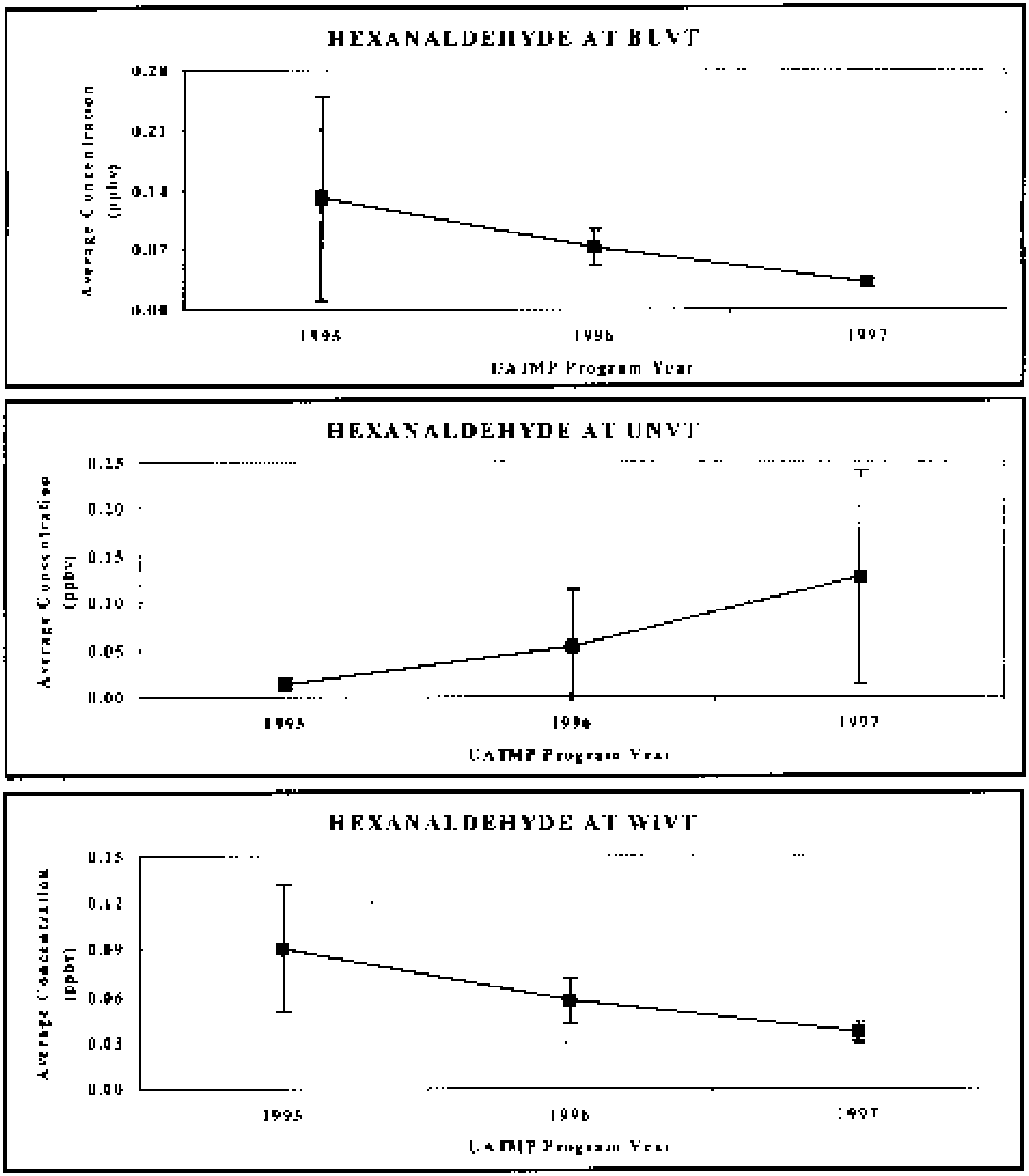
Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-7 (Page 6 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT



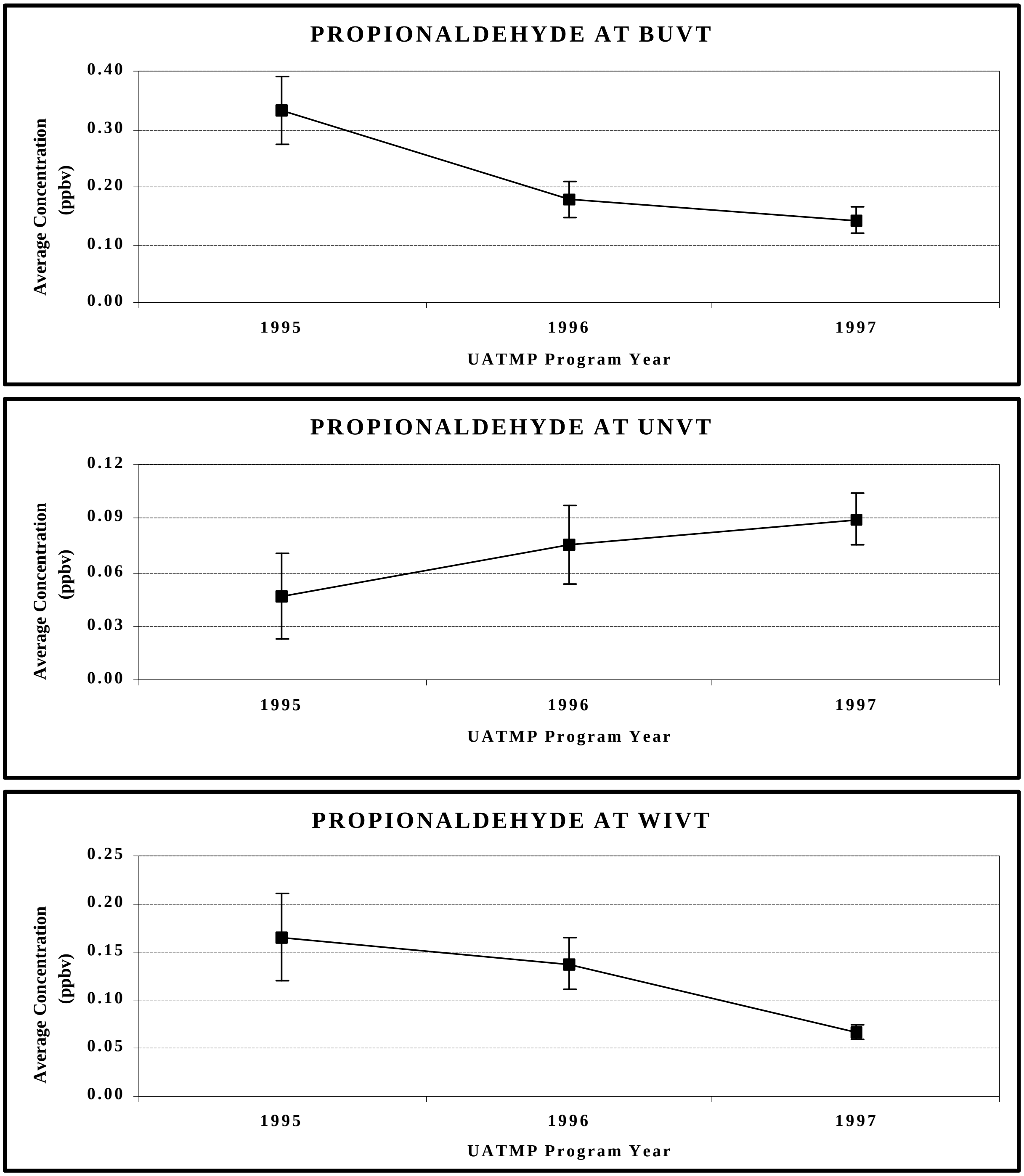
Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-7 (Page 7 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls
at BUVT, UNVT, and WIVT



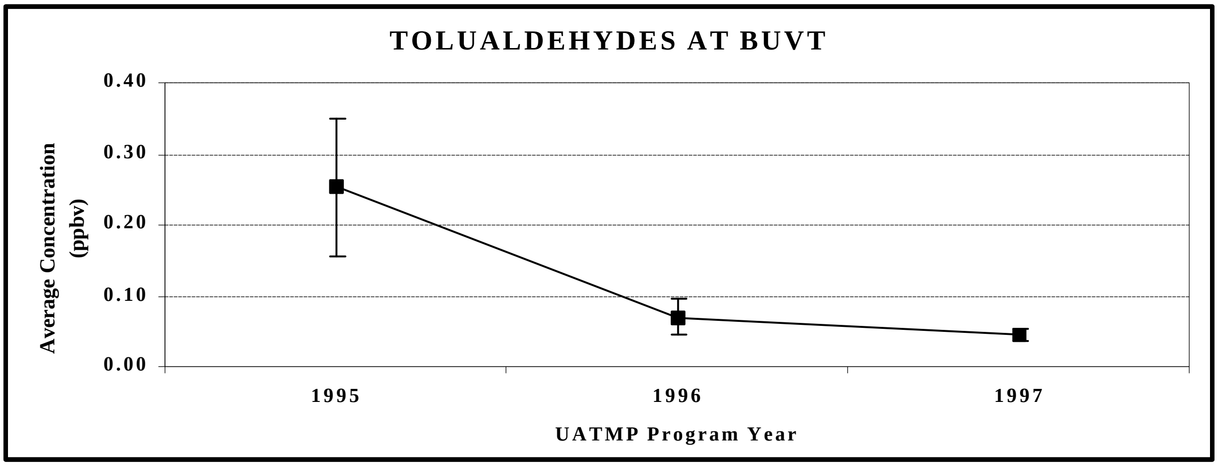
Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95 percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

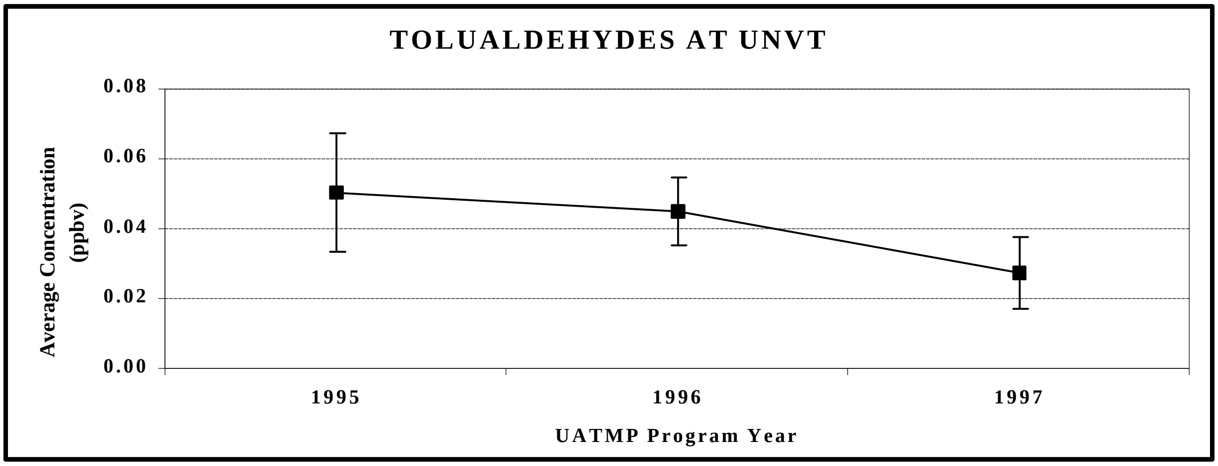
Figure 6-7 (Page 8 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT

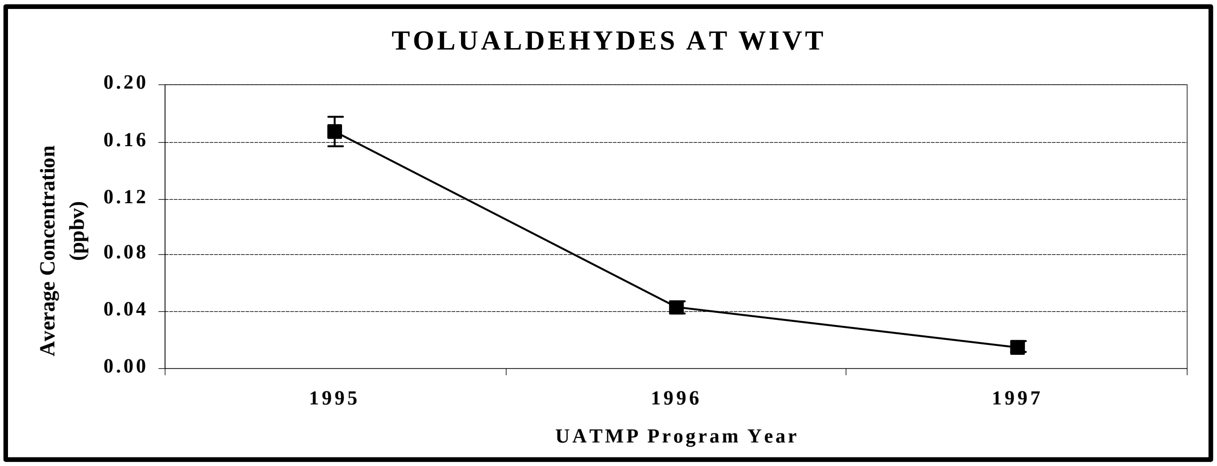


Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-7 (Page 9 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT

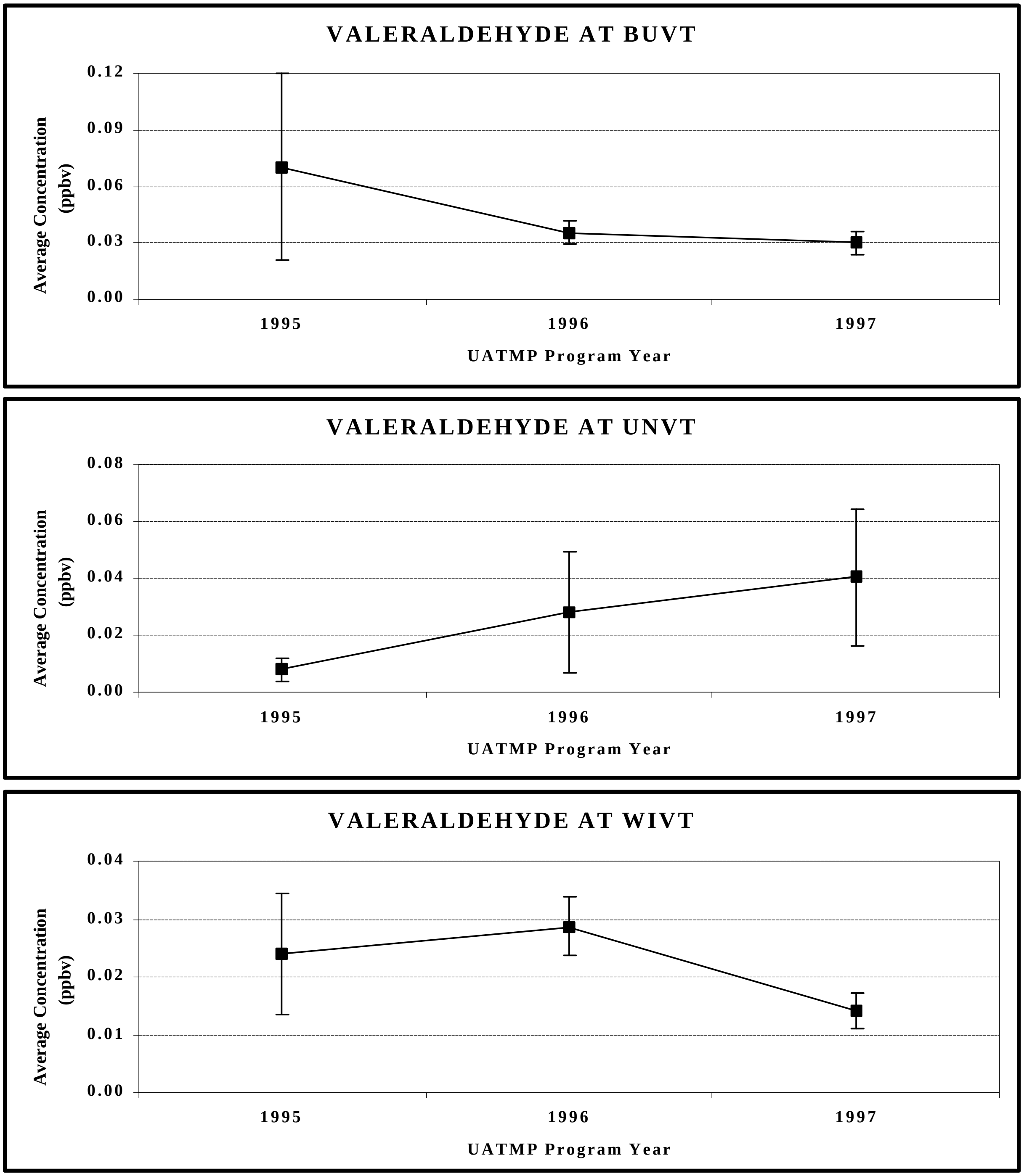






Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Figure 6-7 (Page 10 of 10)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at BUVT, UNVT, and WIVT



Notes: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.
The 1997 data for WIVT should be interpreted with caution, as they only represent 4 months of data.

Table 6-1
Completeness Data for the BUVT, UNVT, and WIVT Monitoring Stations

Parameter	Monitoring Station		
	Burlington, Vermont (BUVT)	Underhill, Vermont (UNVT)	Winooski, Vermont (WIVT)
Number of days when VOC samples were collected	31	31	10
Number of days with valid VOC samples	31	31	10
Completeness for VOC	100 %	100 %	100 %
Number of days when carbonyl samples were collected	31	31	10
Number of days with valid carbonyl samples	30	31	10
Completeness for carbonyls	97 %	100 %	100 %

Note: During the 1997 UATMP, the monitoring station in Winooski collected air samples only from September, 1997, to December, 1997.

Table 6-2
Summary Statistics for VOC Concentrations Measured at Burlington, Vermont (BUVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	30	3%	ND	2.63	0.29	0.31	0.23	0.44	1.42
Acetylene	**0**	**100%**	**0.99**	**7.70**	**2.45**	**2.84**	**2.59**	**1.38**	**0.48**
Acrylonitrile	31	0%	ND	ND	0.11	0.08	0.07	0.03	0.42
Benzene	**0**	**100%**	**0.37**	**2.30**	**0.87**	**0.92**	**0.86**	**0.37**	**0.40**
Bromochloromethane	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.31
Bromodichloromethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.10
Bromomethane	31	0%	ND	ND	0.07	0.06	0.05	0.02	0.42
1,3-Butadiene	**7**	**77%**	**ND**	**0.43**	**0.15**	**0.16**	**0.12**	**0.10**	**0.66**
Carbon tetrachloride	**0**	**100%**	**0.03**	**0.12**	**0.08**	**0.08**	**0.08**	**0.02**	**0.24**
Chlorobenzene	31	0%	ND	ND	0.04	0.03	0.03	0.01	0.23
Chloroethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	27	13%	ND	0.06	0.03	0.03	0.03	0.01	0.29
Chloromethane	**0**	**100%**	**0.15**	**0.79**	**0.60**	**0.56**	**0.53**	**0.17**	**0.30**
Chloroprene	31	0%	ND	ND	0.05	0.04	0.04	0.02	0.41
Dibromochloromethane	31	0%	ND	ND	0.08	0.06	0.05	0.03	0.43
m-Dichlorobenzene	31	0%	ND	ND	0.08	0.07	0.06	0.01	0.21
o-Dichlorobenzene	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.19

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-2 (Continued)
Summary Statistics for VOC Concentrations Measured at Burlington, Vermont (BUVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	30	3%	ND	0.01	0.07	0.06	0.05	0.01	0.25
1,1-Dichloroethane	31	0%	ND	ND	0.05	0.04	0.04	0.02	0.41
1,2-Dichloroethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.14
trans-1,2-Dichloroethylene	31	0%	ND	ND	0.06	0.05	0.05	0.02	0.32
1,2-Dichloropropane	31	0%	ND	ND	0.02	0.03	0.03	0.01	0.42
cis-1,3-Dichloropropylene	31	0%	ND	ND	0.03	0.03	0.02	0.01	0.27
trans-1,3-Dichloropropylene	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.43
Ethyl acrylate	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.34
Ethylbenzene	**0**	**100%**	**0.18**	**0.84**	**0.34**	**0.35**	**0.33**	**0.13**	**0.36**
Ethyl *tert*-butyl ether	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.14
Methylene chloride	**5**	**84%**	**ND**	**0.74**	**0.10**	**0.13**	**0.10**	**0.13**	**1.00**
Methyl ethyl ketone	**3**	**90%**	**ND**	**0.77**	**0.41**	**0.41**	**0.33**	**0.20**	**0.47**
Methyl isobutyl ketone	31	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl methacrylate	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.07
Methyl *tert*-butyl ether	**3**	**90%**	**ND**	**0.82**	**0.25**	**0.31**	**0.23**	**0.22**	**0.71**
***n*-Octane**	**6**	**81%**	**ND**	**0.26**	**0.11**	**0.12**	**0.11**	**0.06**	**0.46**
Propylene	**0**	**100%**	**0.61**	**2.75**	**1.26**	**1.27**	**1.22**	**0.42**	**0.33**
Styrene	**6**	**81%**	**ND**	**0.17**	**0.07**	**0.08**	**0.07**	**0.03**	**0.38**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-2 (Continued)
Summary Statistics for VOC Concentrations Measured at Burlington, Vermont (BUVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	28	10%	ND	0.04	0.04	0.03	0.03	0.00	0.11
1,1,2,2-Tetrachloroethane	31	0%	ND	ND	0.09	0.07	0.06	0.03	0.41
Tetrachloroethylene	19	39%	ND	0.08	0.06	0.07	0.06	0.04	0.51
Toluene	**0**	**100%**	**0.92**	**3.92**	**1.72**	**1.87**	**1.77**	**0.63**	**0.34**
1,1,1-Trichloroethane	**0**	**100%**	**0.04**	**0.28**	**0.09**	**0.11**	**0.10**	**0.05**	**0.47**
1,1,2-Trichloroethane	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.43
Trichloroethylene	30	3%	ND	0.01	0.02	0.02	0.02	0.00	0.21
Vinyl chloride	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.07
***m,p*-Xylene**	**0**	**100%**	**0.46**	**2.58**	**0.97**	**1.03**	**0.97**	**0.40**	**0.39**
***o*-Xylene**	**0**	**100%**	**0.25**	**1.32**	**0.48**	**0.51**	**0.48**	**0.20**	**0.39**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-3
Summary Statistics for VOC Concentrations Measured at Underhill, Vermont (UNVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	26	16%	ND	2.48	0.29	0.31	0.24	0.33	1.07
Acetylene	**0**	**100%**	**0.17**	**1.36**	**0.50**	**0.58**	**0.51**	**0.30**	**0.51**
Acrylonitrile	22	29%	ND	0.58	0.11	0.13	0.10	0.12	0.91
Benzene	**0**	**100%**	**0.07**	**0.41**	**0.18**	**0.21**	**0.19**	**0.08**	**0.40**
Bromochloromethane	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.31
Bromodichloromethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.10
Bromomethane	30	3%	ND	0.01	0.07	0.05	0.05	0.02	0.45
1,3-Butadiene	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.24
Carbon tetrachloride	**0**	**100%**	**0.02**	**0.11**	**0.08**	**0.08**	**0.07**	**0.02**	**0.28**
Chlorobenzene	31	0%	ND	ND	0.04	0.03	0.03	0.01	0.23
Chloroethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.17
Chloromethane	**0**	**100%**	**0.23**	**0.80**	**0.61**	**0.56**	**0.53**	**0.17**	**0.30**
Chloroprene	31	0%	ND	ND	0.05	0.04	0.04	0.02	0.41
Dibromochloromethane	31	0%	ND	ND	0.08	0.06	0.05	0.03	0.43
m-Dichlorobenzene	31	0%	ND	ND	0.08	0.07	0.06	0.01	0.21
o-Dichlorobenzene	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.19

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-3 (Continued)
Summary Statistics for VOC Concentrations Measured at Underhill, Vermont (UNVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	31	0%	ND	ND	0.07	0.06	0.06	0.01	0.20
1,1-Dichloroethane	31	0%	ND	ND	0.05	0.04	0.04	0.02	0.41
1,2-Dichloroethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.14
trans-1,2-Dichloroethylene	31	0%	ND	ND	0.06	0.05	0.05	0.02	0.32
1,2-Dichloropropane	31	0%	ND	ND	0.02	0.03	0.03	0.01	0.42
cis-1,3-Dichloropropylene	31	0%	ND	ND	0.03	0.03	0.02	0.01	0.27
trans-1,3-Dichloropropylene	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.43
Ethyl acrylate	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.34
Ethylbenzene	**7**	**77%**	**ND**	**0.14**	**0.06**	**0.06**	**0.06**	**0.03**	**0.42**
Ethyl *tert*-butyl ether	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.14
Methylene chloride	**10**	**68%**	**ND**	**0.61**	**0.05**	**0.08**	**0.06**	**0.10**	**1.25**
Methyl ethyl ketone	**6**	**81%**	**ND**	**1.02**	**0.31**	**0.35**	**0.28**	**0.20**	**0.59**
Methyl isobutyl ketone	31	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl methacrylate	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.07
Methyl *tert*-butyl ether	24	23%	ND	0.20	0.03	0.05	0.03	0.05	1.03
n-Octane	16	48%	ND	0.56	0.10	0.10	0.08	0.09	0.95
Propylene	**0**	**100%**	**0.05**	**0.57**	**0.25**	**0.26**	**0.23**	**0.12**	**0.48**
Styrene	23	26%	ND	0.07	0.05	0.05	0.05	0.01	0.25

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-3 (Continued)
Summary Statistics for VOC Concentrations Measured at Underhill, Vermont (UNVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.07
1,1,2,2-Tetrachloroethane	31	0%	ND	ND	0.09	0.07	0.06	0.03	0.41
Tetrachloroethylene	30	3%	ND	0.04	0.11	0.09	0.08	0.03	0.32
Toluene	**0**	**100%**	**0.09**	**0.66**	**0.21**	**0.24**	**0.22**	**0.12**	**0.48**
1,1,1-Trichloroethane	**0**	**100%**	**0.04**	**0.19**	**0.07**	**0.09**	**0.08**	**0.04**	**0.43**
1,1,2-Trichloroethane	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.43
Trichloroethylene	31	0%	ND	ND	0.02	0.02	0.02	0.00	0.20
Vinyl chloride	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.07
***m,p*-Xylene**	**1**	**97%**	**ND**	**0.23**	**0.09**	**0.10**	**0.09**	**0.04**	**0.44**
***o*-Xylene**	**5**	**84%**	**ND**	**0.11**	**0.05**	**0.06**	**0.06**	**0.02**	**0.36**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-4
Summary Statistics for VOC Concentrations Measured at Winooski, Vermont (WIVT)
(Based on 10 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	10	0%	ND	ND	0.29	0.29	0.29	0.00	0.00
Acetylene	**0**	**100%**	**0.43**	**2.82**	**1.08**	**1.25**	**1.09**	**0.72**	**0.57**
Acrylonitrile	9	10%	ND	0.25	0.11	0.12	0.11	0.05	0.39
Benzene	**0**	**100%**	**0.18**	**0.70**	**0.40**	**0.41**	**0.38**	**0.16**	**0.39**
Bromochloromethane	10	0%	ND	ND	0.05	0.05	0.05	0.00	0.00
Bromodichloromethane	10	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	10	0%	ND	ND	0.08	0.08	0.08	0.00	0.00
Bromomethane	10	0%	ND	ND	0.07	0.07	0.07	0.00	0.00
1,3-Butadiene	8	20%	ND	0.11	0.05	0.05	0.05	0.02	0.41
Carbon tetrachloride	**0**	**100%**	**0.06**	**0.10**	**0.08**	**0.08**	**0.08**	**0.02**	**0.20**
Chlorobenzene	10	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Chloroethane	10	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	10	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloromethane	**0**	**100%**	**0.24**	**0.84**	**0.46**	**0.49**	**0.45**	**0.20**	**0.40**
Chloroprene	10	0%	ND	ND	0.05	0.05	0.05	0.00	0.00
Dibromochloromethane	10	0%	ND	ND	0.08	0.08	0.08	0.00	0.00
m-Dichlorobenzene	10	0%	ND	ND	0.08	0.08	0.08	0.00	0.00
o-Dichlorobenzene	10	0%	ND	ND	0.08	0.08	0.08	0.00	0.00

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 4 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 6-4 (Continued)
Summary Statistics for VOC Concentrations Measured at Winooski, Vermont (WIVT)
(Based on 10 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	10	0%	ND	ND	0.07	0.07	0.07	0.00	0.00
1,1-Dichloroethane	10	0%	ND	ND	0.05	0.05	0.05	0.00	0.00
1,2-Dichloroethane	10	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
trans-1,2-Dichloroethylene	10	0%	ND	ND	0.06	0.06	0.06	0.00	0.00
1,2-Dichloropropane	10	0%	ND	ND	0.02	0.02	0.02	0.00	0.00
cis-1,3-Dichloropropylene	10	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
trans-1,3-Dichloropropylene	10	0%	ND	ND	0.06	0.06	0.06	0.00	0.00
Ethyl acrylate	10	0%	ND	ND	0.05	0.05	0.05	0.00	0.00
Ethylbenzene	**0**	**100%**	**0.10**	**0.24**	**0.18**	**0.17**	**0.17**	**0.04**	**0.25**
Ethyl *tert*-butyl ether	10	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methylene chloride	**0**	**100%**	**0.04**	**2.26**	**0.17**	**0.42**	**0.19**	**0.68**	**1.63**
Methyl ethyl ketone	**4**	**60%**	**ND**	**0.57**	**0.29**	**0.26**	**0.21**	**0.17**	**0.64**
Methyl isobutyl ketone	10	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl methacrylate	10	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl *tert*-butyl ether	8	20%	ND	0.18	0.03	0.06	0.04	0.06	1.02
***n*-Octane**	**3**	**70%**	**ND**	**0.16**	**0.09**	**0.09**	**0.08**	**0.04**	**0.44**
Propylene	**0**	**100%**	**0.34**	**0.87**	**0.46**	**0.52**	**0.49**	**0.18**	**0.35**
Styrene	5	50%	ND	0.06	0.05	0.05	0.04	0.01	0.26
tert-Amyl methyl ether	10	0%	ND	ND	0.04	0.04	0.04	0.00	0.00

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).
Because only 4 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 6-4 (Continued)
Summary Statistics for VOC Concentrations Measured at Winooski, Vermont (WIVT)
(Based on 10 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
1,1,2,2-Tetrachloroethane	10	0%	ND	ND	0.09	0.09	0.09	0.00	0.00
Tetrachloroethylene	**3**	**70%**	**ND**	**0.07**	**0.06**	**0.06**	**0.05**	**0.04**	**0.63**
Toluene	**0**	**100%**	**0.47**	**1.28**	**0.71**	**0.77**	**0.72**	**0.29**	**0.37**
1,1,1-Trichloroethane	**0**	**100%**	**0.05**	**0.11**	**0.08**	**0.08**	**0.07**	**0.02**	**0.23**
1,1,2-Trichloroethane	10	0%	ND	ND	0.06	0.06	0.06	0.00	0.00
Trichloroethylene	10	0%	ND	ND	0.02	0.02	0.02	0.00	0.00
Vinyl chloride	10	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
***m,p*-Xylene**	**0**	**100%**	**0.18**	**0.67**	**0.24**	**0.30**	**0.28**	**0.15**	**0.50**
***o*-Xylene**	**0**	**100%**	**0.10**	**0.32**	**0.12**	**0.16**	**0.15**	**0.07**	**0.47**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 4 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 6-5
Geometric Mean Concentrations for the Most Prevalent VOC in the Burlington Area

Compound	Geometric Mean Concentration (ppbv), by Monitoring Station		
	BUVT	UNVT	WIVT
Acetylene	2.59	0.51	1.09
Benzene	0.86	0.19	0.38
Carbon tetrachloride	0.08	0.07	0.08
Chloromethane	0.53	0.53	0.45
Ethylbenzene	0.33	0.06	0.17
Methylene chloride	0.10	0.06	0.19
Methyl ethyl ketone	0.33	0.28	0.21
Propylene	1.22	0.23	0.49
Toluene	1.77	0.22	0.72
1,1,1-Trichloroethane	0.10	0.08	0.07
m,p-Xylene	0.97	0.09	0.28
o-Xylene	0.48	0.06	0.15

Note: Because the WIVT monitoring station collected air samples for only 4 months, summary statistics for this station may not represent actual annual averages.

Table 6-6
Summary Statistics for Carbonyl Concentrations Measured at Burlington, Vermont (BUVT)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.05**	**2.43**	**1.19**	**1.22**	**1.06**	**0.52**	**0.42**
Acetone	**0**	**100%**	**0.08**	**3.15**	**1.15**	**1.22**	**0.92**	**0.77**	**0.63**
Acrolein	**0**	**100%**	**0.01**	**0.23**	**0.04**	**0.05**	**0.04**	**0.04**	**0.85**
Benzaldehyde	**0**	**100%**	**0.02**	**0.13**	**0.06**	**0.06**	**0.06**	**0.03**	**0.41**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.02**	**0.32**	**0.13**	**0.15**	**0.13**	**0.07**	**0.45**
Crotonaldehyde	20	33%	ND	0.14	0.00	0.02	0.01	0.03	1.99
2,5-Dimethylbenzaldehyde	21	30%	ND	0.02	0.00	0.00	0.00	0.00	0.85
Formaldehyde	**0**	**100%**	**1.45**	**6.67**	**3.26**	**3.49**	**3.32**	**1.13**	**0.32**
Hexanaldehyde	**0**	**100%**	**0.01**	**0.06**	**0.03**	**0.03**	**0.03**	**0.01**	**0.45**
Isovaleraldehyde	**10**	**67%**	**ND**	**0.05**	**0.01**	**0.01**	**0.01**	**0.01**	**0.90**
Propionaldehyde	**0**	**100%**	**0.02**	**0.28**	**0.12**	**0.14**	**0.13**	**0.06**	**0.44**
Tolualdehydes	**2**	**93%**	**ND**	**0.12**	**0.05**	**0.05**	**0.04**	**0.03**	**0.55**
Valeraldehyde	**0**	**100%**	**0.01**	**0.07**	**0.03**	**0.03**	**0.03**	**0.02**	**0.55**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-7
Summary Statistics for Carbonyl Concentrations Measured at Underhill, Vermont (UNVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.39**	**2.80**	**0.61**	**0.81**	**0.70**	**0.55**	**0.68**
Acetone	**0**	**100%**	**0.18**	**3.07**	**1.05**	**1.17**	**1.03**	**0.57**	**0.49**
Acrolein	**1**	**97%**	**ND**	**0.06**	**0.01**	**0.02**	**0.02**	**0.02**	**0.82**
Benzaldehyde	**5**	**84%**	**ND**	**0.34**	**0.02**	**0.04**	**0.01**	**0.08**	**1.89**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.04**	**0.36**	**0.09**	**0.12**	**0.09**	**0.09**	**0.75**
Crotonaldehyde	24	23%	ND	0.03	0.00	0.01	0.00	0.01	1.34
2,5-Dimethylbenzaldehyde	28	10%	ND	0.02	0.00	0.00	0.00	0.00	0.99
Formaldehyde	**0**	**100%**	**0.89**	**44.16**	**1.63**	**4.97**	**2.08**	**10.72**	**2.16**
Hexanaldehyde	**0**	**100%**	**0.01**	**1.09**	**0.03**	**0.13**	**0.03**	**0.31**	**2.44**
Isovaleraldehyde	17	45%	ND	0.03	0.01	0.01	0.01	0.01	0.66
Propionaldehyde	**0**	**100%**	**0.05**	**0.18**	**0.07**	**0.09**	**0.08**	**0.04**	**0.43**
Tolualdehydes	**11**	**65%**	**ND**	**0.12**	**0.02**	**0.03**	**0.02**	**0.03**	**1.01**
Valeraldehyde	**2**	**94%**	**ND**	**0.28**	**0.02**	**0.04**	**0.02**	**0.07**	**1.62**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 6-8
Summary Statistics for Carbonyl Concentrations Measured at Winooski, Vermont (WIVT)
(Based on 10 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.37**	**1.28**	**0.66**	**0.68**	**0.65**	**0.22**	**0.33**
Acetone	**0**	**100%**	**0.47**	**1.97**	**1.25**	**1.22**	**1.15**	**0.39**	**0.32**
Acrolein	**0**	**100%**	**0.00**	**0.04**	**0.02**	**0.02**	**0.01**	**0.01**	**0.65**
Benzaldehyde	**0**	**100%**	**0.03**	**0.06**	**0.04**	**0.04**	**0.04**	**0.01**	**0.34**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.05**	**0.12**	**0.08**	**0.08**	**0.08**	**0.02**	**0.31**
Crotonaldehyde	10	0%	ND	ND	0.00	0.00	0.00	0.00	0.00
2,5-Dimethylbenzaldehyde	8	20%	ND	0.02	0.00	0.00	0.00	0.00	1.03
Formaldehyde	**0**	**100%**	**0.89**	**2.28**	**1.17**	**1.31**	**1.26**	**0.41**	**0.32**
Hexanaldehyde	**0**	**100%**	**0.03**	**0.06**	**0.03**	**0.04**	**0.04**	**0.01**	**0.27**
Isovaleraldehyde	**4**	**60%**	**ND**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.75**
Propionaldehyde	**0**	**100%**	**0.05**	**0.09**	**0.07**	**0.07**	**0.07**	**0.01**	**0.16**
Tolualdehydes	**2**	**80%**	**ND**	**0.04**	**0.01**	**0.02**	**0.01**	**0.01**	**0.93**
Valeraldehyde	**0**	**100%**	**0.01**	**0.02**	**0.02**	**0.01**	**0.01**	**0.00**	**0.31**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 4 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 6-9
Geometric Mean Concentrations for the Most Prevalent Carbonyls in the Burlington Area during the 1997 UATMP

Compound	Geometric Mean Concentration (ppbv), by Monitoring Station		
	BUVT	UNVT	WIVT
Acetaldehyde	1.06	0.70	0.65
Acetone	0.92	1.03	1.15
Acrolein	0.04	0.02	0.01
Benzaldehyde	0.06	0.01	0.04
Butyr/Isobutyraldehyde	0.13	0.09	0.08
Formaldehyde	3.32	2.08	1.26
Hexanaldehyde	0.03	0.03	0.04
Propionaldehyde	0.13	0.08	0.07
Tolualdehydes	0.04	0.02	0.01
Valeraldehyde	0.03	0.02	0.01

Note: Because the WIVT monitoring station collected air samples for only 4 months, summary statistics for this station may not represent actual annual averages.

Table 6-10
Selected Pearson Correlation Coefficients for Methyl *tert*-Butyl Ether and Benzene at the BUVT Monitoring Station

Compound	Pearson Correlation Coefficient with . . .	
	. . . Methyl *Tert*-Butyl Ether	. . . Benzene
Acetylene	-0.27	0.94
Benzene	-0.17	1.00
1,3-Butadiene	-0.23	0.87
Ethylbenzene	0.05	0.94
Methyl *tert*-Butyl Ether	1.00	-0.17
Propylene	-0.07	0.96
Toluene	0.11	0.86
m,*p*-Xylene	-0.02	0.97
o-Xylene	0.08	0.92

Note: Pearson correlation coefficients closer to 1 indicate pairs of compounds with highly correlated ambient air monitoring data. Pearson correlation coefficients closer to 0 indicate pairs of compounds with essentially uncorrelated data. The 1996 UATMP final report and most basic statistics references describe the significance of Pearson correlation coefficients in greater detail.

7.0 Monitoring Results for Camden, NJ (CANJ)

This section summarizes and interprets ambient air monitoring data collected at the Camden, New Jersey (CANJ), monitoring station during the 1997 and previous UATMPs. The map in Figure 7-1 illustrates land use in the immediate vicinity of the monitoring station. Though the monitors are located in a primarily residential area, many industrial facilities and heavily traveled roadways are located within 10 miles of the monitoring station, and nearly 2,000,000 residents live within this radius. Previous UATMP reports have attributed levels of air pollution measured at CANJ to emissions from both nearby industrial sources and motor vehicle sources throughout the Camden–Philadelphia metropolitan area. During the 1997 UATMP, 31 sampling events were attempted at CANJ. Valid VOC samples were collected on 31 days, and valid carbonyl samples were collected on 30 days. Otherwise stated, the completeness of the VOC and carbonyl sampling at CANJ was 100 percent and 97 percent, respectively.

The remainder of this section summarizes the 1997 UATMP monitoring data for CANJ (Section 7.1), analyzes in detail ambient air concentrations of selected nitriles and oxygenated compounds (Section 7.2), and examines how concentrations of certain compounds have changed since the 1994 UATMP (Section 7.3). The section concludes with a brief summary of the air monitoring data from CANJ (Section 7.4).

7.1 Data Summary Parameters for the 1997 UATMP

Using the data summary parameters defined in Section 3.1, Tables 7-1 and 7-2 summarize the VOC and carbonyl monitoring data, respectively, collected at Camden, New Jersey, during the 1997 program. To facilitate comparisons between monitoring data from different UATMPs, the format used in Tables 7-1 and 7-2 is identical to that used in earlier reports.

7.1.1 Data Summary of VOC

Table 7-1 reveals the following notable trends regarding ambient air concentrations of VOC at Camden, New Jersey:

- *Prevalence.* According to Table 7-1, only 19 of the 47 compounds that the VOC analytical method can identify were detected in more than half of the samples collected at CANJ. Due to their high prevalence, summary statistics for these compounds are least affected by nondetect observations. Accordingly, most of the analyses in this section focuses on these most prevalent compounds:

  Acetylene
  Benzene
  1,3-Butadiene
  Carbon tetrachloride
  Chloromethane
  Ethylbenzene
  Methylene chloride
  Methyl ethyl ketone
  Methyl *tert*-butyl ether
  n-Octane
  Propylene
  Styrene
  tert-Amyl methyl ether
  Tetrachloroethylene
  Toluene
  1,1,1-Trichloroethane
  m,p-Xylene
  o-Xylene

  As Section 7.2 describes in greater detail, the prevalence of *tert*-amyl methyl ether at CANJ (58 percent) was notably higher than the prevalence at any other UATMP monitoring station (all other stations have a prevalence of 17 percent or less).

  Despite the emphasis this section places on these 19 most prevalent compounds, it should not be inferred that the other compounds are not present in ambient air at CANJ. Rather, the least prevalent compounds may be in the air at this monitoring station, but consistently at levels that the VOC analytical method cannot measure. Therefore, statistically meaningful air quality trends for these compounds cannot be calculated due to the large number of nondetect observations.

- *Concentration Range.* The data summary tables also provide information on the range of ambient air concentrations measured at Camden. Of the 47 VOC, only acetylene and propylene had 24-hour average concentrations greater than 5.0 ppbv, and 11 other compounds (acetonitrile, acrylonitrile, benzene, chloromethane, methylene chloride, methyl ethyl ketone, methyl *tert*-butyl ether, *tert*-amyl methyl ether, toluene, and *m,p*-xylene) had at least one 24-hour average concentration greater than 1.0 ppbv. Because ambient air samples were collected on a biweekly schedule, however, it is very likely that ambient air concentrations may have risen to higher levels on days when samples were not collected. As a result, the concentration ranges in Table 7-1 are only estimates of the actual span of ambient air concentrations at CANJ.

- *Central Tendency.* In Table 7-1, only those compounds shown in boldface were detected in more than 50 percent of the VOC samples. Central tendency values for all other compounds should be interpreted with caution, since the higher frequency of nondetects for these compounds probably biased their central tendency calculation. Of the 19 most prevalent compounds, only three—acetylene, propylene, and toluene—had geometric mean concentrations greater than 1.0 ppbv.

Figure 3-1, which compares ambient air concentrations of VOC at CANJ to those at the other UATMP monitoring stations, indicates that geometric mean concentrations of most VOC at Camden were not unusually higher or lower than those at other monitoring stations. In the case of methyl *tert*-butyl ether, however, the geometric mean concentration at CANJ (0.76 ppbv) was at least three times higher than the geometric mean concentrations at every other UATMP monitoring station. Section 7.2 revisits this issue.

Note: When interpreting the graphs in Figure 3-1, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within these areas. Even though ambient air concentrations of methyl *tert*-butyl ether at CANJ were higher than those at other UATMP monitors, it does not necessarily follow that concentrations throughout Camden rank among the highest in the United States.

- *Variability.* With two exceptions, the coefficients of variation for the most prevalent compounds were less than 1.0—a similarity that suggests ambient air concentrations of these compounds have comparable variability. As the exceptions, the coefficients of variation for methylene chloride and *tert*-amyl methyl ether were 2.24 and 1.64, respectively. The relatively high variability for these compounds suggests that the magnitude of their concentrations changes much more significantly from one sampling date to the next than do the concentrations of other VOC. This observation is consistent with the assumption that methylene chloride and *tert*-amyl methyl ether originated from sources found at discrete locations (e.g., industrial emissions sources), and not from sources found throughout urban areas (e.g., motor vehicle sources). Sections 7.2 and 7.3 examine in greater detail air quality trends for *tert*-amyl methyl ether and methylene chloride, respectively.

To elaborate on trends and patterns among the VOC monitoring data, Section 7.2 interprets the 1997 UATMP monitoring data for nitriles and oxygenated compounds, and Section 7.3 evaluates how average concentrations of selected compounds have changed at CANJ since the 1994 UATMP.

7.1.2 Data Summary of Carbonyls

Table 7-2 reveals the following notable trends regarding ambient air concentrations of carbonyls at Camden, New Jersey:

- *Prevalence.* The prevalence data in Table 7-2 show that all but two of the carbonyl compounds (crotonaldehyde and 2,5-dimethylbenzaldehyde) were detected in at least half of the samples collected at CANJ. Thus, summary statistics for most of the carbonyls are expected to represent actual air quality trends in the Camden area.

- *Concentration Range.* During the entire 1997 program, acetaldehyde, acetone, and formaldehyde were the only carbonyls that were detected at CANJ at levels higher than 1.0 ppbv. The highest concentration for formaldehyde (15.99 ppbv) was higher than the peak concentration for all other compounds, including VOC. As noted earlier, the concentration ranges shown in Table 7-2 should be viewed as estimates of the actual ranges, because concentrations may have reached higher and lower levels on nonsampling days.

- *Central Tendency.* According to Table 7-1, geometric mean concentrations of the most prevalent carbonyls at CANJ ranged from 0.01 ppbv (for isovaleraldehyde) to 3.02 ppbv (for formaldehyde). Further, the central tendency data indicate that geometric mean concentrations of three compounds—acetaldehyde, acetone, and formaldehyde—account for over 90 percent of the total concentration of carbonyls detected in the air samples, despite the fact that 14 different carbonyls were consistently detected in the air at CANJ.

  To illustrate how carbonyl concentrations in Camden compare to those in other urban locations, Figure 3-2 shows that geometric mean concentrations of carbonyls in Camden were on the same order of magnitude as those measured at the other UATMP stations. Figure 3-2 indicates that concentrations of acetone and butyr/isobutyraldehyde were higher at CANJ than at any other UATMP monitoring location, but only marginally so. The absence of significant spatial variations in levels of carbonyls implies that they may originate from an emissions source, or a group of emissions sources, common to urban environments. Alternately, they may form in ambient air by the same mechanisms at different urban locations. Section 12.1 discusses these hypotheses further.

  Note: As mentioned earlier, when interpreting the graphs in Figure 3-2, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban centers in the United States and only at discrete locations within selected cities.

- *Variability.* As Table 7-2 shows, coefficients of variation for most of the prevalent carbonyls were lower than 1.0. The relatively low coefficients of variation suggest that these carbonyls are consistently found in ambient air, regardless of changing wind directions. This trend is consistent with the assumption that carbonyls originated from many different emissions sources or were the product of photochemical reactions. As exceptions, coefficients of variation for acrolein (1.56) and isovaleraldehyde (1.94) were higher than 1.0. It is unclear whether emissions from industrial sources might explain the greater variability for these compounds, because no industrial facilities in the vicinity of the CANJ monitoring station reported releases of acrolein to TRI in 1995 and because the current TRI reporting requirements do not require facilities to disclose information on their releases of isovaleraldehyde.

For further information on air quality trends for selected carbonyls, readers should refer to Section 7.3 for a review of annual variations in ambient air concentrations at CANJ and to Section 12.1 for a general overview of carbonyl monitoring data collected at all 12 monitoring stations that participated in the 1997 UATMP.

7.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

As Section 2.2.1 described, the VOC analytical method used in the 1997 UATMP was capable of detecting nine compounds (all nitriles and oxygenated compounds) that could not be detected during earlier UATMPs. Detailed analyses of the ambient air monitoring data for these compounds follow:

- *Compounds that were rarely, if ever, detected.* Of the nine nitriles and oxygenated compounds measured during the 1997 UATMP, five—acetonitrile, ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, and methyl methacrylate—were detected in no more than 1 of the 31 valid VOC sampling events at CANJ. Not only were these compounds rarely detected in the ambient air at Camden, Table 7-3 shows that very few industrial facilities in this area reported air releases of these compounds to TRI. Thus, few conclusions can be drawn for this subset of nitriles and oxygenated compounds, except that they consistently are not found at detectable levels in ambient air near the CANJ monitoring station.

- *Acrylonitrile.* As Table 7-1 shows, acrylonitrile was detected in 8 of the 31 samples collected at CANJ. Not shown in the table is the fact that the detections only occurred during the months of January, February, June, July, and August. No other compounds identified at Camden exhibited similar monthly variations in their concentrations or their prevalence. With no major sources of acrylonitrile located within 10 miles of the CANJ monitoring station, the primary source (or sources) of the acrylonitrile detected at this site during the 1997 UATMP is not known.

- *Methyl ethyl ketone.* According to Table 7-1, methyl ethyl ketone was detected in 30 of the 31 ambient air samples collected at CANJ during the 1997 UATMP. On average, the ambient air concentrations of methyl ethyl ketone during June, July, and August were more than twice as high as those during all other months of the year. The relatively higher concentrations during the warmer summer months may result from greater evaporative losses of methyl ethyl ketone from industrial sources or possibly from seasonal changes in photochemical reactivity or prevailing wind patterns. Analysis of additional monitoring data is needed (1) to confirm that the seasonal trend is not anomalous and (2) to conclude that industrial emissions best account for the observed seasonal variations.

  Though motor vehicles emit methyl ethyl ketone to the air, data correlations among the ambient air monitoring data suggest that mobile sources may not be the primary source of this compound at the CANJ monitoring station. More specifically, ambient air concentrations of methyl ethyl ketone at CANJ were found to be weakly correlated, if not completely uncorrelated, with concentrations of compounds typically found in motor vehicle exhaust (e.g., benzene, ethylbenzene, toluene, and the xylene isomers). The emissions data in Table 7-3 support the hypothesis that releases from industrial sources may account for some fraction of the levels of methyl ethyl ketone observed at CANJ. According to the table, eight facilities within 10 miles of the CANJ monitors reportedly emitted a total of 27,160 pounds of methyl ethyl ketone to the air during 1995. Of these facilities, the closest to the Camden monitoring station is located approximately 1 mile away and reported emitting 2,100 pounds of methyl ethyl ketone during 1995. Despite the proximity of this source to the monitoring station, it is important to note that the combined emissions from many industrial sources—including those not required to report to TRI—probably best explain the concentrations of methyl ethyl ketone detected at CANJ.

- *Methyl tert-butyl ether*. As Table 7-1 shows, methyl *tert*-butyl ether was detected by the Camden monitors on 29 of the 31 sampling dates during the 1997 UATMP. Of the 47 VOC measured at CANJ, the geometric mean concentration of methyl *tert*-butyl ether (0.76 ppbv) ranked fourth highest, behind acetylene (1.89 ppbv), propylene (1.14 ppbv), and toluene (1.09 ppbv). As Section 7.1.1 noted, the geometric mean concentration of methyl *tert*-butyl ether at CANJ was at least three times higher than the geometric mean concentrations of this compound at every other UATMP monitoring station. Although the highest levels of methyl *tert*-butyl ether were observed in July and September, seasonal average concentrations of the compound were no more than 40 percent greater or less than the annual average concentration. Otherwise stated, ambient air concentrations of methyl *tert*-butyl ether did not vary dramatically from one season to the next.

As Section 3.2 explained, ambient air quality trends for methyl *tert*-butyl ether are expected to be influenced by requirements that motor vehicles in selected metropolitan areas use reformulated fuels. Recent studies have reported that, as of January 1, 1995, EPA required all motor vehicle fuels sold in Philadelphia and Camden to be reformulated gasoline (Main et al., 1998). Though the composition of reformulated gasoline varies among urban centers, reformulated gasolines in the Philadelphia–Camden area contain approximately 11 percent methyl *tert*-butyl ether (Main et al., 1998). As a result, motor vehicle emissions in this area are expected to contain this compound, along with many other pollutants typically found in car exhaust.

In support of this hypothesis, ambient air concentrations of methyl *tert*-butyl ether were found to be much more strongly correlated with concentrations of benzene, toluene, ethylbenzene, and xylene isomers (i.e., compounds known to be found in motor vehicle exhaust) than with concentrations of any other compound. To illustrate this correlation, Figure 7-2 compares concentrations of benzene and toluene to concentrations of methyl *tert*-butyl ether. Though the correlation between methyl *tert*-butyl ether and the other compounds is certainly not perfect[1], the figure indicates that concentrations of methyl *tert*-butyl ether were generally higher when concentrations of benzene and toluene were higher, and vice versa. These correlations strongly suggest that emissions from motor vehicles probably account for a large portion of the methyl *tert*-butyl ether measured at CANJ.

For purposes of comparison, Figure 7-2 also shows how concentrations of ethylbenzene and toluene varied during the monitoring program. Though it does not show correlations between all possible pairings of compounds, Figure 7-2 indicates that correlations between methyl *tert*-butyl ether and selected aromatic hydrocarbons are not as strong as correlations between pairs of aromatic hydrocarbons. The correlations for methyl *tert*-butyl ether may be relatively weak because there are other sources of this compound in the CANJ area. As Table 7-3 shows, two industrial facilities within 10 miles of the CANJ monitoring station reported emitting a total of 127,583 pounds of methyl *tert*-butyl ether to the air in 1995. Though neither of these facilities is located within 1 mile of the CANJ

---

[1] The Pearson correlation coefficient between concentrations of methyl-*tert*-butyl ether and concentrations of benzene was 0.73; between concentrations of methyl *tert*-butyl ether and concentrations of toluene, it was 0.76; between concentrations of benzene and toluene, it was 0.90.

monitors, their emissions may explain why levels of methyl *tert*-butyl ether are not as strongly correlated with levels of aromatic hydrocarbons as might be expected. Another explanation for the relatively weaker correlations is that some motor vehicles traveling in the Camden–Philadelphia area may run on fuels purchased in areas where reformulated fuels are not required. Emissions from other facilities that handle reformulated gasoline (e.g., gasoline stations, car dealers) undoubtedly also contributed to the concentrations of methyl *tert*-butyl ether observed at CANJ.

- *tert-Amyl methyl ether.* As Section 7.1.1 noted, *tert*-amyl methyl ether was detected in 58 percent of the samples collected at Camden—a higher prevalence than that for *tert*-amyl methyl ether at all other UATMP monitoring stations. However, the detections were not clustered in any particular season. Correlations between concentrations of *tert*-amyl methyl ether and the compounds typically found in motor vehicle exhaust were notably weaker than those illustrated in Figure 7-2 for methyl *tert*-butyl ether. Although this observation might suggest that industrial sources (as opposed to motor vehicle sources) contribute more significantly to the observed concentrations of *tert*-amyl methyl ether, it is difficult to make such a conclusion because facilities are not required to report releases of this compound to TRI. With no industrial emissions data readily available, further research is needed to determine which factors influence ambient air concentrations of *tert*-amyl methyl ether at CANJ most significantly.

7.3 Annual Variations

The CANJ monitoring station has participated in the UATMP throughout this procurement. Thus, ambient air monitoring data are available for the 1994, 1995, 1996, and 1997 UATMPs. Though the station collected samples during previous procurements, the corresponding monitoring data are not presented here, because important features of the monitoring program (e.g., measurement precision, detection limits) likely changed. The following discussion evaluates annual variations for the most prevalent VOC (Section 7.3.1) and carbonyls (Section 7.3.2). Due to the uncertainty associated with many nondetect observations, annual variations for the least prevalent compounds are not considered.

When reading the following discussion, it is important to note that statistically significant changes from one year to the next can occur for many different reasons, including decreases in emissions and annual changes in meteorological conditions. Note that the UATMP program year does not correspond with the calendar year. The UATMP program year generally begins in September and ends in August of the following calendar year. Therefore, a significant portion of the data collected in a given UATMP program year actually represents air quality from the following calendar year.

7.3.1 Annual Variations for VOC

Figure 7-3 shows how concentrations of the 15 most prevalent VOC changed from the 1994 to the 1997 UATMP. With one exception, average ambient air concentrations of these compounds either did not change significantly or gradually decreased over this time span. As the exception, average levels of *n*-octane during the 1997 UATMP were nearly twice as high as those observed during earlier programs. More detailed analyses of the annual variations for different groups of compounds follow:

- *BTEX compounds.* As indicated in Figure 7-3, annual variations for benzene, toluene, ethylbenzene, and the xylene isomers exhibit two similar trends. First, for every BTEX compound except benzene, average concentrations during the 1994 UATMP were roughly 30 percent higher than concentrations during the 1995, 1996, and 1997 programs. (Note, however, the confidence intervals for these compounds overlap for the 1994 and 1995 programs.) Second, for every BTEX compound, average concentrations during the 1995, 1996, and 1997 programs did not exhibit statistically significant changes. The absence of notable annual variations probably results from the fact that fuels used by motor vehicles in the Philadelphia–Camden area have not changed significantly over much of this time frame. Because EPA implemented its reformulated gasoline requirements during the 1994 UATMP, analyses of annual variations over longer time frames might illustrate better how use of reformulated gasoline has affected air quality at CANJ.

- *Halogenated hydrocarbons.* Of the 15 most prevalent VOC, 5 are halogenated hydrocarbons. Previous UATMP reports have shown that factors other than motor vehicle emissions (e.g., industrial emissions and natural sources) affect ambient air concentrations of this group of compounds most significantly. As Figure 7-3 shows, average concentrations for three of these compounds—carbon tetrachloride, chloromethane, and tetrachloroethylene—were virtually identical at CANJ from one year to the next, suggesting that the factors contributing most significantly to their ambient air concentrations have also changed little during this time. Though average concentrations of methylene chloride decreased by nearly a factor of three from program year 1994 to 1997, the 95-percent upper confidence intervals of the average concentrations in 1994 and 1995 are too broad to verify that these annual variations are statistically significant. For 1,1,1-trichloroethane, however, statistically significant decreases in ambient air concentrations were observed from program year 1994 to 1995 and from program year 1995 to 1996. In both cases, the average concentration of 1,1,1-trichloroethane decreased by nearly a factor of two. Though the exact reason or reasons for this decline is not known, it is worth noting that average concentrations of 1,1,1-trichloroethane exhibited similar declines at many other UATMP monitoring stations. Section 12.1 revisits this issue.

- *Other compounds.* Of the five remaining prevalent VOC, the annual variations for two—1,3-butadiene and propylene—are quite similar to those for the BTEX compounds: annual average concentrations decreased by approximately 30 percent from the 1994 UATMP to the 1995 UATMP, and average concentrations thereafter have changed little. The similarity between annual profiles for 1,3-butadiene, propylene, and the BTEX compounds provides evidence that all of these compounds may, to a certain extent, originate from the same types of sources near CANJ, most likely motor vehicles.

  Like 1,3-butadiene, propylene, and the BTEX compounds, average concentrations of acetylene decreased by approximately 30 percent from the 1994 UATMP to the 1995 program. Unlike the other compounds, however, concentrations of acetylene continued to decrease through the 1996 and 1997 programs. In fact, the average concentration of acetylene at CANJ observed during the 1997 UATMP is nearly three times lower than that observed during the 1994 program. The reason for the relatively greater decrease in concentrations of acetylene at CANJ is not known.

  The remaining two compounds, *n*-octane and styrene, exhibited unique annual variations at CANJ. As noted earlier, *n*-octane was the only VOC frequently detected at Camden that had notably higher concentrations during the 1997 UATMP than during earlier programs. More specifically, the average concentration during the current program was almost exactly twice as high as that during the 1996 program. The reason for this increase, which appears to be statistically significant, is not known. On the other hand, average concentrations of styrene have gradually declined from the 1994 program (0.17 ppbv) to the 1997 program (0.09 ppbv). Since previous UATMP reports have provided evidence that industrial emissions sources probably account for much of the styrene found in urban ambient air, the decreasing concentrations of styrene at CANJ may result from decreasing emissions from industrial sources over the same time frame. This trend is difficult to confirm because TRI emissions data on compact disk are not yet available for reporting year 1996, and the data are not available at all for reporting years 1997 and 1998. (The TRI public data release on compact disk is most useful for conducting detailed queries of industrial emissions data.)

7.3.2 Annual Variations for Carbonyls

Figure 7-4 shows how concentrations of the 14 most prevalent carbonyls have changed since the 1994 UATMP. Unlike concentrations of the VOC, which generally either decreased or stayed the same, ambient air concentrations of carbonyls tended to either increase or stay the same. The following discussion highlights the concentration trends observed for carbonyls:

- *Compounds with no significant annual trends.* For nine carbonyls (acetaldehyde, acetone, benzaldehyde, formaldehyde, isovaleraldehyde, propionaldehyde, and tolualdehydes), annual average concentrations may have differed from one UATMP program year to the next, but the average levels for the 1997 program did not appear to be statistically different from those for the 1994 program. Therefore, the factors that affect ambient air concentrations of these compounds at CANJ probably have not changed over the long term, though they may have varied from year to year. Because annual variations for these nine compounds do not exhibit the same downward trend that was observed for the hydrocarbons typically found in motor vehicle exhaust, it is unlikely that motor vehicles are the primary source of these compounds in the Camden air. (Note: It is quite possible that motor vehicle emissions may have an indirect affect on ambient air concentrations of carbonyls, since these emissions play an important role in photochemical reactions in urban smog.)

- *Compounds with statistically significant trends.* For the remaining five carbonyls (acrolein, butyr/isobutyraldehyde, hexanaldehyde, and valeraldehyde), average ambient air concentrations during the 1997 UATMP were roughly twice as high as those during the 1994 program. In all cases, the change over this 4-year period appeared to be statistically significant, but ambient air concentrations of all four compounds did not steadily increase over this time frame. Nonetheless, the increases in concentrations for these compounds, while concentrations of most VOC steadily decreased, support the hypothesis raised in previous UATMP reports that the mechanisms that most strongly affect ambient air concentrations of VOC and carbonyls in urban areas are different.

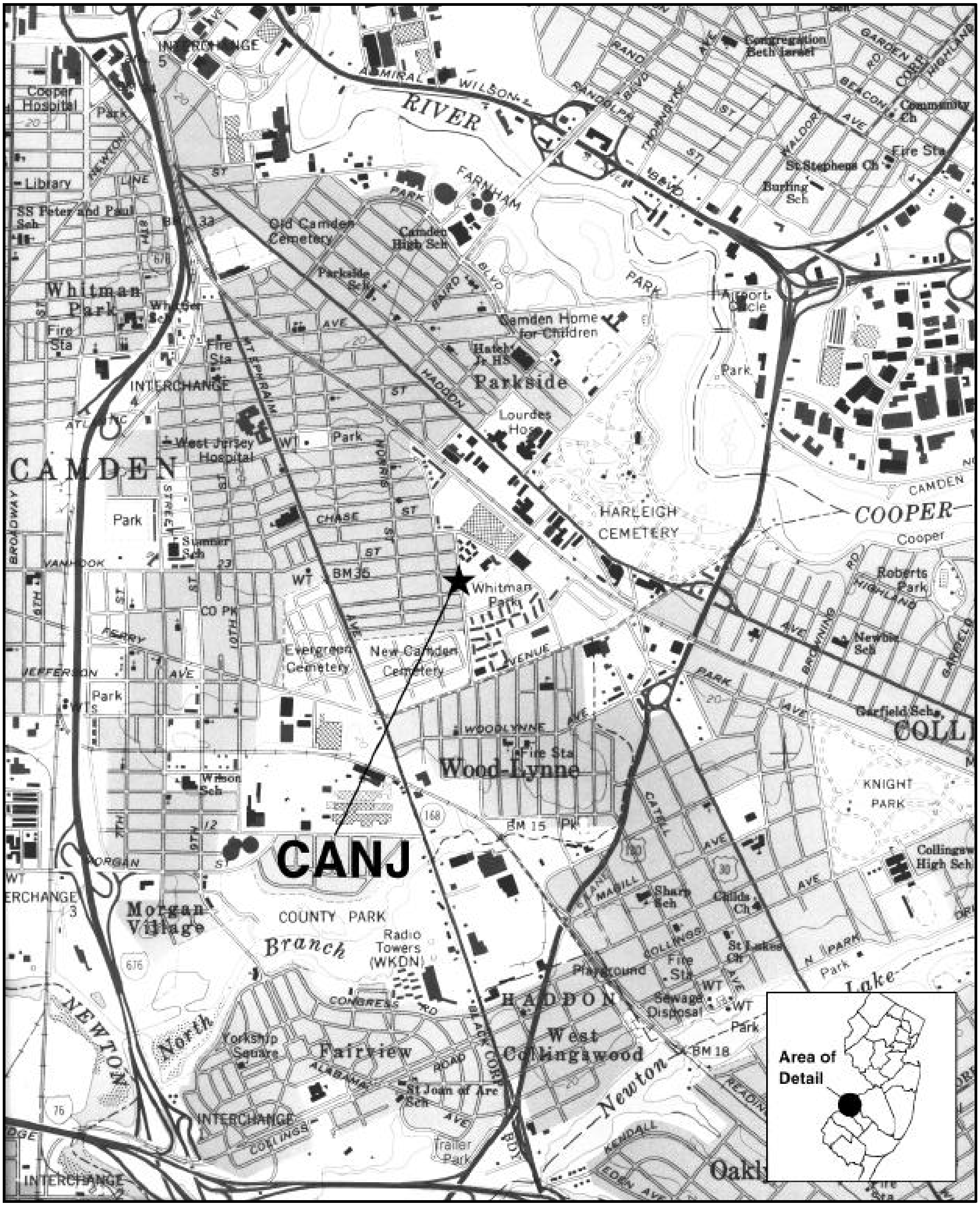
7.4 Summary

During the 1997 UATMP, ambient air concentrations of VOC and carbonyls at CANJ exhibited many trends consistent with previous UATMP monitoring efforts. For example, 15 VOC and 14 carbonyls were detected in over half of the samples. Of these, ambient air concentrations of acetaldehyde, acetone, acetylene, formaldehyde, propylene, and toluene were consistently higher than those of other compounds.

The 1997 UATMP marked the first year in which air samples were analyzed for concentrations of nine nitriles and oxygenated compounds. Of these, only methyl ethyl ketone, methyl *tert*-butyl ether, and *tert*-amyl methyl ether were detected in over half of the samples collected in Camden. The analyses in this section suggest that emissions from industrial sources primarily account for ambient levels of methyl ethyl ketone at CANJ. Though there are significant industrial emissions sources of methyl *tert*-butyl ether in the Philadelphia–Camden area, ambient air concentrations of this compound at CANJ appear to be linked to motor vehicle emissions. Not enough information is available to comment on the sources expected to account for airborne *tert*-amyl methyl ether at CANJ.

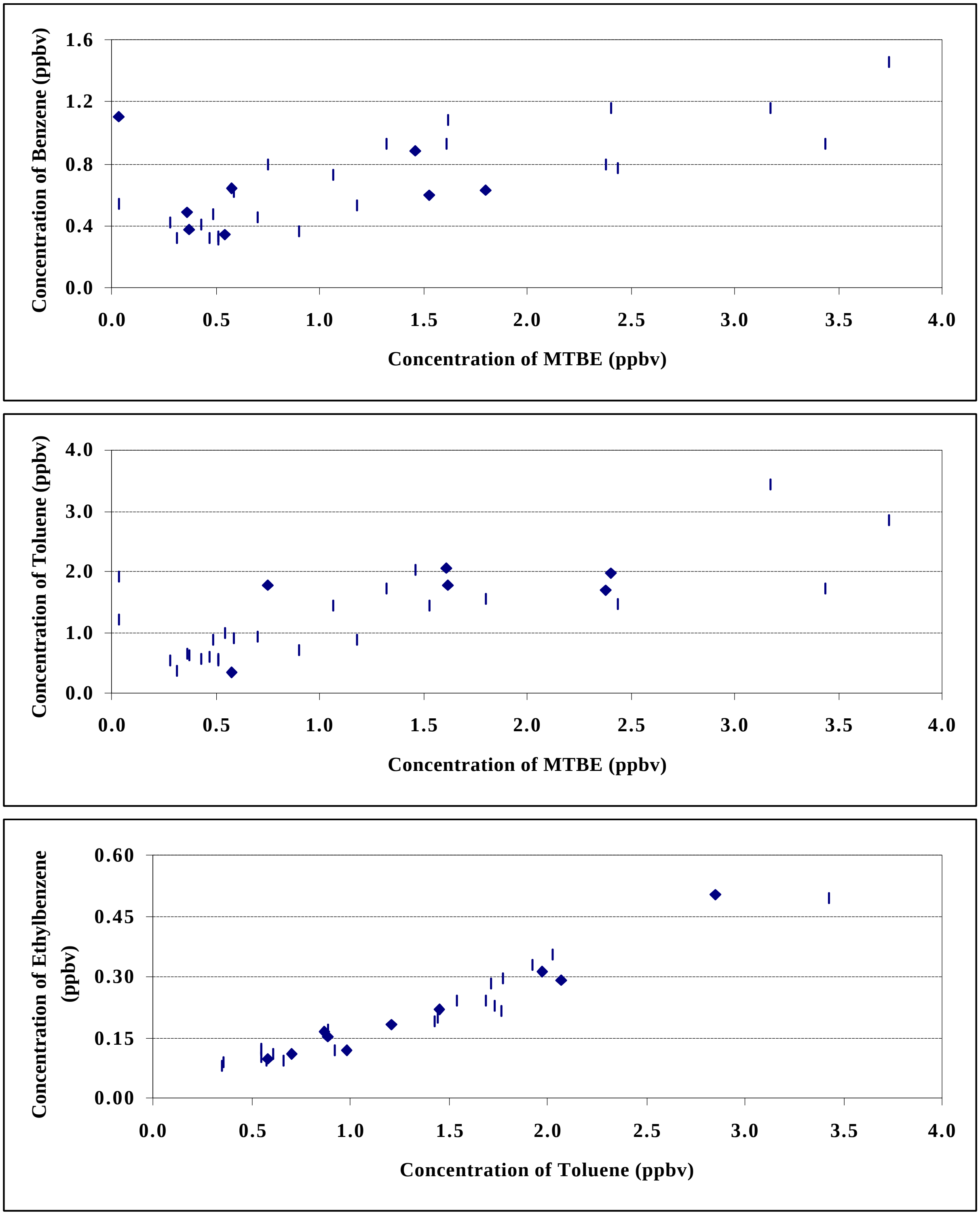
With few exceptions, average ambient air concentrations of the 15 most prevalent VOC at CANJ either decreased or stayed the same from 1994 to 1997, while levels of the most prevalent carbonyls either rose or stayed the same. The different trends for these groups of compounds suggests that the factors that influence concentrations of VOC in the air at Camden probably differ from those that influence concentrations of carbonyls.

Figure 7-1
Camden, New Jersey (CANJ), Monitoring Station



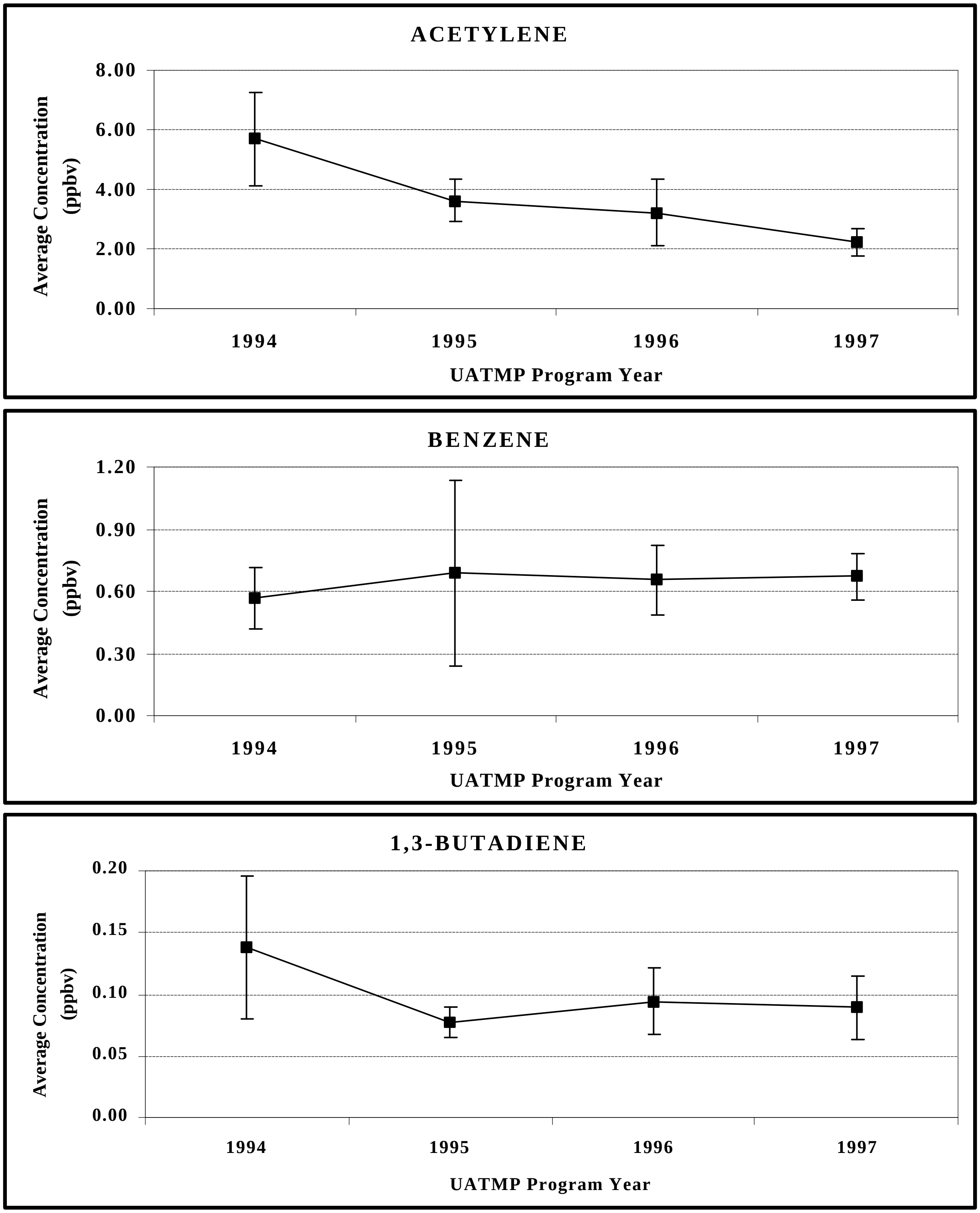
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 7-2
Data Correlations for Ambient Air Concentrations of Selected Compounds



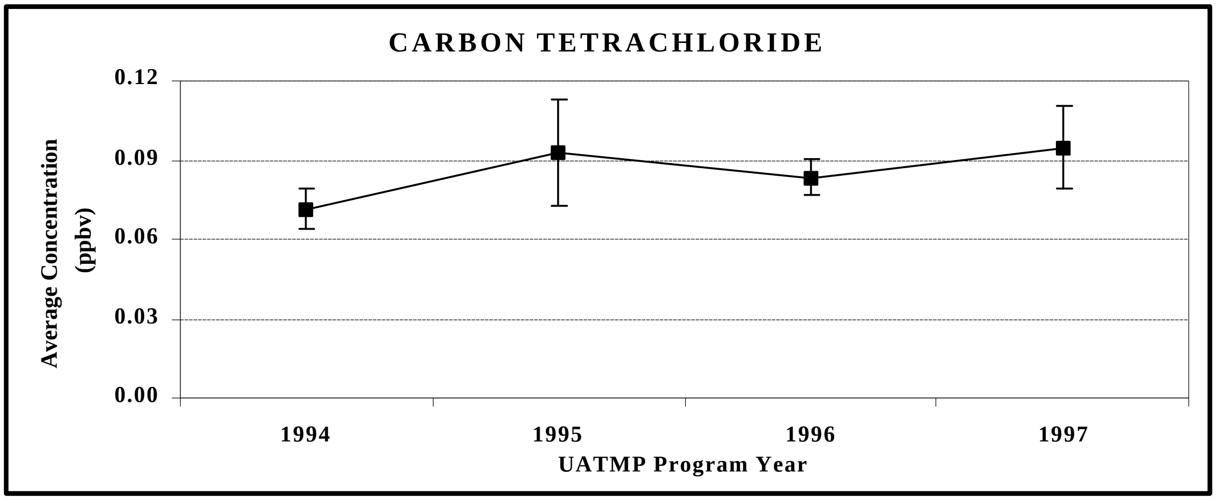
Note: Refer to Section 7.2 for interpretations of these plots.

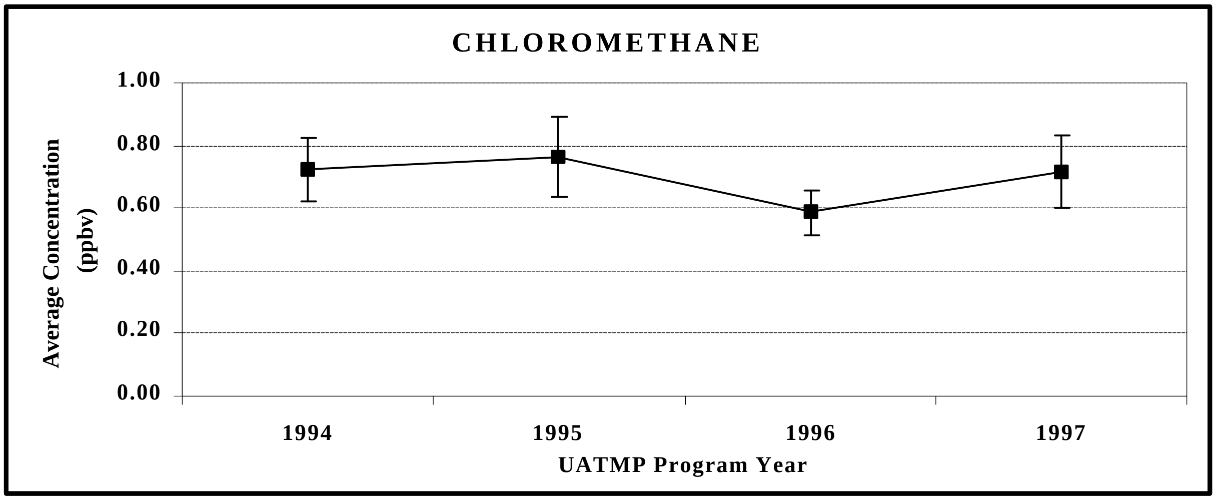
Figure 7-3 (Page 1 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at CANJ

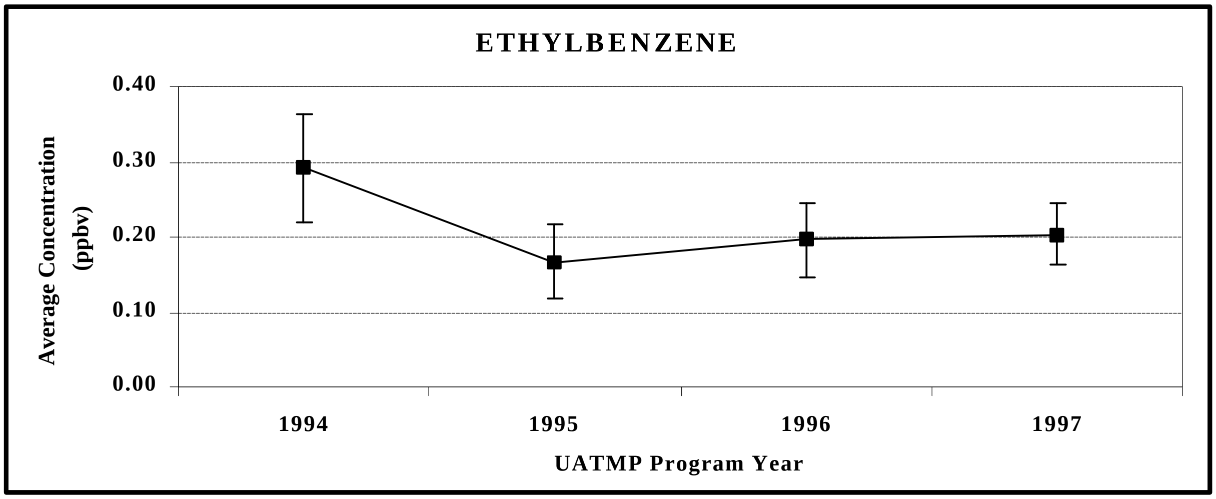


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 7-3 (Page 2 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at CANJ

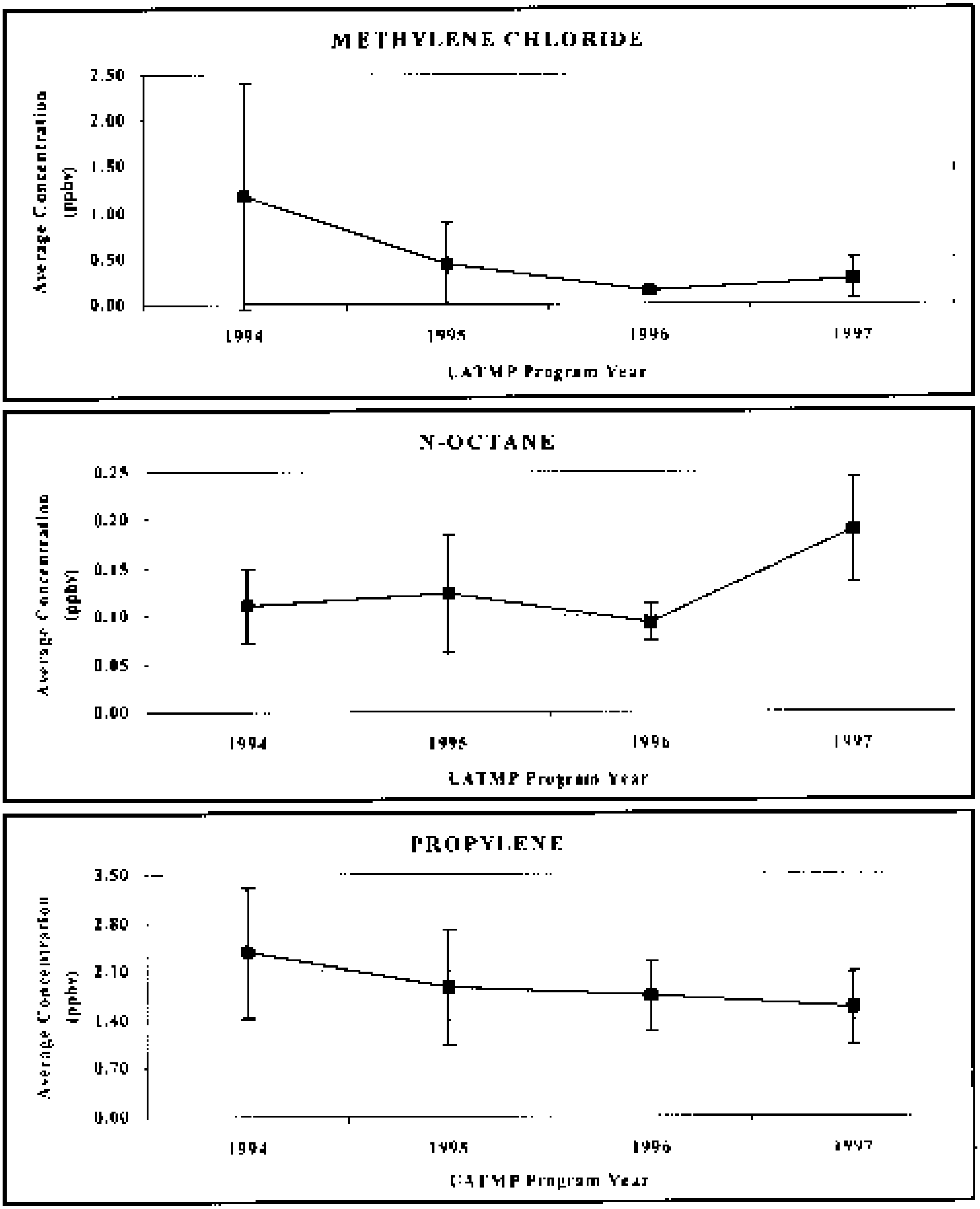






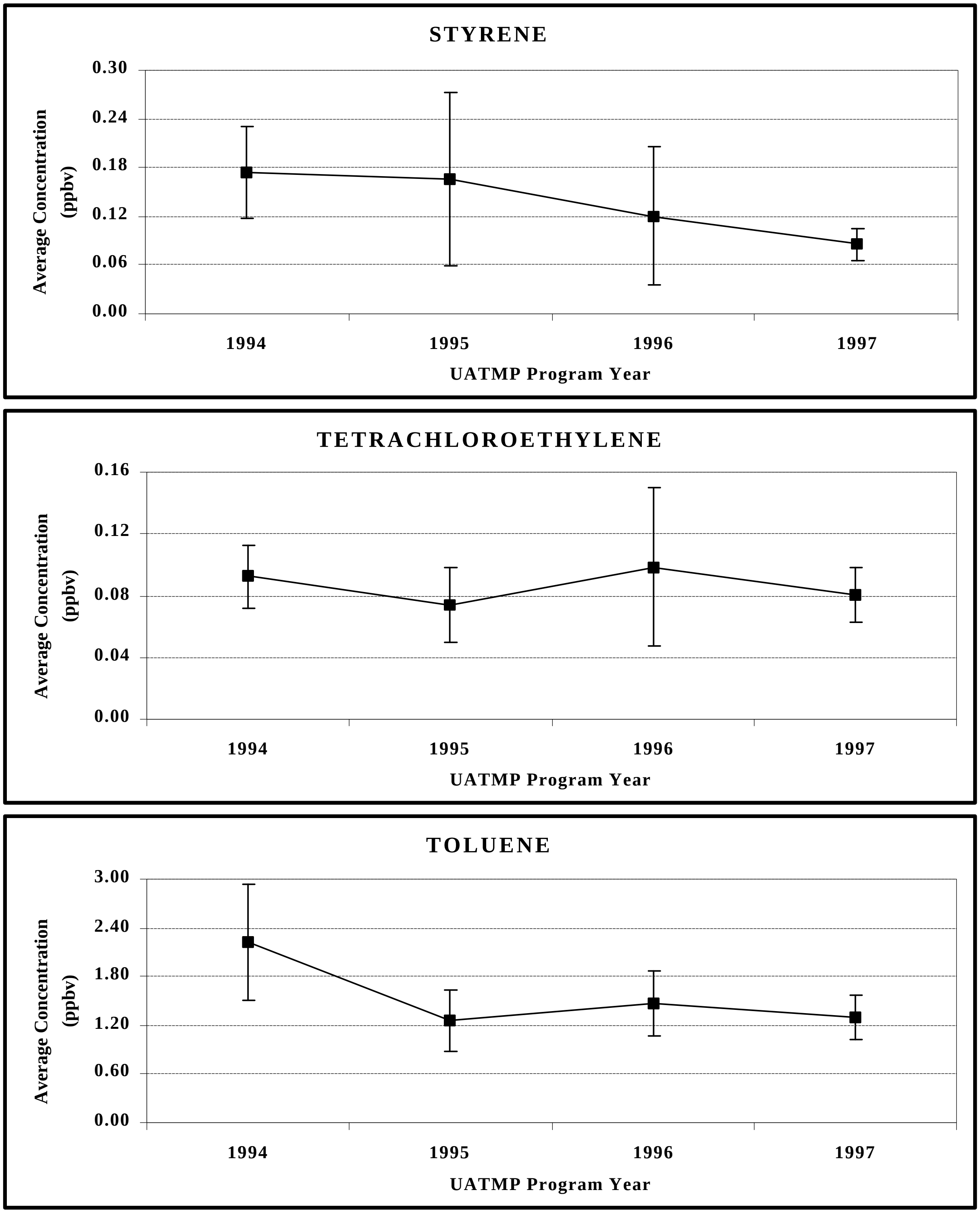
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 7-3 (Page 3 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at CANJ



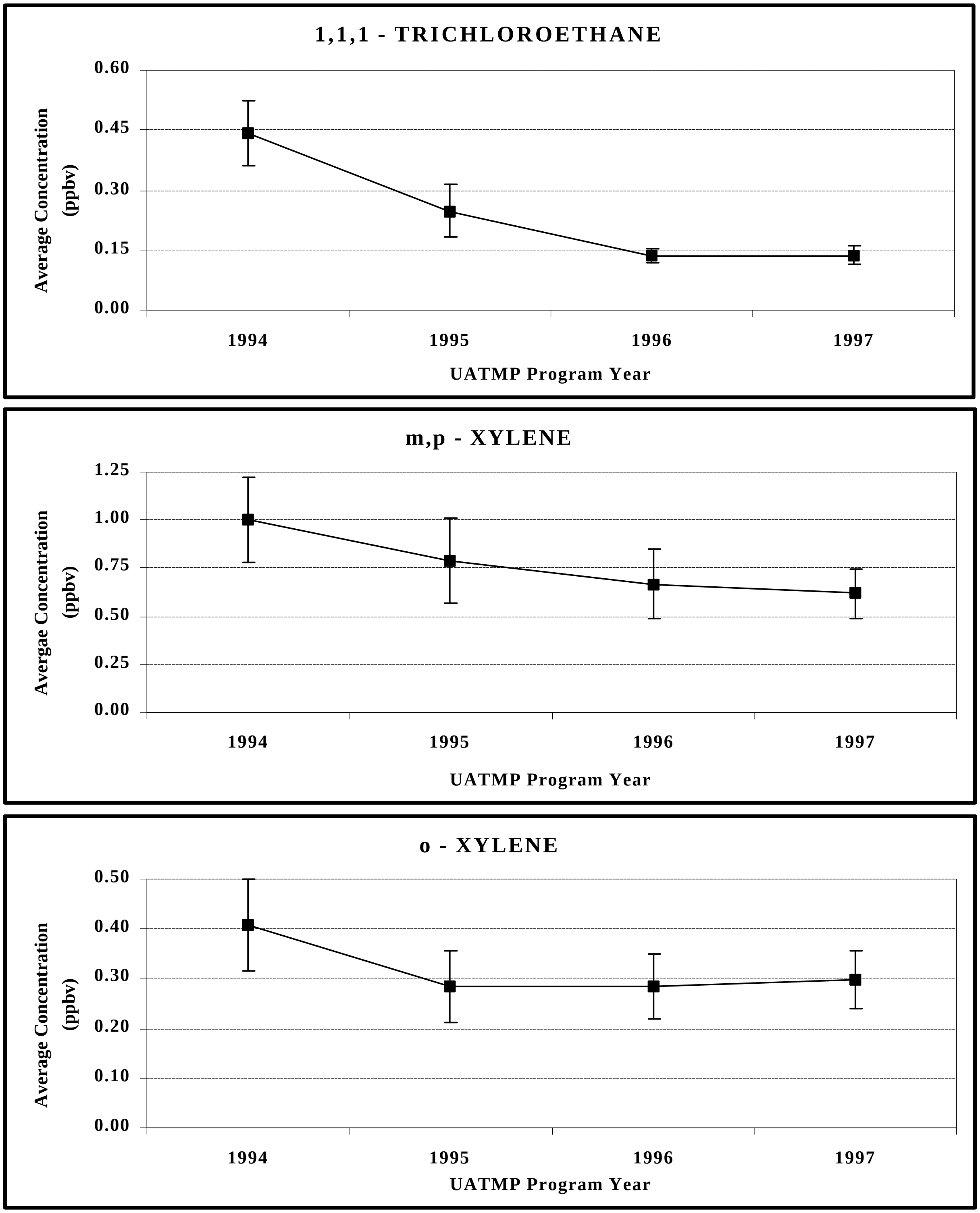
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 7-3 (Page 4 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at CANJ



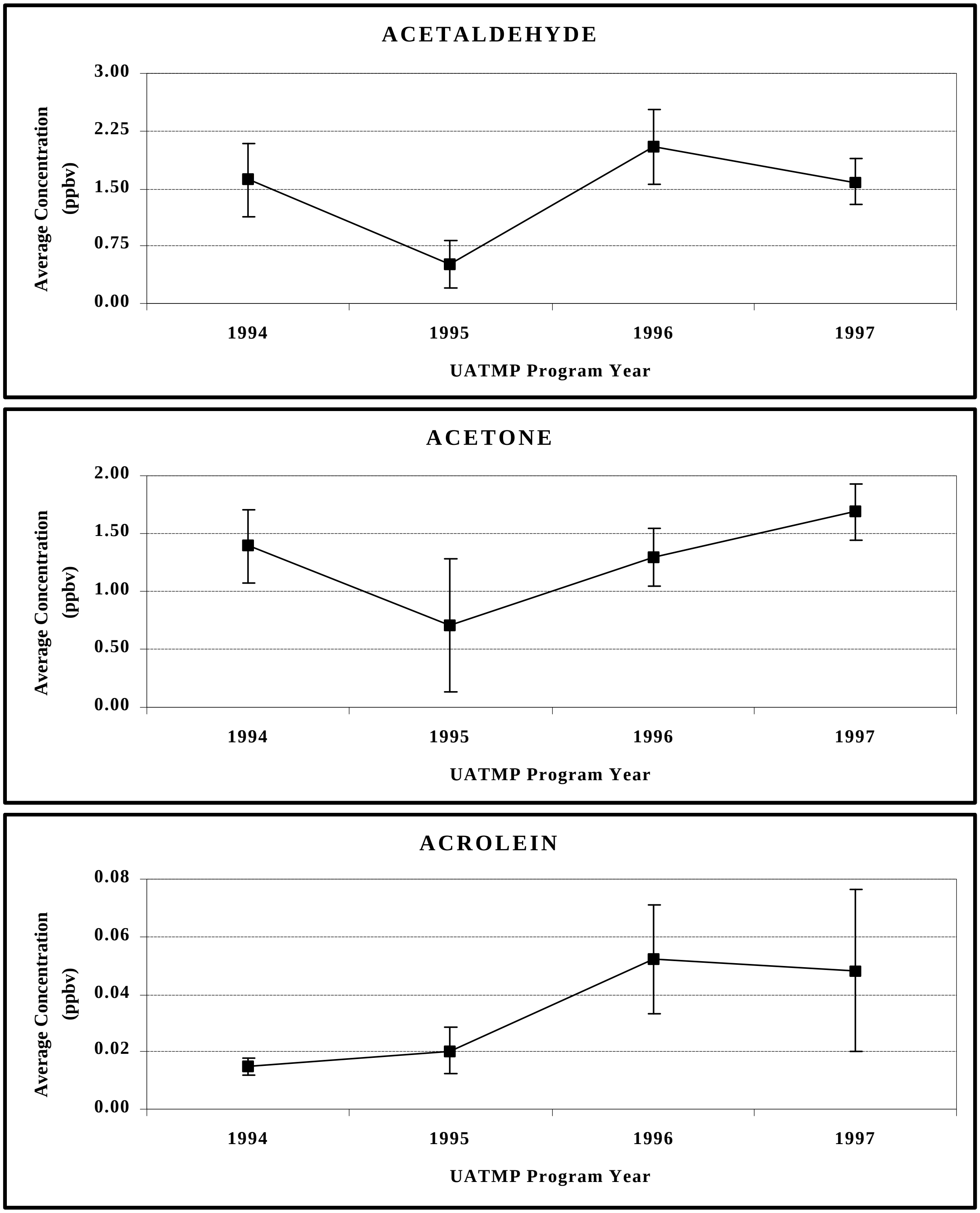
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 7-3 (Page 5 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at CANJ



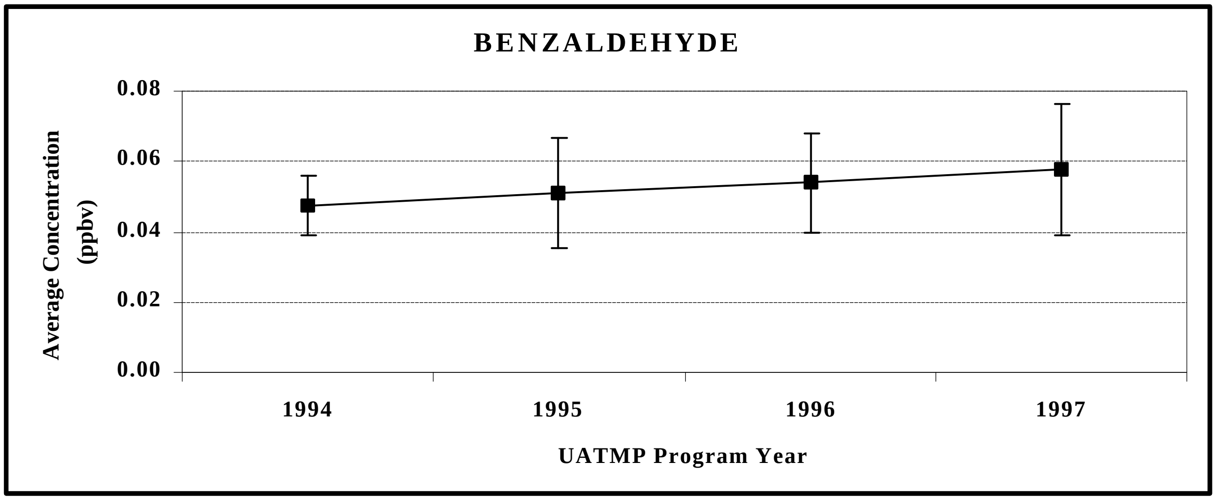
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

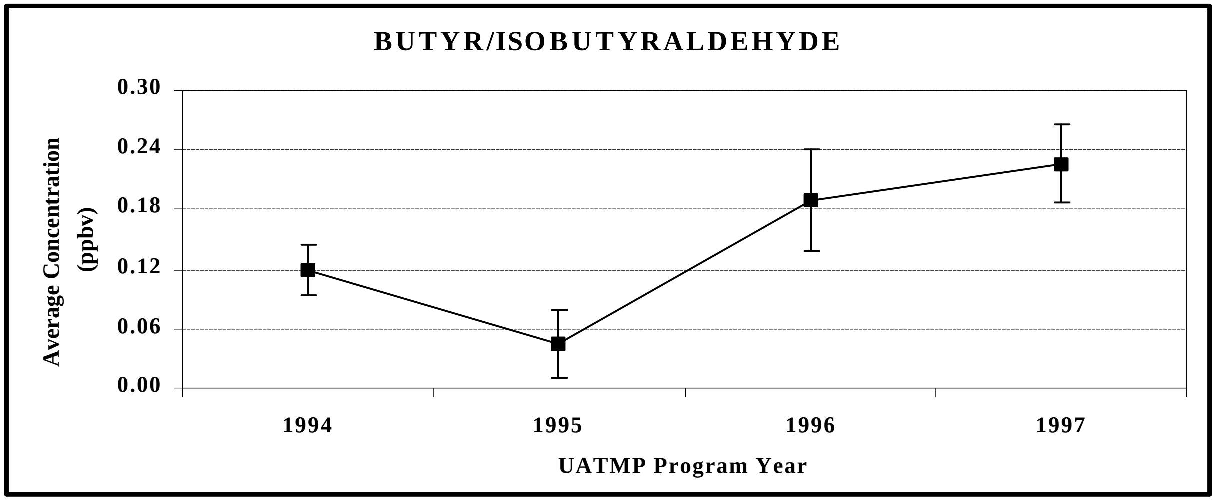
Figure 7-4 (Page 1 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at CANJ

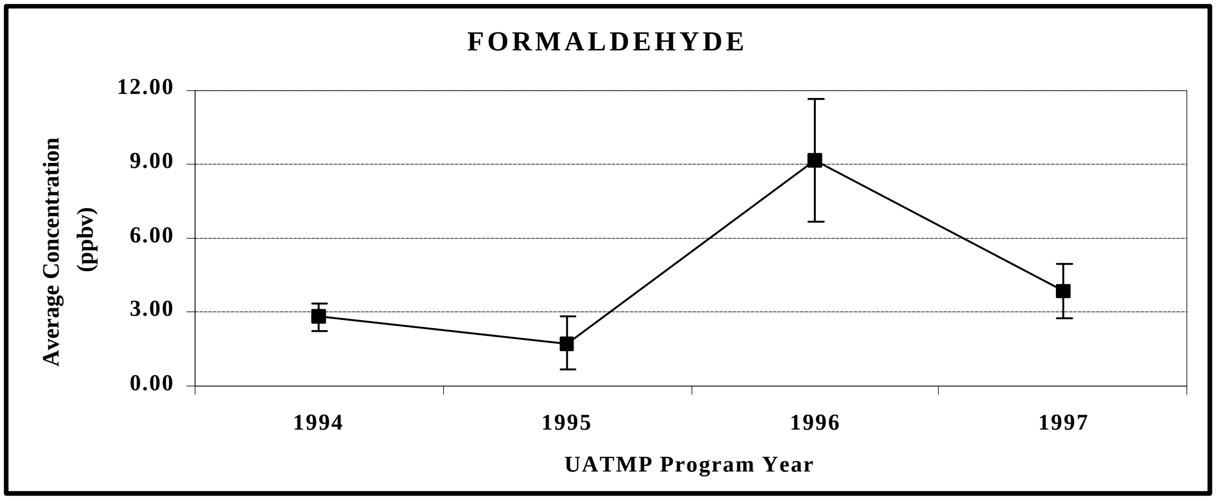


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 7-4 (Page 2 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at CANJ

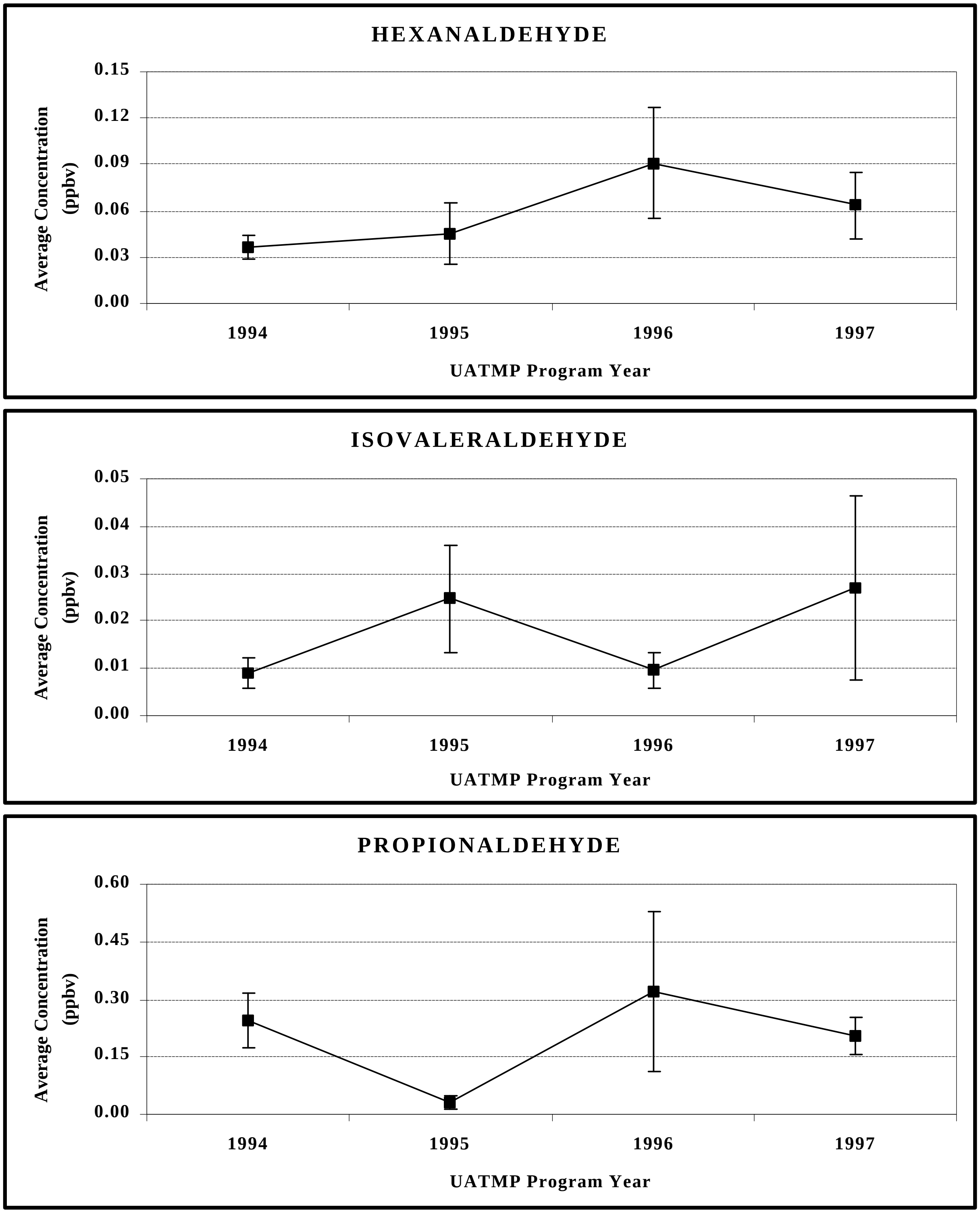

BENZALDEHYDE


BUTYR/ISOBUTYRALDEHYDE


FORMALDEHYDE

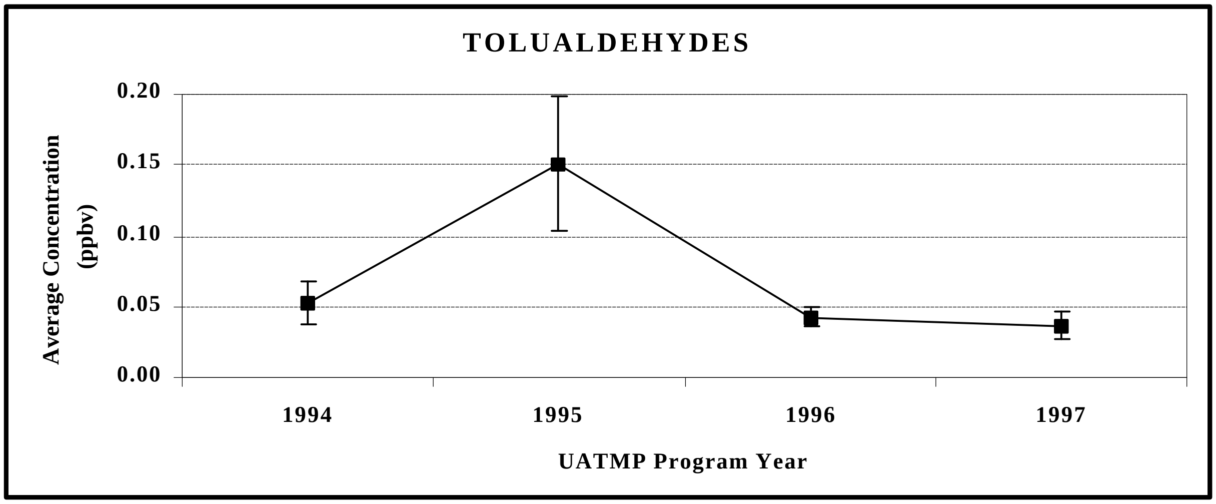
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

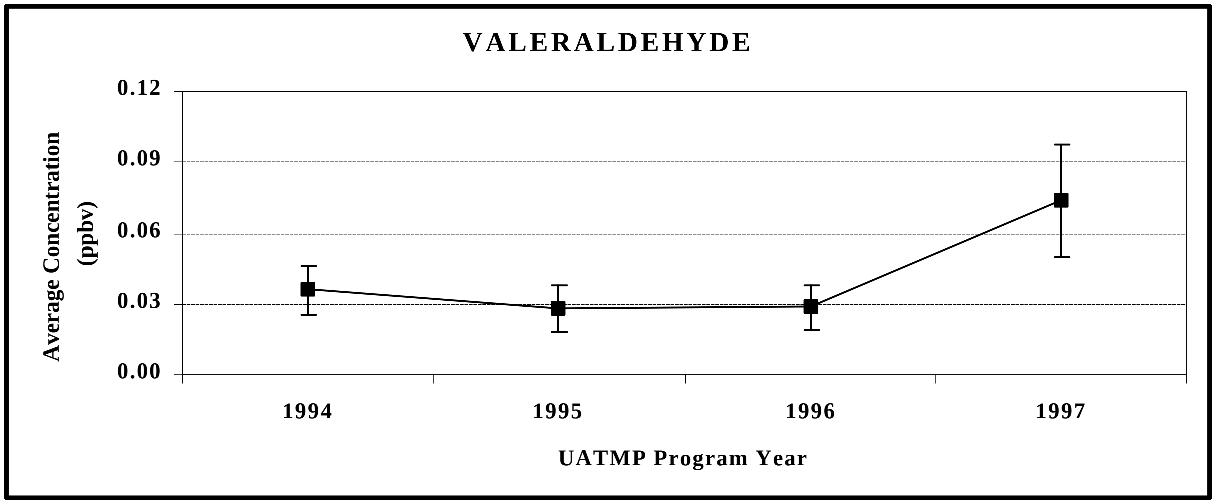
Figure 7-4 (Page 3 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at CANJ



Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 7-4 (Page 4 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at CANJ





Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Table 7-1
Summary Statistics for VOC Concentrations Measured at Camden, New Jersey (CANJ)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	30	3%	ND	2.44	0.29	0.31	0.24	0.40	1.31
Acetylene	**0**	**100%**	**0.56**	**5.95**	**2.01**	**2.22**	**1.89**	**1.27**	**0.57**
Acrylonitrile	23	26%	ND	2.45	0.11	0.29	0.14	0.49	1.66
Benzene	**0**	**100%**	**0.31**	**1.46**	**0.61**	**0.67**	**0.61**	**0.31**	**0.46**
Bromochloromethane	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.29
Bromodichloromethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	31	0%	ND	ND	0.08	0.07	0.07	0.01	0.09
Bromomethane	26	16%	ND	0.41	0.07	0.07	0.06	0.07	0.98
1,3-Butadiene	**12**	**61%**	**ND**	**0.25**	**0.05**	**0.09**	**0.07**	**0.07**	**0.78**
Carbon tetrachloride	**0**	**100%**	**0.03**	**0.29**	**0.09**	**0.09**	**0.09**	**0.04**	**0.44**
Chlorobenzene	30	3%	ND	0.08	0.04	0.03	0.03	0.01	0.33
Chloroethane	29	6%	ND	0.32	0.03	0.04	0.03	0.05	1.31
Chloroform	28	10%	ND	0.07	0.03	0.03	0.03	0.01	0.30
Chloromethane	**0**	**100%**	**0.32**	**2.04**	**0.66**	**0.71**	**0.67**	**0.31**	**0.44**
Chloroprene	30	3%	ND	0.48	0.05	0.05	0.04	0.08	1.47
Dibromochloromethane	31	0%	ND	ND	0.08	0.06	0.05	0.02	0.40
m-Dichlorobenzene	29	6%	ND	0.05	0.08	0.07	0.06	0.02	0.24
o-Dichlorobenzene	30	3%	ND	0.04	0.08	0.07	0.07	0.01	0.21

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 7-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Camden, New Jersey (CANJ)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	17	45%	ND	0.25	0.07	0.07	0.06	0.04	0.64
1,1-Dichloroethane	31	0%	ND	ND	0.05	0.04	0.04	0.02	0.38
1,2-Dichloroethane	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.14
trans-1,2-Dichloroethylene	30	3%	ND	0.02	0.06	0.05	0.05	0.02	0.33
1,2-Dichloropropane	31	0%	ND	ND	0.02	0.03	0.02	0.01	0.42
cis-1,3-Dichloropropylene	31	0%	ND	ND	0.03	0.03	0.03	0.01	0.26
trans-1,3-Dichloropropylene	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.40
Ethyl acrylate	31	0%	ND	ND	0.05	0.04	0.04	0.01	0.32
Ethylbenzene	**0**	**100%**	**0.08**	**0.53**	**0.18**	**0.20**	**0.18**	**0.11**	**0.55**
Ethyl *tert*-butyl ether	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.14
Methylene chloride	**2**	**94%**	**ND**	**3.61**	**0.14**	**0.28**	**0.15**	**0.63**	**2.24**
Methyl ethyl ketone	**1**	**97%**	**ND**	**2.38**	**0.55**	**0.63**	**0.51**	**0.45**	**0.72**
Methyl isobutyl ketone	30	3%	ND	0.30	0.04	0.04	0.04	0.05	1.10
Methyl methacrylate	31	0%	ND	ND	0.04	0.03	0.03	0.00	0.07
Methyl *tert*-butyl ether	**2**	**94%**	**ND**	**4.00**	**0.75**	**1.19**	**0.76**	**1.01**	**0.85**
***n*-Octane**	**3**	**90%**	**ND**	**0.70**	**0.15**	**0.19**	**0.15**	**0.15**	**0.79**
Propylene	**0**	**100%**	**0.37**	**5.66**	**1.07**	**1.56**	**1.14**	**1.43**	**0.92**
Styrene	**7**	**77%**	**ND**	**0.29**	**0.06**	**0.09**	**0.07**	**0.05**	**0.64**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 7-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Camden, New Jersey (CANJ)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
***tert*-Amyl methyl ether**	**13**	**58%**	**ND**	**1.11**	**0.04**	**0.09**	**0.06**	**0.15**	**1.64**
1,1,2,2-Tetrachloroethane	31	0%	ND	ND	0.09	0.07	0.06	0.03	0.38
Tetrachloroethylene	**6**	**81%**	**ND**	**0.24**	**0.07**	**0.08**	**0.07**	**0.05**	**0.61**
Toluene	**0**	**100%**	**0.35**	**3.67**	**1.21**	**1.29**	**1.09**	**0.74**	**0.57**
1,1,1-Trichloroethane	**0**	**100%**	**0.06**	**0.32**	**0.12**	**0.14**	**0.13**	**0.07**	**0.47**
1,1,2-Trichloroethane	31	0%	ND	ND	0.06	0.04	0.04	0.02	0.40
Trichloroethylene	25	19%	ND	0.11	0.02	0.03	0.02	0.01	0.48
Vinyl chloride	31	0%	ND	ND	0.03	0.03	0.03	0.00	0.07
***m,p*-Xylene**	**0**	**100%**	**0.20**	**1.61**	**0.51**	**0.62**	**0.53**	**0.35**	**0.57**
***o*-Xylene**	**0**	**100%**	**0.09**	**0.70**	**0.27**	**0.30**	**0.26**	**0.16**	**0.54**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 7-2
Summary Statistics for Carbonyl Concentrations Measured at Camden, New Jersey (CANJ)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.20**	**4.12**	**1.40**	**1.59**	**1.37**	**0.82**	**0.52**
Acetone	**0**	**100%**	**0.21**	**3.12**	**1.65**	**1.69**	**1.52**	**0.66**	**0.39**
Acrolein	**0**	**100%**	**0.00**	**0.43**	**0.03**	**0.05**	**0.03**	**0.08**	**1.56**
Benzaldehyde	**2**	**93%**	**ND**	**0.22**	**0.05**	**0.06**	**0.04**	**0.05**	**0.86**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.01**	**0.54**	**0.22**	**0.23**	**0.19**	**0.11**	**0.48**
Crotonaldehyde	20	33%	ND	0.06	0.00	0.01	0.01	0.02	1.45
2,5-Dimethylbenzaldehyde	25	17%	ND	0.03	0.00	0.00	0.00	0.01	1.22
Formaldehyde	**0**	**100%**	**0.12**	**15.99**	**2.96**	**3.84**	**3.02**	**2.92**	**0.76**
Hexanaldehyde	**0**	**100%**	**0.01**	**0.28**	**0.05**	**0.06**	**0.05**	**0.06**	**0.90**
Isovaleraldehyde	**8**	**73%**	**ND**	**0.29**	**0.01**	**0.03**	**0.01**	**0.05**	**1.94**
Propionaldehyde	**0**	**100%**	**0.02**	**0.58**	**0.18**	**0.20**	**0.16**	**0.13**	**0.65**
Tolualdehydes	**5**	**83%**	**ND**	**0.11**	**0.04**	**0.04**	**0.03**	**0.02**	**0.67**
Valeraldehyde	**0**	**100%**	**0.00**	**0.28**	**0.05**	**0.07**	**0.05**	**0.06**	**0.87**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 7-3
Total Air Releases of Selected Nitriles and Oxygenated Compounds Reported to TRI by Facilities Within 10 Miles of the CANJ Monitoring Station

Compound	Number of Facilities Within 10 Miles of CANJ That Reported Air Releases of the Compound to TRI in 1995	Total Pounds of Air Releases of the Compound Reported by These Facilities in 1995
Acetonitrile	0	0
Acrylonitrile	0	0
Ethyl acrylate	0	0
Ethyl *tert*-butyl ether	NA	NA
Methyl ethyl ketone	8	27,160
Methyl isobutyl ketone	4	1,900
Methyl methacrylate	3	688
Methyl *tert*-butyl ether	2	127,583
tert-Amyl methyl ether	NA	NA

Source: USEPA, 1997.

NA = Not applicable. The TRI reporting requirements currently do not require facilities to disclose information on environmental releases and waste management practices for ethyl *tert*-butyl ether or *tert*-amyl methyl ether.

Refer to Section 3.2 for a discussion on the limitations of TRI data.

8.0 Monitoring Results for El Paso, TX (EPTX)

This section summarizes and interprets ambient air monitoring data collected at the El Paso, Texas (EPTX), monitoring station during the 1995, 1996 and 1997 UATMPs. El Paso is a large city located at the western tip of Texas, near the borders with New Mexico and Mexico. According to the U.S. Census, approximately 410,000 people live within 10 miles of the EPTX monitoring station. This number represents an underestimate of the actual population living near EPTX, however, because the U.S. Census does not account for individuals in Mexico. Figure 8-1 shows the location of EPTX and illustrates land use in its vicinity. The monitoring station is located downtown, in a high-traffic area, where emissions from motor vehicles are expected to have a significant impact on levels of air pollution. Industrial activities in Mexico and El Paso also contribute to air pollution at the site. During the 1997 UATMP, ambient air samples were collected at EPTX on 30 days. Carbonyl samples from one date were invalid, and every VOC sample was valid. In other words, the completeness of carbonyl sampling was 97 percent, and the completeness of VOC sampling was 100 percent.

The remainder of this section is organized as follows: Section 8.1 summarizes the 1997 monitoring data for EPTX; Section 8.2 analyzes ambient air concentrations of selected nitriles and oxygenated compounds; Section 8.3 describes how concentrations of certain compounds have changed since the 1995 UATMP; and Section 8.4 reviews the most notable findings of the previous subsections.

8.1 Data Summary Parameters for the 1997 UATMP

Tables 8-1 and 8-2 present data summary parameters for VOC and carbonyl monitoring data, respectively, collected at EPTX during the 1997 UATMP. For reference, Section 3.1 defines the four data summary parameters used below.

8.1.1 Data Summary of VOC

The data in Table 8-1 indicate the following notable trends among the VOC ambient air monitoring data from EPTX:

- *Prevalence*. According to Table 8-1, the following 16 compounds were detected in more than half the samples collected at EPTX: acetylene, benzene, 1,3-butadiene, carbon tetrachloride, chloromethane, ethylbenzene, methylene chloride, methyl ethyl ketone, *n*-octane, propylene, styrene, toluene, 1,1,1-trichloroethane, *m,p*-xylene, and *o*-xylene. Summary statistics for these compounds are believed to be most representative of annual trends, due to the small number of nondetect observations. Therefore, most of the discussion in this section focuses on these 16 most prevalent VOC. However, it should not be inferred that the VOC detected in fewer than half the samples are not present in ambient air at EPTX: they may be present at varying concentrations over time, or consistently present at concentrations the VOC analytical method cannot measure. In short, statistically meaningful air quality trends cannot be calculated for these compounds because of their high number of nondetect observations.

- *Concentration Range*. Table 8-1 also provides information on the range of ambient air concentrations measured at EPTX. Of the 47 VOC identified by the analytical method, only acetylene and toluene had at least one 24-hour average concentration above 10.0 ppbv. The highest 24-hour average concentrations of benzene, propylene, and *m,p*-xylene were all between 5.0 and 10.0 ppbv. The highest concentrations of the following nine compounds were between 1.0 and 5.0 ppbv: acrylonitrile, 1,3-butadiene, chloromethane, ethylbenzene, methylene chloride, methyl ethyl ketone, methyl *tert*-butyl ether, styrene, and *o*-xylene.

  It is interesting to note that the highest concentrations for eight of the most prevalent VOC at EPTX (acetylene, benzene, 1,3-butadiene, ethylbenzene, toluene, and the xylene isomers) were higher than those observed for the same compounds at the 11 other monitoring stations that participated in the 1997 UATMP. As previous UATMP reports have shown, these eight compounds—all hydrocarbons—are typically found in motor vehicle exhaust. This observation, along with several other observations noted throughout this section, provide evidence that mobile source emissions near the EPTX monitoring station are likely greater than those in the vicinity of the other stations.

  It should be noted that the highest concentrations listed in Table 8-1 only estimate the actual concentration ranges, since it is likely that ambient air concentrations rose to higher levels on days when samples were not collected.

- *Central Tendency*. Central tendency values for compounds detected in fewer than 50 percent of samples should be interpreted with caution, as the high frequency of nondetects probably biases the central tendency calculations. Of the most prevalent VOC at EPTX, however, the highest geometric mean concentrations were observed for acetylene (4.04 ppbv), toluene (2.48 ppbv), propylene (1.39

ppbv), benzene (1.29 ppbv), and *m,p*-xylene (1.26 ppbv). All other VOC at this station had geometric mean concentrations less than 1.0 ppbv.

According to Figure 3-1, which compares geometric mean concentrations for selected VOC across the 12 monitoring stations that participated in the 1997 UATMP, geometric mean concentrations at EPTX were higher than those of any of the monitoring stations for the following 11 compounds: acetylene, 1,3-butadiene, benzene, ethylbenzene, methylene chloride, *n*-octane, propylene, toluene, *m,p*-xylene, and *o*-xylene. Of these compounds, ten are hydrocarbons typically found in motor vehicle exhaust, and one (methylene chloride) is a halogenated hydrocarbon used in various industrial applications. The fact that central tendency concentrations of many hydrocarbons were highest at EPTX suggests that motor vehicle sources affect air quality at this station more than they do at the other UATMP monitoring stations. In fact, Figure 3-1 shows that geometric mean concentrations for several hydrocarbons at EPTX were more than twice as high as the geometric mean concentrations at most of the other UATMP monitoring stations. Section 8.3 offers reasons for the elevated levels of methylene chloride at EPTX during the 1997 UATMP—a trend that was not observed during the 1995 and 1996 programs.

Note: When interpreting the graphs in Figure 3-1, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within these areas. Even though ambient air concentrations of many compounds at EPTX were higher than those at other UATMP monitors, this trend may result simply from the placement of the EPTX monitors in a high-traffic, downtown area. Concentrations throughout El Paso are not necessarily as high as those measured by the EPTX monitors.

- *Variability*. With the exception of methylene chloride and styrene, the coefficients of variation for the most prevalent compounds were lower than 1.0—a similarity that suggests that ambient air concentrations of these compounds have comparable variability. The coefficients of variation for methylene chloride and styrene were 1.00 and 1.43, respectively. The relatively higher variability for these two compounds suggests that their ambient air concentrations changed more significantly from one sampling date to the next than did the concentrations of the other VOC. This result is best explained by the assumption that methylene chloride and styrene probably originated, to a large extent, from emissions sources found at discrete locations (e.g., industrial sources), as opposed to originating from emissions sources found throughout the El Paso area (e.g., motor vehicles). This hypothesis is supported by the fact that ambient air concentrations of methylene chloride and styrene at EPTX were very weakly correlated, if not completely uncorrelated, with concentrations of hydrocarbons typically found in motor vehicle exhaust.

Section 8.2, which analyzes the ambient air monitoring data for nitriles and oxygenated compounds, and Section 8.3, which evaluates how average concentrations at EPTX have changed since the 1995 UATMP, provide further discussion of trends and patterns in the VOC monitoring data from El Paso, Texas.

8.1.2 Data Summary of Carbonyls

The data in Table 8-2 indicate the following notable trends among the ambient air monitoring data for carbonyls at EPTX:

- *Prevalence*. As Table 8-2 shows, every carbonyl sampled for during the 1997 UATMP, except 2,5-dimethylbenzaldehyde, was detected in at least half of the samples collected at EPTX. Thus, summary statistics for most of the carbonyls are expected to represent actual air quality trends in the vicinity of the monitoring station.

- *Concentration Range*. Of the 16 compounds identified by the carbonyl analytical method, only acetaldehyde (10.75 ppbv), acetone (7.68 ppbv), and formaldehyde (37.99 ppbv) were measured at levels greater than 1.0 ppbv in the El Paso air. Further, ambient air concentrations of formaldehyde at EPTX were consistently higher than those for other carbonyls. In fact, concentrations of formaldehyde at EPTX were greater than 10 ppbv on roughly 25 percent of the sampling dates during the 1997 UATMP. As observed earlier, concentration ranges shown in Table 8-2 only estimate the actual concentration ranges, because concentrations may have reached higher or lower levels on days when sampling did not occur.

- *Central Tendency*. According to Table 8-2, there was an obvious break in the central tendency data for carbonyls at EPTX: three compounds (acetaldehyde, acetone, and formaldehyde) had geometric mean concentrations greater than 1.40 ppbv during the 1997 UATMP, and every other carbonyl had geometric mean concentrations less than 0.20 ppbv. As an indicator of this break in the data, the combined geometric mean concentrations of acetaldehyde, acetone, and formaldehyde at EPTX account for over 90 percent of the total concentration of carbonyls measured at this site. Moreover, the geometric mean concentration of formaldehyde (4.52 ppbv) was higher than that of every other compound at this monitoring station, including VOC.

Of all the UATMP monitoring stations, EPTX had the highest geometric mean concentrations of six carbonyls: acetaldehyde, benzaldehyde, formaldehyde, and tolualdehydes (see Figure 3-2). Since Section 8.1.1 and previous UATMP reports have provided evidence that motor vehicle emissions have a greater impact on air quality the vicinity of the El Paso monitoring station than at the other monitoring stations, a logical explanation for the spatial variations of acetaldehyde, benzaldehyde, formaldehyde, and tolualdehydes is that they originate, to a large extent, from motor vehicle emissions. Further research is needed, however, to determine the extent to which motor vehicle emissions and other factors (e.g., industrial emissions and photochemical reactions) affect ambient air concentrations of these compounds.

Except for the six compounds discussed above, geometric mean concentrations of carbonyls measured at El Paso were not unusually higher or lower than those observed at other monitoring stations. Because these other carbonyls did not have the highest concentrations at EPTX (the UATMP station believed to be most influenced by motor vehicle emissions), it is likely that these carbonyls originate from a combination of different emissions sources or their concentrations may be highly dependent on photochemical reactions. Sections 3.1.2 and 12.1 discuss this hypothesis further.

Note: When interpreting the graphs in Figure 3-2, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within selected areas. Thus, it is quite possible that concentrations of certain carbonyls averaged throughout the El Paso area are not as high as the summary statistics indicate.

- *Variability*. Most of the prevalent carbonyls at EPTX had coefficients of variation between 0.81 and 1.21. The similar magnitudes of these coefficients of variation suggest that these carbonyls are consistently found in ambient air, regardless of changing wind directions. This trend is consistent with the assumption that carbonyls originated from “sources” throughout the El Paso area, such as motor vehicle emissions, certain industrial sources, and as the products of photochemical reactions (which tend to occur throughout a region).

  The only carbonyls with coefficients of variation higher than 1.21 were acrolein (1.75) and isovaleraldehyde (2.27). It is unclear if industrial emissions are responsible for these compounds’ greater variability, since no industrial facilities in the vicinity of the monitoring station reported releases of acrolein to TRI in 1995 and industrial facilities are not required to report releases of isovaleraldehyde to TRI. Since these compounds might have been released by facilities not subject to the TRI reporting requirements, a more detailed review of local emissions sources is encouraged.

For more information on ambient air concentrations of carbonyls at EPTX, readers should refer to Section 8.3, which discusses how ambient levels of carbonyls have changed at the station since the 1995 UATMP, and to Section 12.1, which provides a general overview of carbonyl monitoring data collected at the 12 monitoring stations that participated in the 1997 UATMP.

8.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

As Section 2.2.1 explained, improvements to the VOC analytical method allowed the 1997 UATMP to measure nine compounds (all nitriles or oxygenated compounds) that were not measured in earlier UATMPs. Since most of these compounds were rarely, if ever, detected at EPTX, it is difficult to draw any conclusions about their ambient air concentrations. Nonetheless, a summary of the data trends for these compounds follows:

- *Compounds that were rarely, if ever, detected*. Of the nine nitriles and oxygenated compounds, all but methyl ethyl ketone were detected in fewer than 20 percent of the valid sampling events at EPTX. Therefore, actual air quality trends for these eight compounds are highly uncertain, due to their large number of nondetects. Nonetheless, it is interesting to assess whether industrial emissions data are consistent with these compounds' absence from the ambient air at EPTX. Emissions data for the eight compounds fall into three categories. First, for five of the nitriles and oxygenated compounds (acetonitrile, acrylonitrile, ethyl acrylate, methyl isobutyl ketone, and methyl methacrylate), no industrial facilities in El Paso County reported environmental releases to the 1995 TRI. Second, two compounds (ethyl *tert*-butyl ether and *tert*-amyl methyl ether) were not subject to TRI reporting in 1995. Third, according to TRI, one facility in El Paso County reported releasing 952 pounds of methyl *tert*-butyl ether to the air in 1995, but this facility is approximately 5 miles from the monitoring station. Overall, for this subset of compounds, the TRI data generally support the ambient air monitoring data: the eight compounds were rarely, if ever, detected in the ambient air and do not appear to have major industrial emissions sources in the El Paso area.

  The infrequent detections at EPTX (the monitoring station believed to be affected most by mobile sources) suggests that motor vehicles in the area probably do not emit these eight compounds in large quantities. Although EPA requires motor vehicles in El Paso County to use oxygenated fuels during the winter, gasoline distributors meet this requirement by adding ethanol to the fuels and not by adding methyl *tert*-butyl ether—the additive of choice for areas that must use oxygenated fuels year round (see Section 3.2). For more information on concentrations of methyl *tert*-butyl ether observed in such an area, readers should refer to the analyses for the Camden monitoring station in Section 7.2.

- *Methyl ethyl ketone*. Of the nine nitriles and oxygenated compounds, methyl ethyl ketone was detected most frequently at EPTX: it was detected in more than 90 percent of the samples, and its geometric mean concentration was 0.51 ppbv, which ranked seventh among the geometric mean concentrations of VOC at EPTX. Several aspects of the ambient air monitoring data at EPTX suggest that industrial emissions or photochemical reactions might account for much of the methyl ethyl ketone that was measured at EPTX, even though the compound has been found in motor vehicle exhaust. For instance, geometric mean concentrations of methyl ethyl ketone at five of the UATMP monitoring stations were greater than or equal to that at EPTX. This fact indicates that motor vehicles are probably not the primary source of methyl ethyl ketone at the UATMP stations, since EPTX consistently detected the highest levels of those compounds primarily associated with motor vehicle exhaust. Further, ambient air concentrations of methyl ethyl ketone at EPTX were found to be weakly correlated, if not completely uncorrelated, with concentrations of compounds typically found in motor vehicle exhaust (e.g., benzene, ethylbenzene, toluene, and the xylene isomers).

  Though the previous observations imply that motor vehicles are not the primary source of airborne methyl ethyl ketone in El Paso, they do not necessarily confirm that industrial emissions account for the measured levels of the compound. Since no industrial facilities in El Paso County reported air releases of methyl ethyl ketone to the 1995 TRI, estimates of the impact of industrial emissions are not readily available. Local emissions inventories that include facilities not subject to TRI reporting, as well as inventories of sources in Juarez, Mexico, may provide insight into the primary sources of airborne methyl ethyl ketone at EPTX.

  The ambient air monitoring data collected at almost every monitoring station during the 1997 UATMP suggested that concentrations of methyl ethyl ketone were highest during the warmer summer months. Consistent with this observation, the concentration of methyl ethyl ketone at EPTX during June, July, August, and September was, on average, more than twice as high as that during the other months of the year. This trend may result from many different factors, such as greater evaporative losses from industrial sources during the summer, seasonal changes in photochemical reactivity, or seasonal changes in prevailing wind patterns. Analyses of additional monitoring data, once available, are encouraged to confirm whether the seasonal variations for this compound are part of a trend over the longer term. If so, further research may provide insight into the primary causes of these seasonal variations.

8.3 Annual Variations

Most of the compounds sampled for at EPTX during the 1997 UATMP were also sampled for during the 1995 and 1996 programs, allowing an analysis of long-term trends in air quality. Though annual average concentrations of air pollutants typically change, to a certain extent, from year to year, these changes are not necessarily statistically significant and could simply result from the uncertainty associated with calculating annual average concentrations from the results of ambient air samples collected on a biweekly basis. As Section 3.3 explained, this report considers annual variations to be “significant” only when the entire 95-percent confidence interval of an annual average concentration for a compound is lower or higher than that of another.

Statistically significant annual variations can occur for many different reasons, including increases or decreases in emissions and fluctuating meteorological conditions. Figures 8-2 and 8-3 show how annual average concentrations and their corresponding confidence intervals changed for each of the most prevalent VOC and carbonyls from the 1995 UATMP to the 1997 UATMP. Because central tendency estimates for compounds with many nondetect observations are highly uncertain, annual variations for compounds detected in fewer than 50 percent of samples are not considered.

When reading about “annual” changes in average concentrations, it is important to note that the UATMP year does not correspond with the calendar year. The UATMP year generally begins in September and ends in August of the following calendar year. Therefore, a significant portion of the data collected in a given UATMP year actually represents air quality during the following calendar year.

8.3.1 Annual Variations for VOC

According to Figure 8-2, annual average concentrations for most of the VOC were not notably different between the 1995, 1996, and 1997 UATMPs. However, levels of several VOC (acetylene, methylene chloride, styrene, and 1,1,1-trichloroethane) during the 1997 program were more than a factor of two different from levels during the 1995 program. More detailed analyses of the annual variations for different groups of compounds follow:

- *BTEX compounds*. As the graphs in Figure 8-2 show, average concentrations of benzene, toluene, ethylbenzene, and the xylene isomers—a group of compounds known to be emitted largely by motor vehicles—decreased slightly from the 1995 UATMP to the 1996 UATMP and increased slightly the following year. In all cases, annual average concentrations changed by less than 35 percent from one year to the next, and every annual variation for the BTEX compounds at EPTX does not appear to be statistically significant. The absence of any notable change in average concentrations between the three UATMPs is consistent with traffic patterns and fuels used in motor vehicles in the El Paso area also not changing significantly over this time frame, but not enough information is available on mobile sources to confirm these explanations.

- *Halogenated hydrocarbons*. Unlike the BTEX compounds, halogenated hydrocarbons in ambient air tend to originate from sources other than motor vehicles, such as industrial and natural emissions sources. Of the 14 most prevalent VOC at EPTX, four—carbon tetrachloride, chloromethane, methylene chloride, and 1,1,1-trichloroethane—are halogenated hydrocarbons. As Figure 8-2 shows, average concentrations of these compounds either were virtually unchanged from the 1995 UATMP to the 1997 UATMP, increased significantly during this time, or decreased significantly during this time. The following analyses consider each of these data patterns separately.

  First, ambient air concentrations of carbon tetrachloride and chloromethane were virtually no different during the 1995, 1996, and 1997 UATMPs. In fact, average concentrations of carbon tetrachloride during each of these three years were within 0.005 ppbv of this compound’s 3-year average concentration, and average levels of chloromethane were all within 0.02 ppbv of the 3-year average. As another indication of the unchanging levels, annual average concentrations for both compounds were different by no more than 15 percent from one year to the next. The data trend for these compounds, which was observed to a certain extent at almost every other UATMP monitoring station, suggests that ambient air concentrations of these VOC tend to be quite similar from year to year, regardless of the fact that other compounds’ concentrations may change significantly. The

1996 UATMP report suggested that the levels of carbon tetrachloride in the air near EPTX likely represent "global background" levels and that concentrations of chloromethane may result from natural sources (e.g., biogenic production in large bodies of salt water).

As Figure 8-2 shows, airborne levels of methylene chloride decreased by approximately a factor of two from the 1995 UATMP to the 1996 UATMP, then increased dramatically from the 1996 UATMP to the 1997 UATMP. The nearly seven-fold increase in concentrations of methylene chloride over the last two programs—a change that appears to be statistically significant—was the largest annual variation observed among all of the most prevalent VOC at EPTX. Due to this increase, concentrations of methylene chloride at EPTX during the 1997 program were, on average, higher than those at every other monitoring station that participated (see Figure 3-1). Though the 1996 UATMP report suggests that various industrial sources and consumer products emit methylene chloride, the exact reason for the increasing levels at EPTX is not known. Since no industrial facilities in the El Paso area reported emitting methylene chloride to the 1995 TRI, the air quality trends for this compound are probably attributable to nearby facilities that do not meet the TRI reporting requirements (see Section 3.2).

Closer examination of the monitoring data for methylene chloride at EPTX reveals a peculiar data trend that may help researchers identify the most likely source of this compound in the area: the average concentration of methylene chloride for samples collected on or after January 23, 1998 (1.20 ppbv), is eight times higher than that for samples collected before that date (0.15 ppbv). Therefore, prior to January 23, 1998, the average concentration for methylene chloride was virtually the same as that observed during the 1996 UATMP (see Figure 8-2), and the sharp increase in concentrations after this date is most likely explained by the operation of new emissions sources in the area or modifications to existing ones. This hypothesis should be tested by reviewing more current emissions inventories as they become available, and the data trend should be verified by reviewing ambient air monitoring data collected at this site in the future.

In contrast to the increasing concentrations of methylene chloride, annual average concentrations of 1,1,1-trichloroethane at EPTX have decreased over the last 3 years: from 0.26 ppbv during the 1995 UATMP, to 0.10 ppbv during the 1996 UATMP, to 0.11 ppbv during the 1997 UATMP. Otherwise stated, levels of 1,1,1-trichloroethane decreased by 60 percent from the 1995 to 1996 programs and did not change significantly the following year. The statistically significant decrease observed between the 1995 and 1996 programs most likely results from local industries using less 1,1,1-trichloroethane (or optimizing their use of this compound), but this finding cannot be corroborated by TRI data since no industrial facilities in the area reported releases of the compound in 1995.

- *Other compounds.* Annual variations for the five other VOC shown in Figure 8-2 (acetylene, 1,3-butadiene, *n*-octane, propylene, and styrene) exhibit some features that are similar to those discussed for other groups of compounds and other features that are unique. For instance, annual average concentrations for both 1,3-butadiene and *n*-octane decreased between the 1995 and 1996 programs, then increased between the 1996 and 1997 programs. Because this trend closely parallels that for the BTEX compounds (though the annual variations for *n*-octane are slightly more pronounced), it is reasonable to infer that motor vehicle emissions account for a notable portion of the annual variations for 1,3-butadiene and *n*-octane at EPTX.

  Also similar to the trends observed for the BTEX compounds, average concentrations of acetylene and propylene decreased by 30–50 percent from the 1995 UATMP to the 1996 UATMP. Unlike the BTEX compounds, however, levels of acetylene and propylene decreased again the following year, but only slightly. The report for the 1996 UATMP suggests that motor vehicle emissions contribute to airborne levels of both acetylene and propylene, but acknowledges that other categories of emissions sources also affect ambient air concentrations of these compounds. The extent of industrial emissions of acetylene and propylene in the El Paso area is difficult to assess, because industries are not required to report releases of acetylene to TRI and only one facility in El Paso County reported releasing propylene to TRI in 1995. Despite the lack of information on industrial emissions, it is reasonable to infer from the annual variations shown in Figure 8-2 that El Paso's levels of acetylene and propylene are affected not only by vehicular sources, but also by other source categories.

  Though the annual variations for styrene are similar to those for other compounds in some regards, several observations suggest that the variations for styrene result primarily from industrial sources. First, the annual average concentration of styrene during the 1996 UATMP was nearly half that during the 1995 UATMP. This decline, though possibly not statistically significant, is more pronounced than the decreasing concentrations of BTEX compounds over the same period. Second, as Section 8.1.1 noted, the relatively high coefficient of variation for styrene at EPTX is consistent with the compound originating from sources at discrete locations, as opposed to those found all around the monitoring station. Third, concentrations of styrene at EPTX were essentially uncorrelated with concentrations of BTEX compounds and other compounds typically found in motor vehicle exhaust. Combined, these observations provide compelling evidence that decreased emissions of styrene from industrial sources from 1995 to 1998 probably account for the notable decline in concentrations of styrene at EPTX over that time.

8.3.2 Annual Variations for Carbonyls

Figure 8-3 shows how annual average concentrations of the 15 most prevalent carbonyls changed at EPTX since the 1995 UATMP. Like the average concentrations of VOC, average levels of carbonyls tended to either decrease or not change significantly. The following discussion describes the annual trends for carbonyls in greater detail:

- *Compounds with decreasing concentrations.* As Figure 8-3 shows, annual average concentrations of the following 12 carbonyls decreased by varying magnitudes from the 1995 to the 1996 UATMP, and again from the 1996 to the 1997 UATMP: acetaldehyde, acetone, benzaldehyde, butyr/isobutyraldehyde, crotonaldehyde, formaldehyde, propionaldehyde, the tolualdehyde isomers, and valeraldehyde. Overall, the decreasing concentrations for these 12 compounds amount to a very notable improvement in the air quality at EPTX: Combined, the concentration of the 12 compounds was 29.8 ppbv during the 1995 UATMP and only 14.6 ppbv during the 1997 UATMP. In short, the amount of carbonyls in the ambient air at EPTX has decreased by a factor of two over the last 3 years, due largely to decreasing concentrations of acetaldehyde and acetone. Results from ongoing monitoring efforts should help confirm whether the relatively lower concentrations observed during the 1997 UATMP persist or whether the decreasing concentrations are merely part of air quality fluctuations over a longer time frame.

  Also interesting is that the notable decline in ambient air concentrations of carbonyls at EPTX was not paralleled by a comparable decline in ambient air concentrations of compounds that are primarily emitted by mobile sources (see Section 8.3.1). Thus, at first glance, the air quality trend for carbonyls at EPTX does not appear to be correlated with changing levels of motor vehicle emissions. Decreased emissions of "lighter" hydrocarbons from cars and gasoline stations may indirectly cause lower ambient air concentrations of selected carbonyls, particularly those that form in the air as oxidation products of hydrocarbons. Such an air quality trend would be difficult to discern from the monitoring data from this program, because the analytical methods used in the UATMP do not measure ambient levels of many hydrocarbons that react readily in urban smog. Further research is needed, therefore, to identify the primary causes for the notable decline in airborne carbonyls in El Paso.

- *Compounds with levels that increased and decreased*. The three remaining carbonyls shown in Figure 8-3 (acrolein, hexanaldehyde, and isovaleraldehyde) each exhibited different annual variations. Variations for hexanaldehyde are quite similar to the annual variations for the carbonyls listed in the previous bulleted item, except for the slight increase in concentrations of this compound from the

> 1995 to the 1996 UATMPs. It is difficult to comment on the trends for hexanaldehyde because the changing annual average concentrations for the compound do not appear to be statistically significant.
>
> Though the annual variations for acrolein and isovaleraldehyde shown in Figure 8-3 are obviously different, they do have some notable similarities. First, average levels for both compounds during the 1997 UATMP were nearly the same as those during the 1995 UATMP, suggesting that no long-term air quality trend for these compounds is apparent. Second, as Section 8.1.2 noted, acrolein and isovaleraldehyde had the highest coefficients of variation of the 15 most prevalent carbonyls at EPTX. The greater variability among ambient air monitoring data for these compounds certainly does not explain their annual variations, but it does suggest that acrolein and isovaleraldehyde in the El Paso air may be linked, to a certain extent, to industrial emissions sources—an important observation for ongoing efforts to attribute annual variations in ambient air concentrations to specific sources.

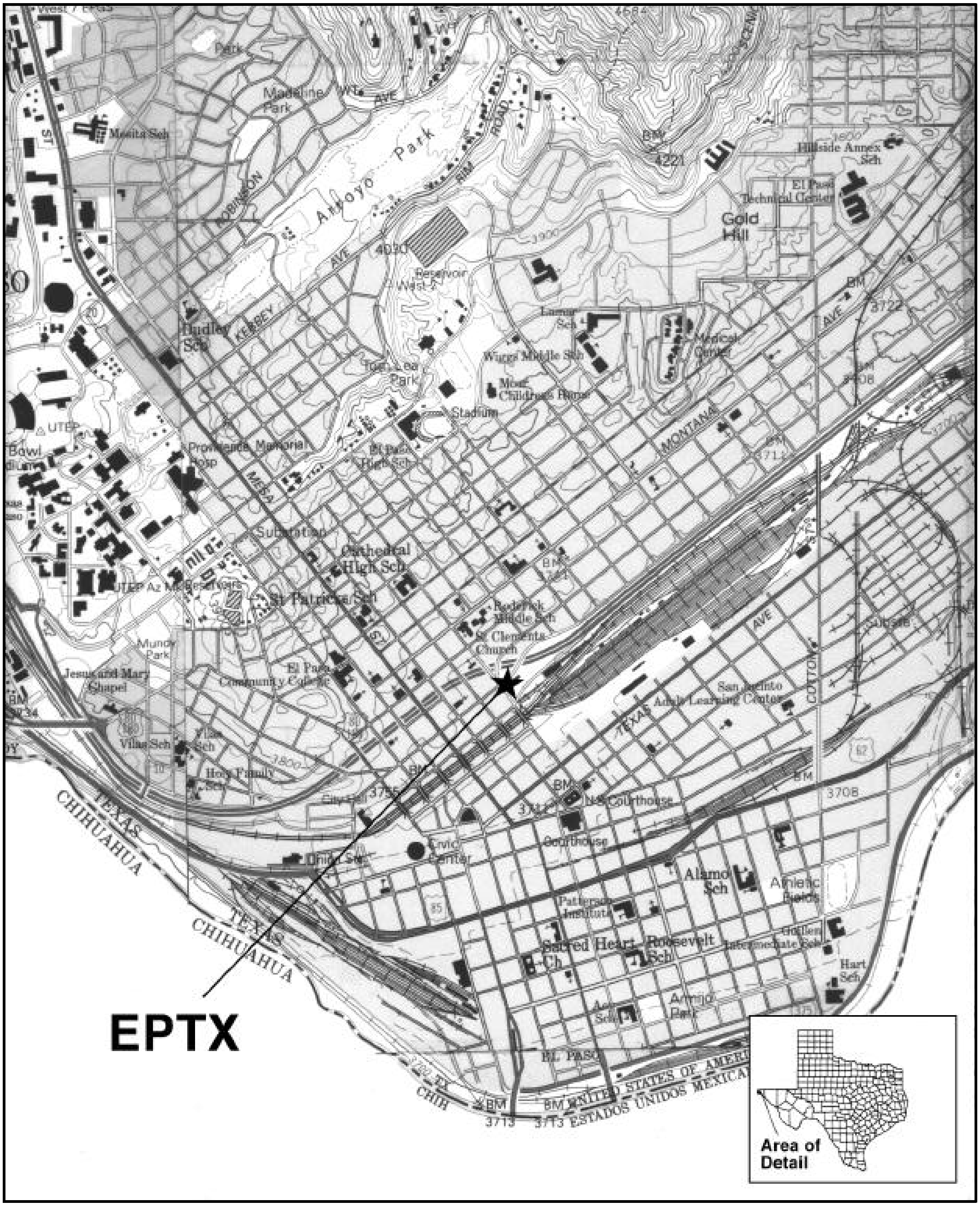
8.4 Summary

During the 1997 UATMP, ambient air concentrations of VOC and carbonyls at the EPTX monitoring station exhibited many trends consistent with those identified during previous UATMPs. For example, 16 VOC and 15 carbonyls were detected in over half the samples at this monitoring location, and ambient air concentrations of acetaldehyde, acetone, acetylene, benzene, formaldehyde, propylene, toluene, and *m,p*-xylene were consistently higher than those of the other compounds. Contrary to observations from previous monitoring efforts, concentrations of methylene chloride increased dramatically during the 1997 UATMP. The cause for this increase was not known, but was believed to result from the operation of new emissions sources in the area or from modifications to existing sources.

The 1997 UATMP marked the first year in which air samples were analyzed for concentrations of nine nitriles and oxygenated compounds. Of these, only methyl ethyl ketone was detected in over half of the samples collected at EPTX, and it was detected at its highest levels during the warmer summer months. There was strong evidence that motor vehicle emissions were not the source of airborne concentrations of this compound at EPTX. Emissions from industrial sources and links to photochemical reactions seemed a more likely explanation for the levels of methyl ethyl ketone observed during the 1997 UATMP, even though TRI data indicate that no facilities in El Paso County reported releasing methyl ethyl ketone to the air in 1995. Review of ongoing monitoring data and detailed emissions inventories should provide greater insight into why this compound is frequently detected in the El Paso air.

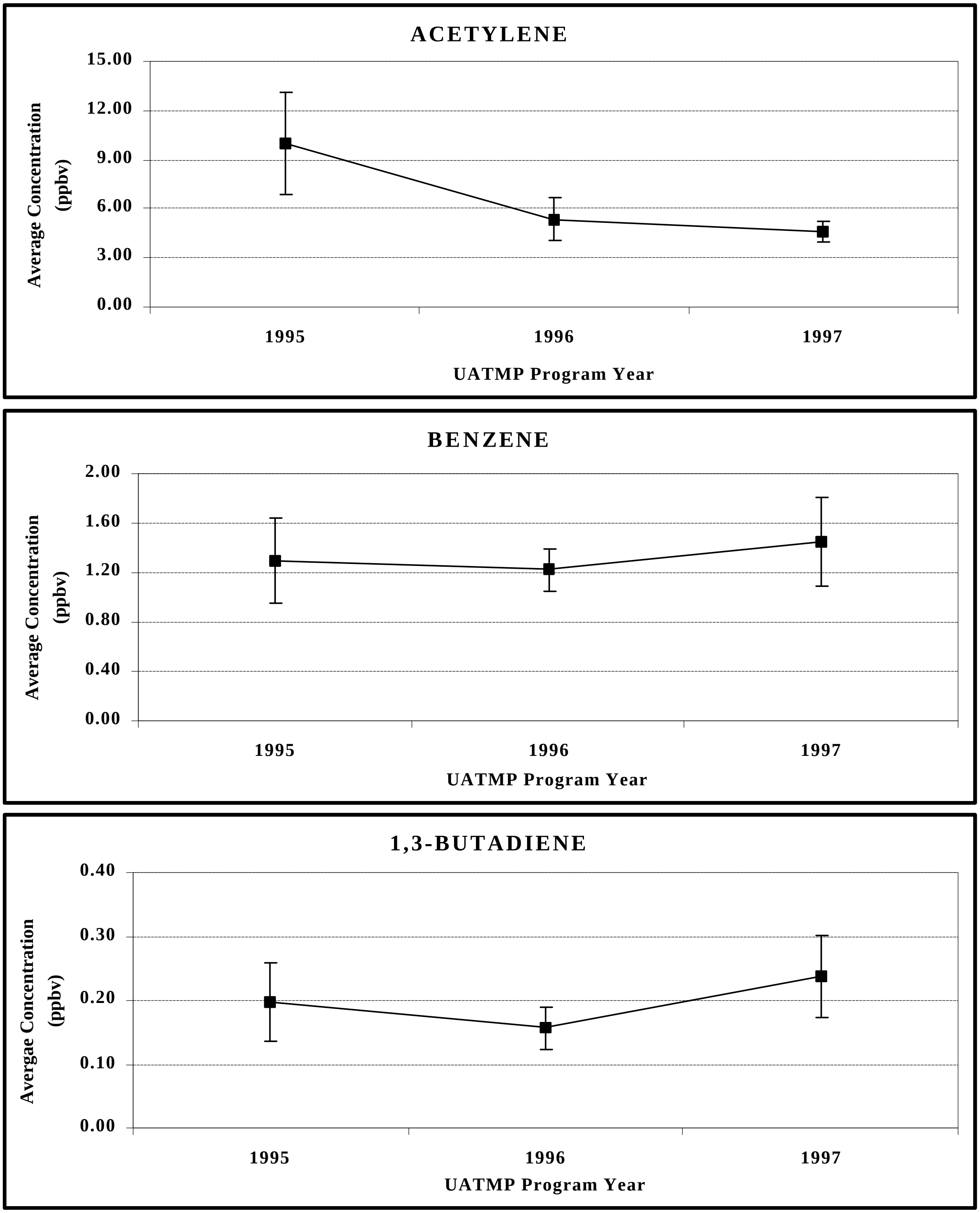
Almost without exception, annual average concentrations of the most prevalent VOC and carbonyls either decreased or did not change significantly from the 1995 UATMP to the 1997 UATMP. The magnitude of the decrease varied between different groups of compounds and within the groups, suggesting that no one factor has an overriding influence on the concentrations of the different carbonyls and VOC at EPTX.

Figure 8-1
El Paso, Texas (EPTX), Monitoring Station



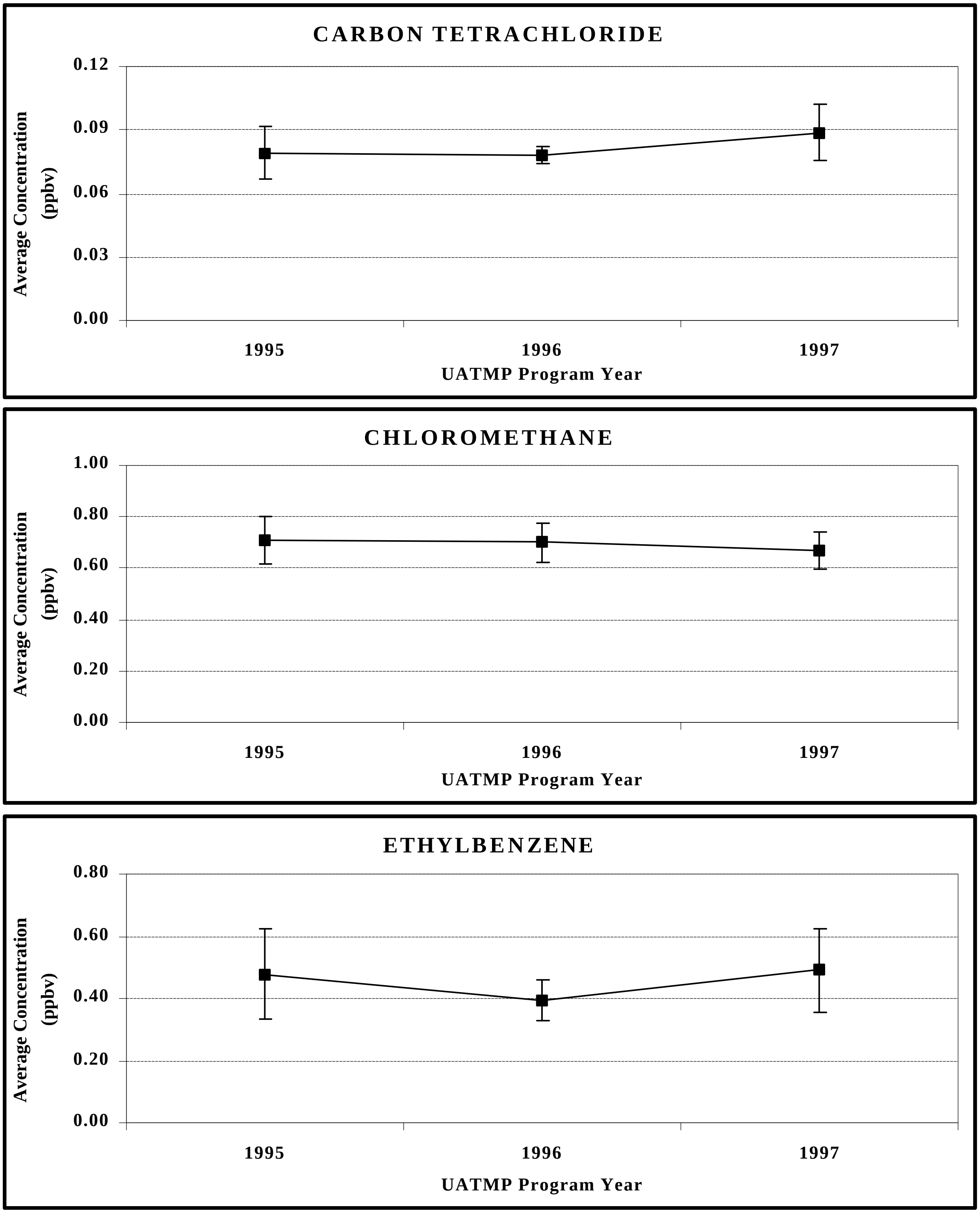
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 8-2 (Page 1 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at EPTX



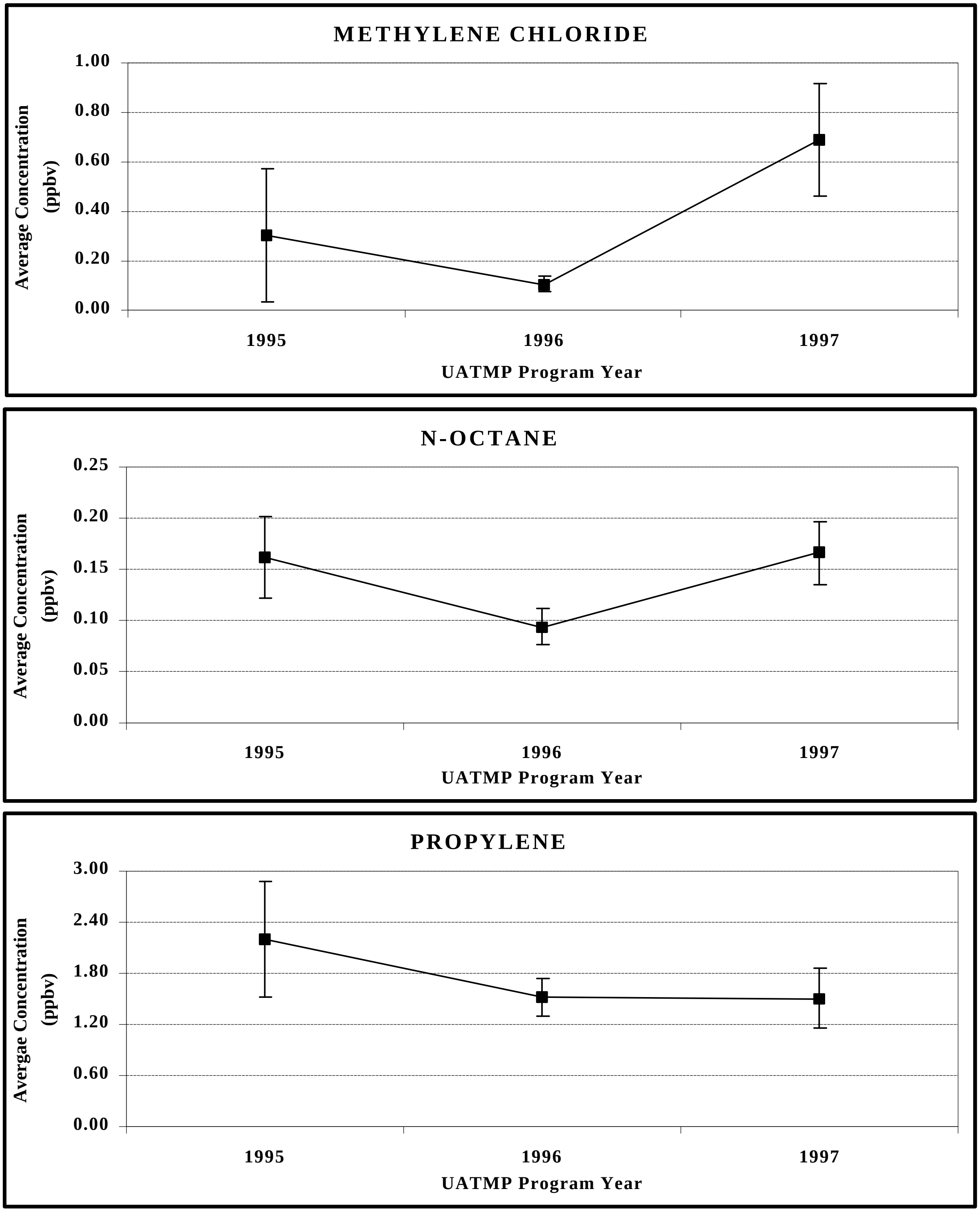
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 8-2 (Page 2 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at EPTX



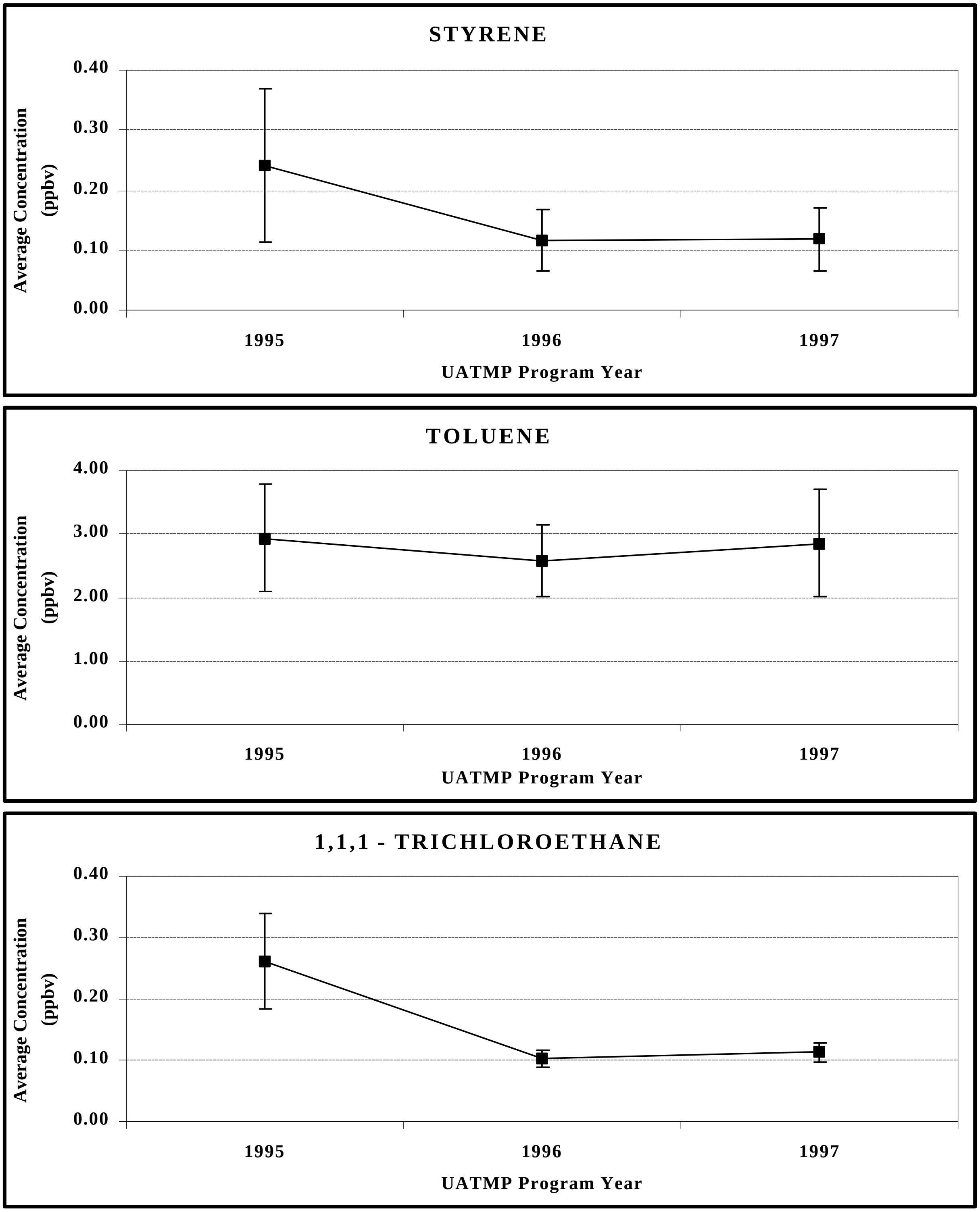
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 8-2 (Page 3 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at EPTX



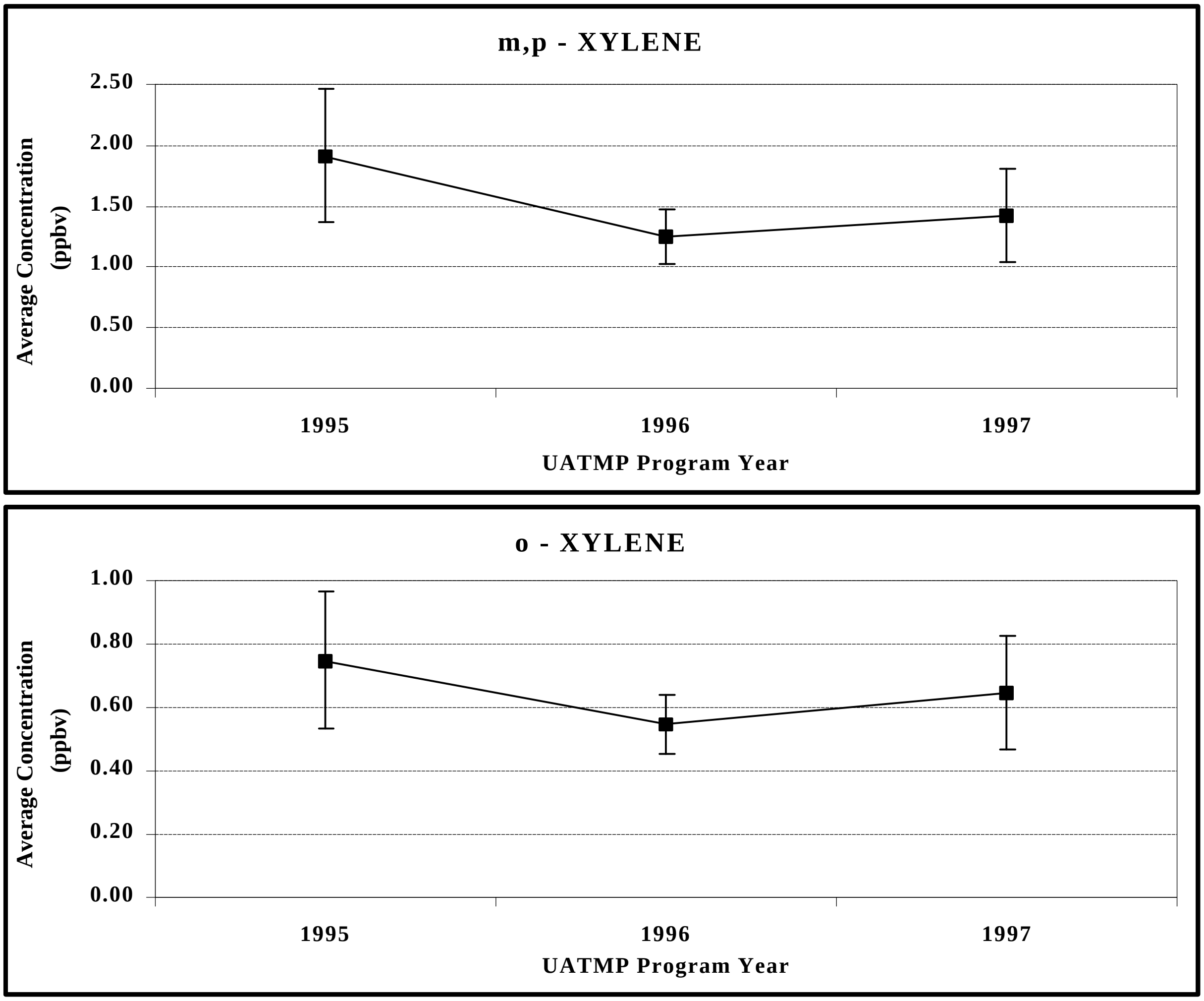
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 8-2 (Page 4 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at EPTX



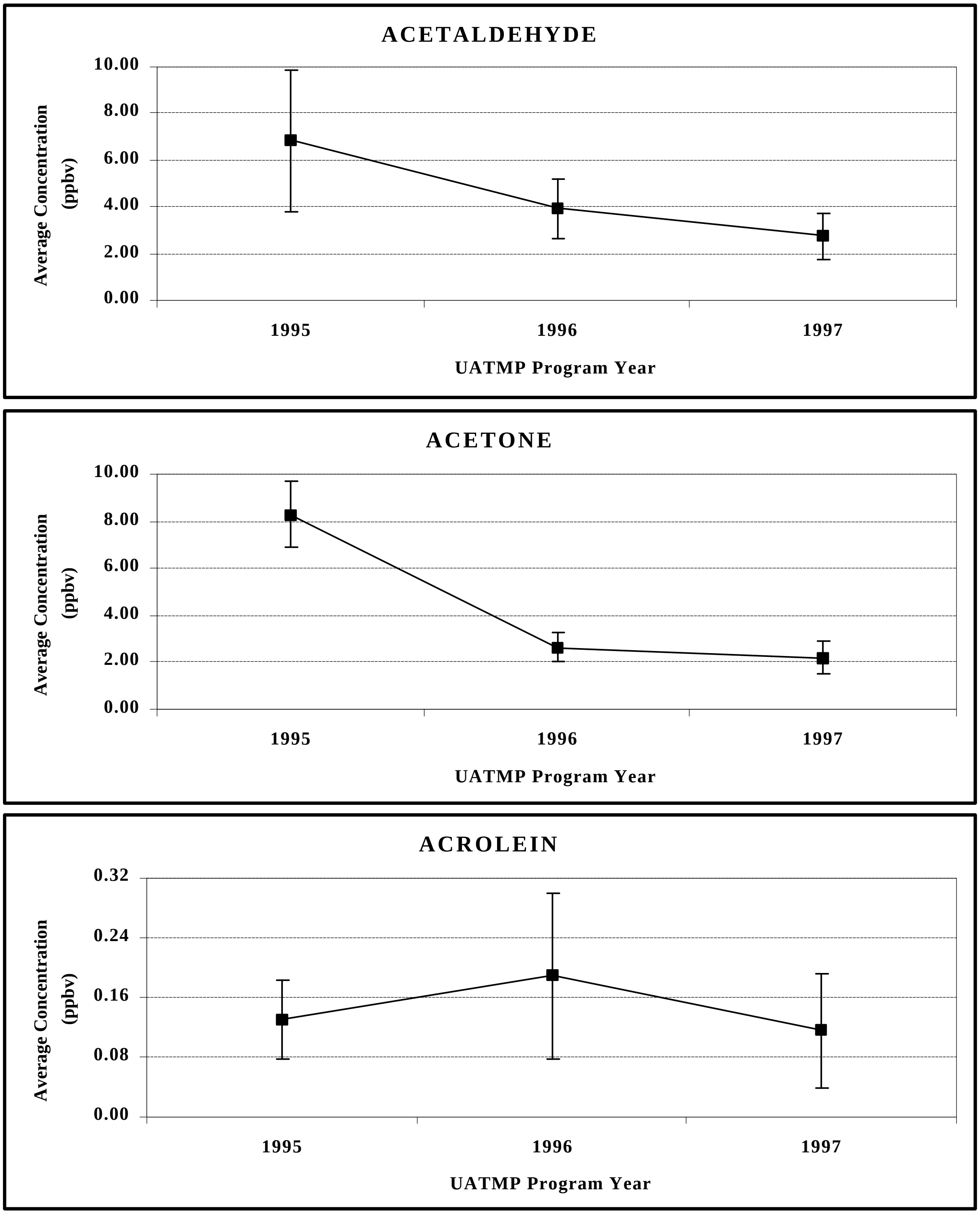
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 8-2 (Page 5 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at EPTX



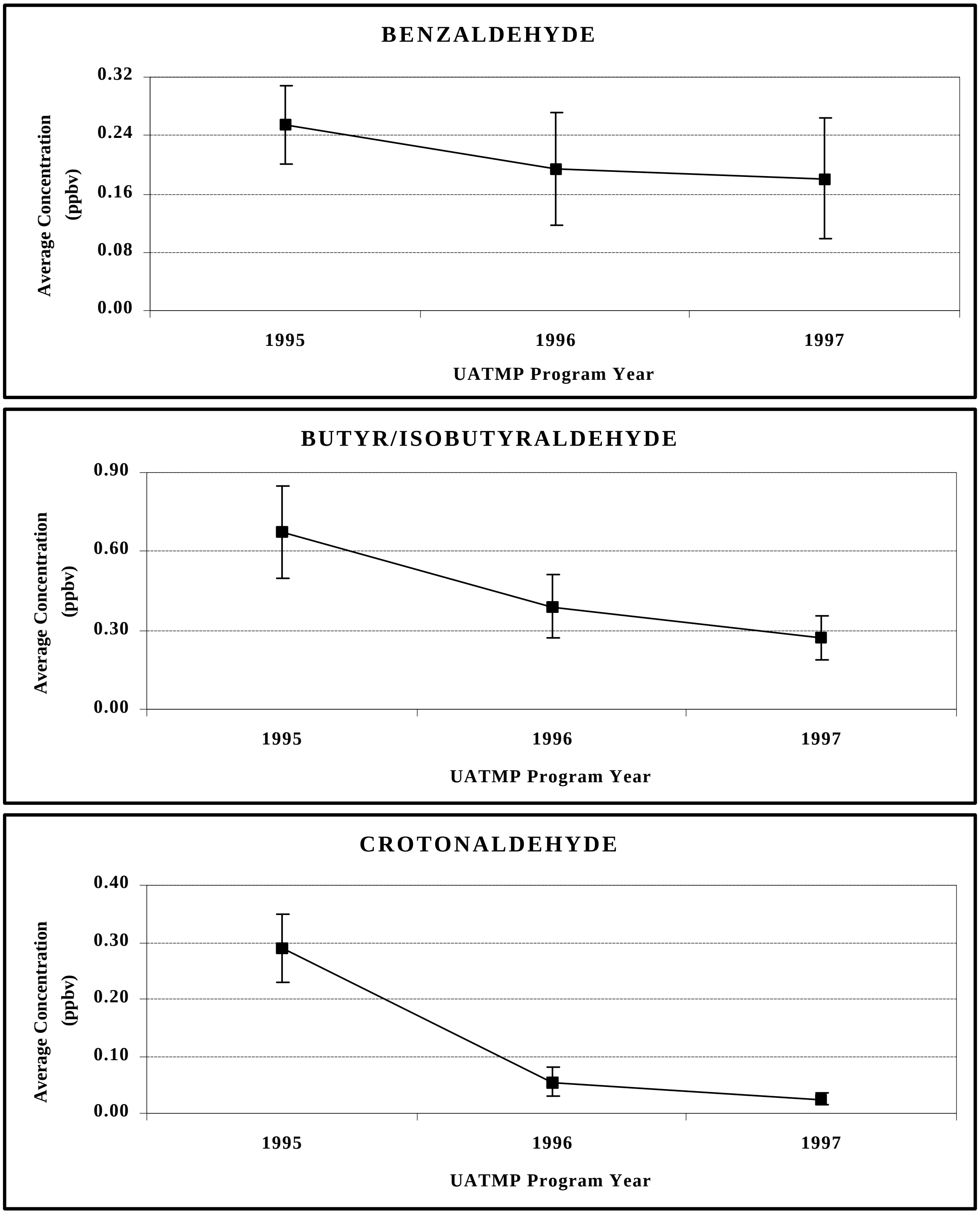
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 8-3 (Page 1 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at EPTX



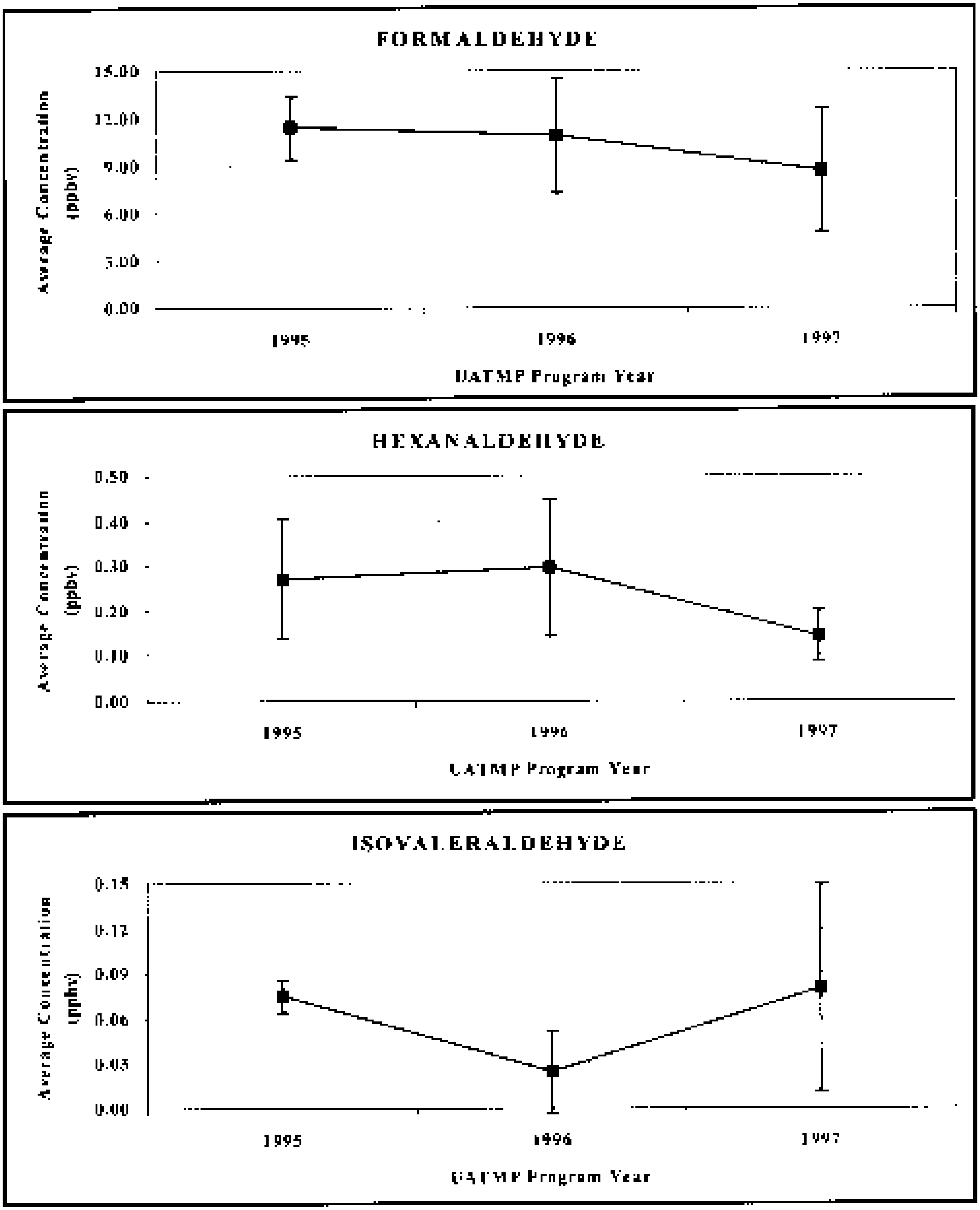
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 8-3 (Page 2 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at EPTX



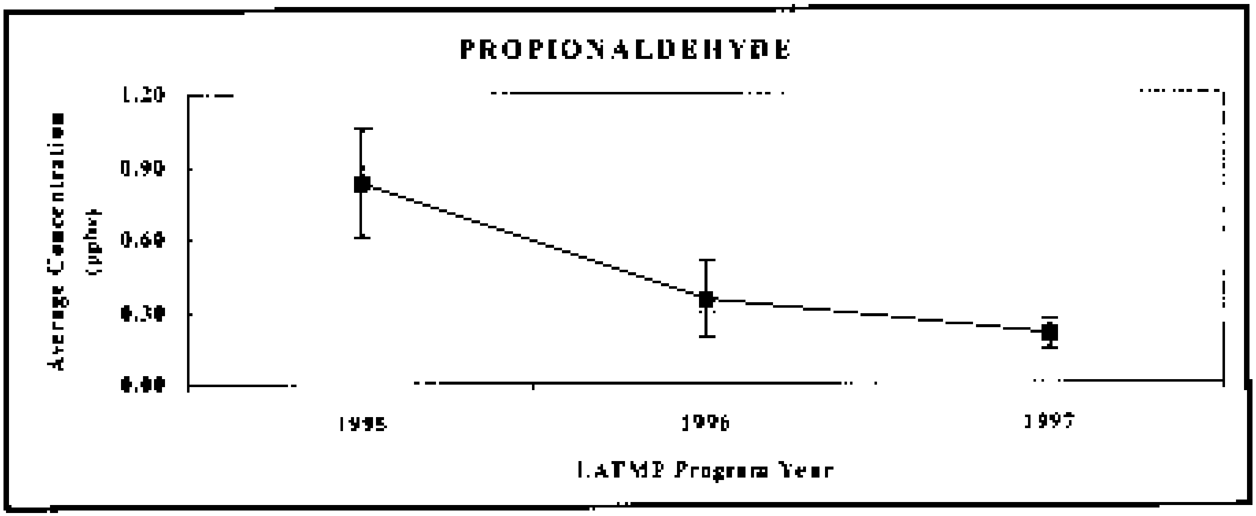
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

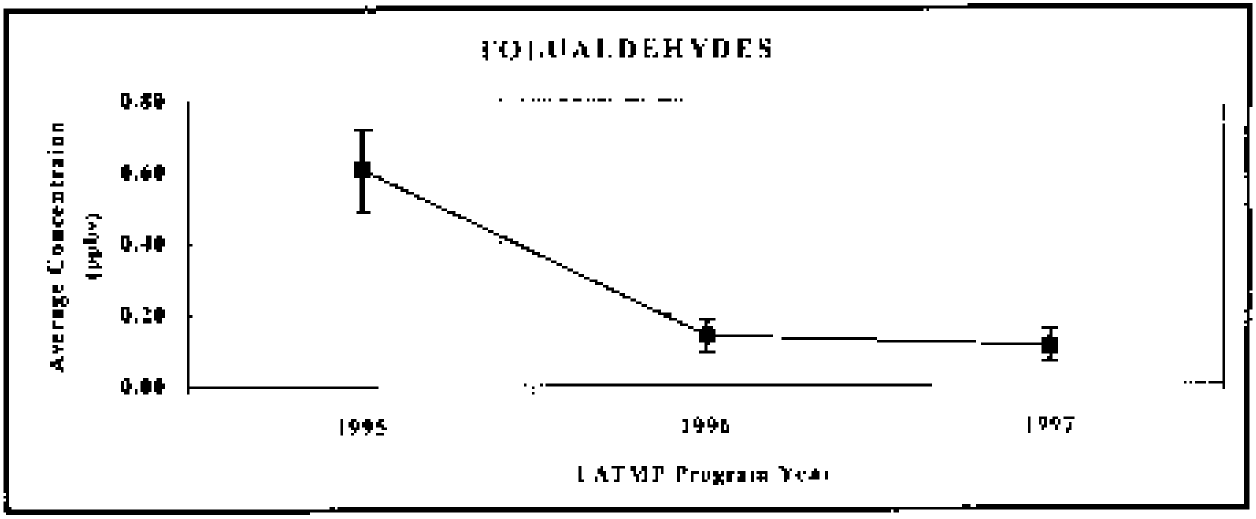
Figure 8-3 (Page 3 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at EPTX

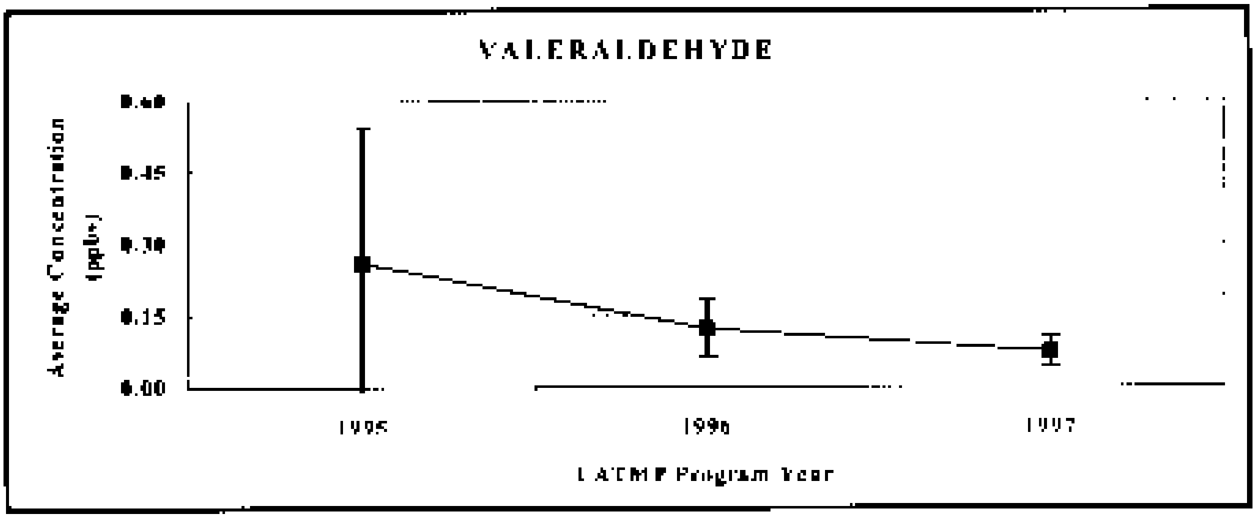


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95 percent confidence interval of the average concentration.

Figure 8-3 (Page 4 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at EPTX







Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration

Table 8-1
Summary Statistics for VOC Concentrations Measured at El Paso, Texas (EPTX)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	30	0%	ND	ND	0.29	0.24	0.23	0.08	0.32
Acetylene	**0**	**100%**	**0.77**	**10.06**	**4.20**	**4.61**	**4.04**	**2.14**	**0.46**
Acrylonitrile	27	10%	ND	1.74	0.11	0.17	0.10	0.32	1.88
Benzene	**0**	**100%**	**0.33**	**7.47**	**1.17**	**1.56**	**1.29**	**1.27**	**0.82**
Bromochloromethane	30	0%	ND	ND	0.05	0.04	0.04	0.01	0.27
Bromodichloromethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	29	3%	ND	0.12	0.08	0.07	0.07	0.01	0.15
Bromomethane	29	3%	ND	0.03	0.07	0.06	0.05	0.02	0.39
1,3-Butadiene	**4**	**87%**	**ND**	**1.24**	**0.19**	**0.25**	**0.18**	**0.23**	**0.93**
Carbon tetrachloride	**1**	**97%**	**ND**	**0.32**	**0.08**	**0.09**	**0.08**	**0.05**	**0.53**
Chlorobenzene	30	0%	ND	ND	0.04	0.03	0.03	0.01	0.20
Chloroethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.16
Chloromethane	**0**	**100%**	**0.21**	**1.60**	**0.69**	**0.67**	**0.62**	**0.26**	**0.38**
Chloroprene	30	0%	ND	ND	0.05	0.04	0.04	0.02	0.36
Dibromochloromethane	30	0%	ND	ND	0.08	0.06	0.06	0.02	0.38
m-Dichlorobenzene	29	3%	ND	0.13	0.08	0.07	0.07	0.02	0.25
o-Dichlorobenzene	30	0%	ND	ND	0.08	0.07	0.07	0.01	0.18

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 8-1 (Continued)
Summary Statistics for VOC Concentrations Measured at El Paso, Texas (EPTX)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	16	47%	ND	0.17	0.06	0.06	0.05	0.04	0.61
1,1-Dichloroethane	30	0%	ND	ND	0.05	0.04	0.04	0.02	0.36
1,2-Dichloroethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.13
trans-1,2-Dichloroethylene	30	0%	ND	ND	0.06	0.05	0.05	0.02	0.29
1,2-Dichloropropane	30	0%	ND	ND	0.02	0.03	0.02	0.01	0.42
cis-1,3-Dichloropropylene	30	0%	ND	ND	0.03	0.03	0.03	0.01	0.24
trans-1,3-Dichloropropylene	30	0%	ND	ND	0.06	0.05	0.04	0.02	0.38
Ethyl acrylate	30	0%	ND	ND	0.05	0.04	0.04	0.01	0.30
Ethylbenzene	**0**	**100%**	**0.14**	**2.68**	**0.43**	**0.54**	**0.44**	**0.47**	**0.87**
Ethyl *tert*-butyl ether	30	0%	ND	ND	0.04	0.03	0.03	0.00	0.13
Methylene chloride	**3**	**90%**	**ND**	**3.37**	**0.77**	**0.78**	**0.41**	**0.78**	**1.00**
Methyl ethyl ketone	**2**	**93%**	**ND**	**1.83**	**0.49**	**0.65**	**0.51**	**0.46**	**0.71**
Methyl isobutyl ketone	30	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl methacrylate	29	3%	ND	0.27	0.04	0.04	0.04	0.02	0.51
Methyl *tert*-butyl ether	26	13%	ND	1.07	0.03	0.09	0.04	0.21	2.41
***n*-Octane**	**2**	**93%**	**ND**	**0.65**	**0.15**	**0.18**	**0.15**	**0.11**	**0.62**
Propylene	**0**	**100%**	**0.41**	**7.38**	**1.35**	**1.62**	**1.39**	**1.23**	**0.76**
Styrene	**2**	**93%**	**ND**	**1.08**	**0.09**	**0.13**	**0.09**	**0.19**	**1.43**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 8-1 (Continued)
Summary Statistics for VOC Concentrations Measured at El Paso, Texas (EPTX)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	25	17%	ND	0.43	0.04	0.06	0.04	0.08	1.37
1,1,2,2-Tetrachloroethane	29	3%	ND	0.92	0.09	0.10	0.07	0.16	1.59
Tetrachloroethylene	18	40%	ND	0.15	0.06	0.07	0.06	0.04	0.51
Toluene	**0**	**100%**	**0.67**	**17.12**	**2.35**	**3.14**	**2.48**	**2.99**	**0.95**
1,1,1-Trichloroethane	**0**	**100%**	**0.02**	**0.26**	**0.10**	**0.11**	**0.10**	**0.05**	**0.48**
1,1,2-Trichloroethane	30	0%	ND	ND	0.06	0.05	0.04	0.02	0.38
Trichloroethylene	23	23%	ND	0.37	0.02	0.05	0.03	0.07	1.50
Vinyl chloride	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.07
***m,p*-Xylene**	**0**	**100%**	**0.38**	**7.68**	**1.26**	**1.56**	**1.26**	**1.34**	**0.86**
***o*-Xylene**	**1**	**97%**	**ND**	**3.58**	**0.57**	**0.70**	**0.54**	**0.64**	**0.91**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 8-2
Summary Statistics for Carbonyl Concentrations Measured at El Paso, Texas (EPTX)
(Based on 29 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.04**	**10.75**	**1.62**	**2.75**	**1.57**	**2.66**	**0.97**
Acetone	**0**	**100%**	**0.05**	**7.68**	**1.81**	**2.18**	**1.49**	**1.81**	**0.83**
Acrolein	**1**	**97%**	**ND**	**0.82**	**0.04**	**0.12**	**0.04**	**0.20**	**1.75**
Benzaldehyde	**1**	**97%**	**ND**	**0.89**	**0.09**	**0.18**	**0.09**	**0.22**	**1.21**
Butyr/Isobutyraldehyde	**2**	**93%**	**ND**	**0.84**	**0.20**	**0.27**	**0.16**	**0.22**	**0.81**
Crotonaldehyde	**13**	**55%**	**ND**	**0.09**	**0.01**	**0.03**	**0.01**	**0.03**	**1.16**
2,5-Dimethylbenzaldehyde	16	45%	ND	0.06	0.00	0.01	0.01	0.01	1.42
Formaldehyde	**0**	**100%**	**0.13**	**37.99**	**4.69**	**8.68**	**4.52**	**10.24**	**1.18**
Hexanaldehyde	**0**	**100%**	**0.01**	**0.50**	**0.06**	**0.14**	**0.07**	**0.15**	**1.04**
Isovaleraldehyde	**12**	**59%**	**ND**	**0.77**	**0.01**	**0.08**	**0.02**	**0.18**	**2.27**
Propionaldehyde	**1**	**97%**	**ND**	**0.63**	**0.15**	**0.21**	**0.13**	**0.17**	**0.81**
Tolualdehydes	**2**	**93%**	**ND**	**0.50**	**0.08**	**0.11**	**0.07**	**0.12**	**1.06**
Valeraldehyde	**1**	**97%**	**ND**	**0.39**	**0.04**	**0.07**	**0.04**	**0.08**	**1.16**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1)

9.0 Monitoring Results for North Little Rock, AR (PARR)

This section focuses on ambient air monitoring data collected at the North Little Rock, Arkansas (PARR), monitoring station during the 1997 UATMP. As Figure 9-1 shows, the monitors at PARR are adjacent to a railroad track, a diesel tank farm, vacant land, a residential neighborhood, and the Arkansas River. The downtown area of Little Rock, the largest city in Arkansas, is located immediately across the Arkansas River from PARR. Three interstate highways (I-30, I-40, and I-630) and numerous heavily traveled surface streets pass within approximately 1 mile of the monitoring station.

During the 1997 UATMP, the monitors at PARR collected samples from February to August, 1998. Thus, only 7 months of data are available for this station. While most sites participating in the UATMP collected samples roughly biweekly, PARR generally sampled once a week, on a total of 33 occasions. Overall, valid VOC samples were collected on 32 days, and valid carbonyl samples were collected on 24 days, which is equivalent to a completeness of 97 percent for VOC and 73 percent for carbonyls.

The remainder of this section summarizes the 1997 UATMP monitoring data for PARR (Section 9.1), analyzes in detail air quality trends for selected nitriles and oxygenated compounds (Section 9.2), and examines other notable characteristics of the 1997 monitoring data collected at PARR (Section 9.3). Section 9.4 summarizes the main findings of the section. This section does not consider annual variations, since the PARR monitoring station did not participate in earlier UATMPs and no historical air monitoring data for the station are readily available for comparison.

9.1 Data Summary Parameters for the 1997 UATMP

Using the data summary parameters defined in Section 3.1, Tables 9-1 and 9-2 summarize the 1997 VOC and carbonyl monitoring data, respectively, for PARR. To facilitate comparisons with air quality trends for other cities, the format used in these summary tables is identical to that used throughout this report and in earlier UATMP final reports.

9.1.1 Data Summary of VOC

Table 9-1 reveals the following characteristics regarding ambient air concentrations of VOC at North Little Rock, Arkansas:

- *Prevalence.* According to the data summary table, 15 of the 47 compounds that the VOC analytical method could identify were detected in more than half the samples collected at PARR. These most prevalent compounds are:

  Acetylene
  Benzene
  Carbon tetrachloride
  Chloromethane
  Ethylbenzene
  Methylene chloride
  Methyl ethyl ketone
  n-Octane
  Propylene
  Tetrachloroethylene
  Toluene
  1,1,1-Trichloroethane
  m,p-Xylene
  o-Xylene

  Since these compounds were detected in most of the samples, their summary statistics are biased least by nondetect observations, which are assigned an estimated concentration of one-half the detection limit. As a result, most of the discussion in this section focuses on these 15 most prevalent compounds. It should not be inferred, however, that other VOC are not present in the ambient air at PARR. They may be present at varying concentrations over time or consistently at levels that the VOC analytical method cannot measure.

- *Concentration Range*. Table 9-1 also indicates the range of ambient air concentrations of VOC measured at PARR. Of the 47 compounds identified by the VOC analytical method, only 7—acetonitrile, acetylene, chloromethane, methylene chloride, methyl ethyl ketone, propylene, and toluene—were measured at concentrations greater than 1.0 ppbv. The highest concentrations observed at PARR during the 1997 UATMP were 5.02 ppbv of acetylene, 2.98 ppbv of methyl ethyl ketone, and 2.46 ppbv of toluene. Since samples were not collected daily, it is likely that the actual maximum 24-hour average concentrations of VOC occurred on days when samples were not collected. Therefore, the concentration ranges in Table 9-1 should be viewed as estimates of the actual span of concentrations at PARR.

- *Central Tendency*. Table 9-1 presents medians, arithmetic means, and geometric means as three different measures of the central tendency concentrations for VOC. As noted earlier, the summary statistics for the most prevalent compounds (i.e., those shown in Table 9-1 in boldface) are believed to be most accurate. Central tendency values for compounds detected in fewer than half of the samples should be interpreted with caution, as the high frequency of nondetects probably biases the central tendency calculations. When interpreting the central tendency data, it is also important to note that they may not reflect annual average concentrations, since only 7 months of monitoring data were collected at this site.

Of the 15 most prevalent VOC at PARR, the highest geometric mean concentrations were observed for acetylene (1.16 ppbv), chloromethane (0.88 ppbv), toluene (0.64 ppbv), propylene (0.57 ppbv), and methyl ethyl ketone (0.56 ppbv). Every other VOC had geometric mean concentrations less than 0.50 ppbv. Data analyses in Sections 9.2 and 9.3 identify the factors that appear to most significantly affect ambient air concentrations of these compounds.

As Figure 3-1 shows, the geometric mean concentrations of the most prevalent VOC at North Little Rock, Arkansas, were not unusually higher or lower than those at the other monitoring stations that participated in the 1997 UATMP, with the possible exceptions of carbon tetrachloride and chloromethane. Although the highest geometric mean concentration of carbon tetrachloride during the 1997 UATMP was observed at PARR, the geometric mean concentration at every other monitoring station was only marginally lower. Similarly, the second highest geometric mean concentration of chloromethane was observed at PARR, but levels at several other stations (GALA, GREY, and HALA) were comparable to those at PARR. In short, ambient air concentrations of carbon tetrachloride and chloromethane were relatively high at PARR, when compared to those observed at the other UATMP monitoring stations, but not significantly so. Section 9.3 discusses air quality trends for these compounds in greater detail.

Note: When interpreting the spatial variations shown in Figure 3-1, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States and only at discrete locations within these areas. Therefore, additional comparisons of air monitoring data from other sampling programs are encouraged to assess how levels of air pollution in North Little Rock compare to other locations in the state and in the country.

- *Variability*. The coefficients of variation for the most prevalent VOC were all lower than 0.75, except for that of methylene chloride, which was 1.55. The similar variability for these VOC suggests that relative changes in ambient air concentrations from sample to sample are not notably different. However, levels of methylene chloride exhibited the greatest variability (on a relative scale)—a trend suggesting that the measured concentrations were affected most by time-dependent parameters, such as changing emissions levels and meteorological conditions. Since motor vehicle emissions do not change dramatically over time in most urban settings, the variability for methylene chloride probably results from emissions originating at discrete locations (e.g., industrial sources) and transporting to the PARR monitors under certain meteorological conditions. Section 9.3 revisits this issue.

To provide additional insight into the VOC monitoring data collected in North Little Rock, Arkansas, Section 9.2 analyzes and interprets air quality trends for selected nitriles and oxygenated compounds, and Section 9.3 describes other notable characteristics of the VOC monitoring data.

9.1.2 Data Summary of Carbonyls

The summary statistics in Table 9-2 indicate the following trends regarding ambient air concentrations of carbonyls at PARR:

- *Prevalence*. As Table 9-2 shows, every carbonyl considered in the 1997 UATMP, except for crotonaldehyde and 2,5-dimethylbenzaldehyde, was detected in at least half of the samples collected at PARR. As a result, nondetect observations, which are assigned an estimated concentration of one-half the detection limit, probably introduce little bias into the summary statistics for the carbonyls. Otherwise stated, the summary statistics shown in Table 9-2 for the most prevalent carbonyls are believed to represent actual air quality trends in the North Little Rock area.

- *Concentration Range*. Of the 16 carbonyls listed in Table 9-2, only acetaldehyde, acetone, and formaldehyde had ambient air concentrations greater than 1.0 ppbv during the 7 months of sampling at PARR. In fact, almost every concentration of formaldehyde exceeded 1.0 ppbv, just over one-half of the concentrations of acetone exceeded this level, and roughly one-third of the concentrations of acetaldehyde exceeded this level. The highest concentration observed for formaldehyde (6.76 ppbv) was higher than those observed for all other compounds at PARR, including VOC. When reviewing this data on highest concentrations, it is important to note that the ranges listed in Table 9-2 only estimate the actual ranges; concentrations may have reached higher and lower levels on nonsampling days.

- *Central Tendency*. According to Table 9-2, geometric mean concentrations for most carbonyls at PARR were below 0.15 ppbv. As exceptions, the geometric mean concentrations of acetaldehyde, acetone, and formaldehyde were 0.78 ppbv, 0.83 ppbv, and 2.55 ppbv, respectively. The combined concentration of these three carbonyls account for over 90 percent of the total carbonyls detected at PARR during the 1997 UATMP—a data trend that was observed at almost every monitoring station that participated in the current program.

To provide insight into how levels of air pollution at PARR compared to those in other parts of the country, Figure 3-2 presents geometric mean concentrations of the most prevalent carbonyls observed at the 12 monitoring stations that participated in the 1997 UATMP. From this figure, it is apparent that ambient levels of most carbonyls at PARR were not unusually higher or lower than those at the other monitoring stations. As the only exception, the geometric mean concentration of acrolein at PARR (0.04 ppbv) ranked second highest among those observed at the UATMP monitoring stations. However, it is unclear whether this trend is meaningful, since the concentration at PARR is only marginally higher than those observed at other stations. Section 9.3 provides more details on air quality trends for carbonyls at PARR.

Note: As discussed earlier and throughout this report, it is important to interpret the graphs in Figure 3-2 in proper context: the bar charts in the figure indicate levels of air pollution observed at specific monitoring locations within a city and do not necessarily represent air quality throughout that entire urban area. Thus, it is possible that concentrations of carbonyls in parts of the Little Rock metropolitan area are notably higher or lower than national averages, even though the data from PARR suggest that this is probably not the case.

- *Variability*. The most prevalent carbonyls at PARR all had coefficients of variation less than or equal to 1.00. This comparable variability suggests that concentrations of carbonyls do not fluctuate greatly with time, regardless of changing prevailing wind patterns. The comparable, and relatively low, variability for the carbonyls is consistent with the assumption that these compounds originated primarily from emissions sources that are located throughout the Little Rock area (e.g., cars) or as the result of other regional phenomena (e.g., as the product of photochemical reactions). One would expect to see much greater variability for these compounds if only a few emissions sources in the area emitted them. Section 9.3 comments further on the likely sources of carbonyls in the North Little Rock area.

For additional reference, Section 12.1 provides a general overview of carbonyl monitoring data collected at all 12 monitoring stations that participated in the 1997 UATMP.

9.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

This section analyzes and interprets air quality trends for nine compounds (all nitriles and oxygenated compounds) that were measured during the 1997 UATMP, but not during previous program years. As discussed below, most of these compounds were rarely, if ever, detected at PARR:

- *Compounds that were rarely, if ever, detected*. Of the nine nitriles and oxygenated compounds, all but methyl ethyl ketone were detected in fewer than 10 percent of the valid sampling events at North Little Rock. Thus, it is difficult to draw any conclusions about the ambient air concentrations for these eight compounds: acetonitrile, acrylonitrile, ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, methyl methacrylate, methyl *tert*-butyl ether, and *tert*-amyl methyl ether. If these compounds are consistently present in the air at PARR, they must be present at levels less than the detection limits listed in Table 2-2.

  With one exception, which is discussed below, the TRI emissions data available at the writing of this report are generally consistent with the fact that the eight nitriles and oxygenated compounds listed above were rarely, if ever, detected in the air at North Little Rock. According to the 1995 TRI data, no industrial facilities within 10 miles of PARR reported releasing acetonitrile, acrylonitrile, methyl methacrylate, and methyl *tert*-butyl ether to the air. Since facilities were not required to report their uses of ethyl *tert*-butyl ether or *tert*-amyl methyl ether to TRI, little can be said about emissions of these compounds. However, given that neither compound was detected at PARR during the entire 1997 UATMP, it is likely that local industrial emissions of these two ethers are probably insignificant.

  Of the eight nitriles and oxygenated compounds that were rarely, if ever, detected, only methyl isobutyl ketone had emissions data from sources near PARR in the 1995 TRI: a facility roughly 3 miles from the monitoring station reported emitting 11,200 pounds of methyl isobutyl ketone to the air during the 1995 reporting year, and a facility roughly 6 miles away reported emitting 864 pounds of the compound. The extent to which emissions from these facilities might have contributed to the three detections of methyl isobutyl ketone at PARR is unknown. Analyses of future monitoring data from this site can help determine if periodic detections of the compound at PARR are typical or if the detections during the 1997 UATMP were spurious.

- *Methyl ethyl ketone*. Methyl ethyl ketone was detected in 97 percent of the samples collected at PARR, and its geometric mean concentration was 0.56 ppbv. This level ranked fourth highest of the geometric mean concentrations of methyl ethyl ketone observed at all monitoring stations during the 1997 UATMP. There is evidence that airborne levels of methyl ethyl ketone at PARR exhibited a seasonal trend: ambient air concentrations of the compound from June to August were, on average, nearly 50 percent higher than those from February to May. Since only 7 months of monitoring data were collected at this station, however, it is uncertain whether this seasonal trend persists over the longer term.

Though the 7 months of monitoring data considered in this report may be insufficient for identifying the predominant sources of methyl ethyl ketone at PARR, patterns among the data are generally consistent with the assumption that the compound originates primarily from industrial sources or as the product of photochemical reactions, and not from motor vehicles. For instance, the concentrations of methyl ethyl ketone at PARR were found to be weakly correlated, if not completely uncorrelated, with concentrations of compounds typically found in motor vehicle exhaust (including benzene, ethylbenzene, toluene, and the xylene isomers). This lack of correlations suggests that the primary source of methyl ethyl ketone in North Little Rock is probably not motor vehicles emissions, even though cars are known to emit the compound.

The industrial emissions data reported to the 1995 TRI offer a better explanation for the likely sources of methyl ethyl ketone at PARR, but the TRI data do not include emissions from small facilities that are not subject to the reporting requirements (see Section 3.2). According to the 1995 TRI, four facilities within 10 miles of the North Little Rock monitoring station reported releasing a total of 79,445 pounds of methyl ethyl ketone to the air. Since three of these facilities are located southeast of the monitoring station, and since their combined emissions are nearly 73,000 pounds, analyses of prevailing wind patterns on sampling days may help determine the extent to which these three facilities affect concentrations of methyl ethyl ketone at PARR. Such analyses are planned for the final report for the 1998 UATMP.

9.3 Other Notable Characteristics

For additional insight into the ambient air monitoring data collected at PARR, the following analyses characterize the average composition of the air samples from this station, the magnitude of industrial emissions within 10 miles of PARR, and data correlations that may not be readily apparent from a cursory inspection of the monitoring data:

- *Composition of air samples*. When analyzing trends in air quality, it is important to consider both the magnitude and the composition of air pollution. As an indicator of the chemical composition of the air samples collected at PARR during the 1997 UATMP, Figure 9-2 indicates the relative quantities of the most prevalent carbonyls, halogenated hydrocarbons, and hydrocarbons. The basis for this composition calculation was the geometric mean concentrations of the 29 compounds (15 carbonyls[1], 5 halogenated hydrocarbons, and 9 hydrocarbons) that were detected at measurable levels in at least half of the samples collected at this monitoring station. As the figure shows, carbonyls accounted for 51 percent of the total concentration of the most prevalent compounds, with hydrocarbons and halogenated hydrocarbons accounting for 36 percent and 13 percent, respectively. Not shown in the figure is the fact that formaldehyde alone accounted for just over 25 percent of the total concentration of the most prevalent compounds. Such relative composition data, along with the relative toxicities of individual compounds, may help regulatory agencies prioritize their ongoing air pollution control efforts.

When interpreting the data in Figure 9-2, it is important to note that the composition data are based only on the compounds that the VOC and carbonyl analytical methods could identify, which represents a small subset of all components of urban air pollution. Thus, the composition data are useful for appreciating the relative amounts of selected carbonyls, halogenated hydrocarbons, and hydrocarbons, but information on ambient air concentrations of other components typically found in urban air (e.g., inorganic acids, metals, semivolatile organic compounds, and so on) would be needed to understand the overall composition of air pollution at PARR.

- *Summary of emissions data reported to TRI*. To better understand the sources of air pollution in the Little Rock metropolitan area, Table 9-3 summarizes emissions data that industrial facilities located within 10 miles of PARR reported to the 1995 TRI. Because the TRI reporting requirements do not apply to all industries and generally do not apply to small businesses, the emissions data in Table 9-3 provide a very rough estimate, and probably an underestimate, of the actual air emissions from industrial sources in the vicinity of North Little Rock.

  Despite the limitations associated with TRI emissions data, which Section 3.2 describes in detail, the information in Table 9-3 helps explain several aspects of the ambient air monitoring data collected at PARR. For example, none of the facilities in the Little Rock metropolitan area reported releases of aldehydes to TRI. Thus, it is unlikely that the levels of acetaldehyde and formaldehyde observed at PARR originated primarily from industrial facilities, at least from the manufacturing industries that are subject to the TRI reporting requirements. Further research is needed to determine the extent to which aldehydes measured at PARR originated from mobile sources, natural emissions sources, photochemical reactions, and

---

[1] Though it is measured by the VOC analytical method, methyl ethyl ketone technically is a carbonyl and was classified as such for purposes of calculating composition data.

industrial sources not subject to the 1995 TRI reporting requirements (e.g., incinerators, electric utilities).

Another important feature in Table 9-3 is the fact that air emissions of methylene chloride (120,535 pounds) were notably higher than those for every other compound subject to the 1995 TRI reporting requirements. This finding supports the hypothesis, raised in Section 9.1.1, that the levels of methylene chloride detected at PARR probably originated, to a certain extent, from industrial emissions sources in the area. Understanding the impacts from these sources is complicated by the fact that methylene chloride is a common component of many industrial solvents, coatings, and consumer products, and is therefore likely to be emitted by sources throughout the Little Rock metropolitan area. Analyses of local emissions inventories that are more comprehensive than TRI might provide greater insight into the origins of the methylene chloride measured at PARR.

In addition to methylene chloride, the emissions data in Table 9-3 indicate that industrial facilities in the Little Rock metropolitan area released to the air relatively large quantities of methyl ethyl ketone (79,445 pounds), toluene (85,723 pounds), and xylenes (86,250 pounds). Section 9.2 discussed the significance of the reported emissions of methyl ethyl ketone. Though the emissions reported for toluene and xylenes undoubtedly affect air quality at PARR, it has been well documented that motor vehicles also emit large quantities of these and other aromatic compounds (Conner et al., 1995). Because several heavily-traveled roadways are much closer to PARR than are the industrial emissions sources listed in Table 9-3, the amounts of toluene and xylenes measured during the 1997 UATMP probably originated largely from nearby mobile sources, and, to a lesser but unknown extent, from industrial sources. The correlation data, presented below, support this hypothesis.

Although qualitative comparisons between emissions data and ambient air monitoring data are useful for characterizing certain air quality trends, these comparisons are insufficient for gaining a comprehensive understanding of the factors affecting air pollution at PARR. A more extensive emissions inventory of local sources and detailed atmospheric dispersion modeling analyses are needed to assess the impact of industrial emissions more quantitatively. Such analyses, however, are not included in the scope of work for this contract.

- *Data correlations*. The extent to which concentrations of different compounds are correlated is an important element for understanding the sources of urban air pollution: compounds with highly correlated ambient air monitoring data likely originate from the same groups of sources; and compounds with weakly correlated ambient air monitoring data are probably affected by different factors. To quantify the correlations among the ambient air monitoring data collected at PARR, Pearson correlation coefficients were calculated for the 300 different possible pairings of the most prevalent VOC and carbonyls.

As described in greater detail in earlier UATMP reports and in most introductory statistics texts, Pearson correlation coefficients characterize data correlations as follows: (1) A correlation coefficient of -1 indicates a perfectly “negative” relationship, or a relationship in which increases in the magnitude of one parameter are associated with proportionate decreases in the magnitude of the other parameter, and vice versa. (2) A Pearson correlation coefficient of 0 indicates completely uncorrelated data, or a relationship in which the data trends of one parameter cannot be explained by the data trends in the other. (3) A Pearson correlation coefficient of 1 indicates a perfectly “positive” relationship, or a relationship in which the magnitudes of two parameters both increase and decrease proportionately. In short, the sign (positive or negative) and the magnitude of Pearson correlation coefficients indicate the direction and strength, respectively, of data correlations. The Pearson correlation coefficients presented in this report are only for pairwise correlations; thus, potential multivariate relationships were not examined.

To summarize the most notable data correlations observed at PARR, Table 9-4 lists the 11 pairs of compounds that had Pearson correlation coefficients greater than 0.70. Several observations can be made from this brief summary of data correlations. First, ambient air concentrations for the so-called BTEX compounds (benzene, toluene, ethylbenzene, and the xylene isomers) clearly had the strongest correlations of all pairs of compounds at PARR. In fact, the correlations between the xylene isomers and ethylbenzene were so strong as to suggest a nearly perfect linear relationship between their air concentrations. The strong data correlations provide compelling evidence that the BTEX compounds measured at PARR may originate, to a large extent, from the same group of sources. These sources most likely include motor vehicles and possibly include the tank farm adjacent to the monitoring station.

Second, relatively strong correlations were observed for three pairs of carbonyls (acetaldehyde and propionaldehyde, acrolein and methyl ethyl ketone, and formaldehyde and isovaleraldehyde), which indicates that each of these pairs may originate from similar sources. The fact that concentrations of these compounds were very weakly correlated with concentrations of BTEX compounds suggests that motor vehicle emissions may not be the primary source of the listed carbonyls. However, the correlation data cannot rule out the possibility that photochemical reactions involving motor vehicle emissions may produce carbonyls in the air. Further research is encouraged to determine the extent to which photochemical reactions affect ambient air concentrations of carbonyls at PARR.

> Third, the most prevalent halogenated hydrocarbons were relatively weakly correlated with all other compounds, including carbonyls, hydrocarbons, and other halogenated hydrocarbons. The absence of notable correlations for halogenated hydrocarbons suggests that the factors affecting ambient air concentrations of each compound may be unique. At the very least, the weak correlations between the BTEX compounds and halogenated hydrocarbons emphasizes that mobile source emissions probably have a minor influence on ambient air concentrations of the halogenated hydrocarbons—a finding consistently noted for other monitoring locations in earlier UATMP reports.

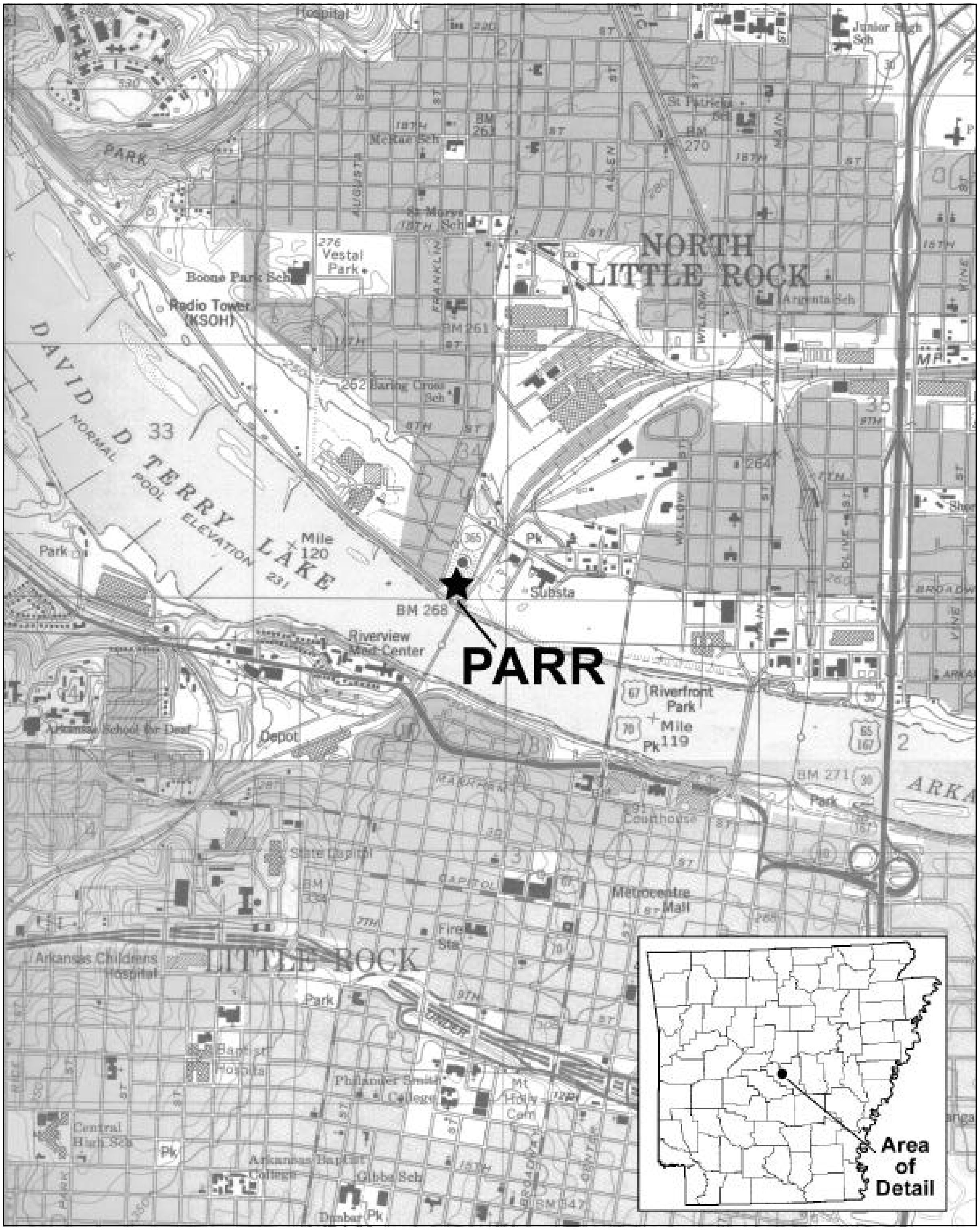
9.4 Summary

During the 1997 UATMP, ambient air concentrations of 63 compounds (47 VOC and 16 carbonyls) were measured at the North Little Rock, Arkansas, monitoring station. Overall, 15 VOC and 14 carbonyls were detected in over half of the samples collected at PARR. On average, concentrations of acetaldehyde, acetone, acetylene, chloromethane, formaldehyde, methyl ethyl ketone, propylene, and toluene were consistently higher than those of other compounds. In general, carbonyls accounted for 51 percent of the air pollution measured at PARR during the 1997 UATMP, while hydrocarbons and halogenated hydrocarbons accounted for 36 percent and 13 percent, respectively. However, these composition estimates do not include contributions from many other components of urban air pollution not considered in this program.

The 1997 UATMP measured concentrations of a group of compounds (i.e., nine nitriles and oxygenated compounds) that were not measured during earlier programs. Of these nine compounds, only methyl ethyl ketone was detected in more than half of the samples collected at PARR. Trends among the air monitoring data suggested that emissions from industrial facilities or photochemical reactions may be the primary sources of ambient concentrations of methyl ethyl ketone at PARR, but there was little evidence from these trends that mobile source emissions account for a large portion of the airborne methyl ethyl ketone at this station. Further research is encouraged to determine the extent to which emissions from four specific industrial facilities in the area (i.e., those facilities that reported emissions to TRI) might explain the air quality trends for this compound.

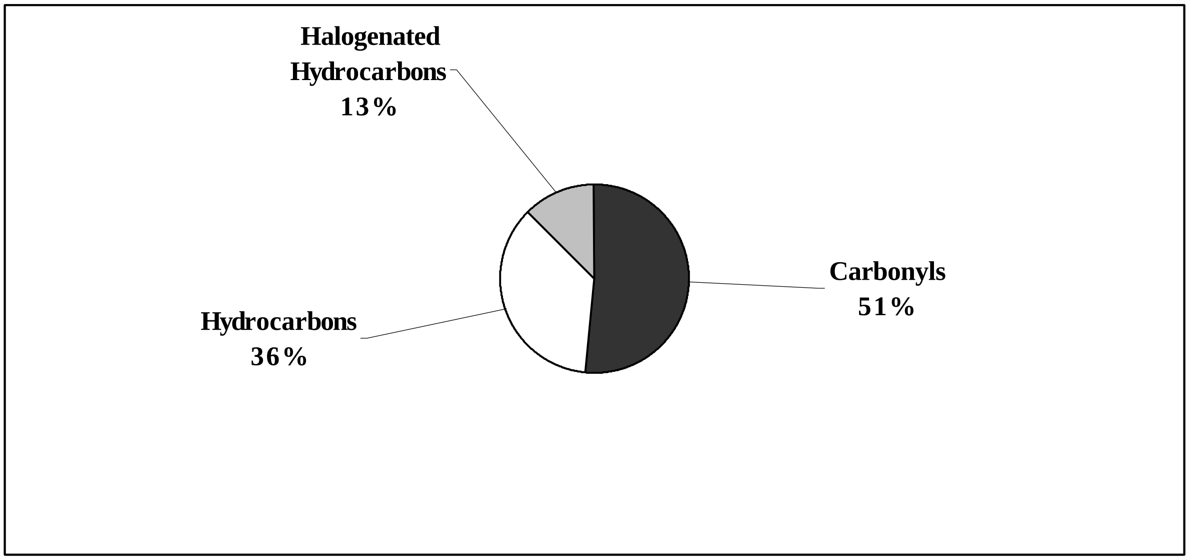
On a qualitative level, some trends in the monitoring data were consistent with TRI emissions data, but further analyses of detailed local emissions inventories are encouraged for a more complete understanding of the factors affecting air pollution in North Little Rock.

Figure 9-1
North Little Rock, Arkansas (PARR), Monitoring Station



Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 9-2
Composition of Air Samples at PARR



Note: As Section 9.3 explains, the composition data in this figure should be viewed only as *an indicator* of the composition of air pollution at PARR. Because this figure considers only the most prevalent compounds measured during the 1997 UATMP, and because the UATMP does not measure concentrations of every component of air pollution, this figure does not present the actual composition of air pollution at PARR.

Table 9-1
Summary Statistics for VOC Concentrations Measured at North Little Rock, Arkansas (PARR)
(Based on 32 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	30	6%	ND	1.53	0.20	0.25	0.19	0.27	1.09
Acetylene	**0**	**100%**	**0.39**	**5.02**	**1.15**	**1.32**	**1.16**	**0.84**	**0.63**
Acrylonitrile	31	3%	ND	0.34	0.07	0.07	0.06	0.06	0.82
Benzene	**0**	**100%**	**0.17**	**0.76**	**0.41**	**0.44**	**0.41**	**0.15**	**0.34**
Bromochloromethane	32	0%	ND	ND	0.03	0.03	0.03	0.01	0.39
Bromodichloromethane	31	3%	ND	0.12	0.03	0.03	0.03	0.02	0.58
Bromoform	32	0%	ND	ND	0.07	0.07	0.07	0.01	0.11
Bromomethane	29	9%	ND	0.07	0.07	0.05	0.04	0.03	0.54
1,3-Butadiene	20	38%	ND	0.11	0.04	0.04	0.04	0.02	0.55
Carbon tetrachloride	**0**	**100%**	**0.07**	**0.29**	**0.09**	**0.10**	**0.10**	**0.04**	**0.39**
Chlorobenzene	32	0%	ND	ND	0.03	0.03	0.03	0.01	0.28
Chloroethane	31	3%	ND	0.08	0.03	0.03	0.03	0.01	0.28
Chloroform	29	9%	ND	0.09	0.03	0.03	0.03	0.02	0.53
Chloromethane	**0**	**100%**	**0.31**	**1.63**	**0.86**	**0.91**	**0.88**	**0.24**	**0.26**
Chloroprene	32	0%	ND	ND	0.03	0.03	0.03	0.02	0.55
Dibromochloromethane	32	0%	ND	ND	0.05	0.05	0.04	0.03	0.59
m-Dichlorobenzene	32	0%	ND	ND	0.06	0.06	0.06	0.02	0.25
o-Dichlorobenzene	31	3%	ND	0.03	0.07	0.06	0.06	0.02	0.25

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 9-1 (Continued)
Summary Statistics for VOC Concentrations Measured at North Little Rock, Arkansas (PARR)
(Based on 32 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	30	6%	ND	0.03	0.05	0.05	0.05	0.01	0.27
1,1-Dichloroethane	32	0%	ND	ND	0.03	0.03	0.03	0.02	0.55
1,2-Dichloroethane	32	0%	ND	ND	0.04	0.04	0.03	0.01	0.15
trans-1,2-Dichloroethylene	32	0%	ND	ND	0.04	0.04	0.04	0.02	0.42
1,2-Dichloropropane	32	0%	ND	ND	0.03	0.03	0.03	0.01	0.39
cis-1,3-Dichloropropylene	32	0%	ND	ND	0.02	0.02	0.02	0.01	0.34
trans-1,3-Dichloropropylene	32	0%	ND	ND	0.04	0.04	0.03	0.02	0.58
Ethyl acrylate	32	0%	ND	ND	0.04	0.04	0.03	0.02	0.44
Ethylbenzene	**0**	**100%**	**0.06**	**0.38**	**0.16**	**0.18**	**0.16**	**0.09**	**0.51**
Ethyl *tert*-butyl ether	32	0%	ND	ND	0.03	0.03	0.03	0.01	0.17
Methylene chloride	**6**	**81%**	**ND**	**1.62**	**0.13**	**0.19**	**0.12**	**0.30**	**1.55**
Methyl ethyl ketone	**1**	**97%**	**ND**	**2.98**	**0.59**	**0.71**	**0.56**	**0.53**	**0.74**
Methyl isobutyl ketone	29	9%	ND	0.30	0.04	0.05	0.04	0.05	1.05
Methyl methacrylate	31	3%	ND	0.16	0.03	0.04	0.03	0.02	0.63
Methyl *tert*-butyl ether	29	9%	ND	0.14	0.03	0.03	0.02	0.02	0.82
***n*-Octane**	**4**	**88%**	**ND**	**0.61**	**0.14**	**0.14**	**0.12**	**0.10**	**0.73**
Propylene	**0**	**100%**	**0.08**	**1.63**	**0.61**	**0.65**	**0.57**	**0.31**	**0.48**
Styrene	17	47%	ND	0.20	0.06	0.07	0.06	0.04	0.56
tert-Amyl methyl ether	32	0%	ND	ND	0.03	0.03	0.03	0.00	0.08

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 9-1 (Continued)
Summary Statistics for VOC Concentrations Measured at North Little Rock, Arkansas (PARR)
(Based on 32 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
1,1,2,2-Tetrachloroethane	31	3%	ND	0.05	0.04	0.05	0.05	0.03	0.56
Tetrachloroethylene	**13**	**59%**	**ND**	**0.17**	**0.05**	**0.06**	**0.05**	**0.04**	**0.65**
Toluene	**0**	**100%**	**0.24**	**2.46**	**0.61**	**0.74**	**0.64**	**0.45**	**0.62**
1,1,1-Trichloroethane	**0**	**100%**	**0.06**	**0.20**	**0.10**	**0.11**	**0.10**	**0.04**	**0.34**
1,1,2-Trichloroethane	32	0%	ND	ND	0.04	0.04	0.03	0.02	0.58
Trichloroethylene	31	3%	ND	0.03	0.03	0.03	0.02	0.01	0.21
Vinyl chloride	32	0%	ND	ND	0.03	0.03	0.03	0.00	0.08
***m,p*-Xylene**	**0**	**100%**	**0.15**	**0.89**	**0.36**	**0.41**	**0.37**	**0.20**	**0.49**
***o*-Xylene**	**0**	**100%**	**0.07**	**0.42**	**0.19**	**0.21**	**0.18**	**0.10**	**0.50**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 9-2
Summary Statistics for Carbonyl Concentrations Measured at North Little Rock, Arkansas (PARR)
(Based on 24 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.41**	**1.29**	**0.84**	**0.83**	**0.78**	**0.27**	**0.33**
Acetone	**0**	**100%**	**0.25**	**2.08**	**1.04**	**1.03**	**0.83**	**0.60**	**0.59**
Acrolein	**0**	**100%**	**0.01**	**0.27**	**0.03**	**0.07**	**0.04**	**0.07**	**1.00**
Benzaldehyde	**4**	**83%**	**ND**	**0.18**	**0.04**	**0.04**	**0.02**	**0.04**	**1.00**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.05**	**0.28**	**0.14**	**0.15**	**0.14**	**0.06**	**0.42**
Crotonaldehyde	18	25%	ND	0.02	0.00	0.00	0.00	0.00	0.92
2,5-Dimethylbenzaldehyde	24	0%	ND	ND	0.00	0.00	0.00	0.00	0.16
Formaldehyde	**0**	**100%**	**0.84**	**6.76**	**2.56**	**3.10**	**2.55**	**1.91**	**0.62**
Hexanaldehyde	**0**	**100%**	**0.01**	**0.08**	**0.04**	**0.04**	**0.04**	**0.01**	**0.38**
Isovaleraldehyde	**4**	**83%**	**ND**	**0.07**	**0.02**	**0.02**	**0.01**	**0.02**	**0.81**
Propionaldehyde	**0**	**100%**	**0.04**	**0.21**	**0.12**	**0.12**	**0.11**	**0.05**	**0.39**
Tolualdehydes	**6**	**75%**	**ND**	**0.13**	**0.04**	**0.04**	**0.03**	**0.03**	**0.63**
Valeraldehyde	**1**	**96%**	**ND**	**0.11**	**0.03**	**0.04**	**0.03**	**0.02**	**0.59**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 9-3
Total Air Releases of VOC Reported to TRI by Facilities Within 10 Miles of the PARR Monitoring Station

Compound	Number of Facilities Within 10 Miles of PARR That Reported Air Releases of the Compound to TRI in 1995	Total Pounds of Air Releases of the Compound Reported by These Facilities in 1995
Ethylbenzene	2	1,730
Methylene chloride	2	120,535
Methyl ethyl ketone	4	79,445
Methyl isobutyl ketone	2	12,064
Propylene	1	650
Styrene	5	22,560
Toluene	4	85,723
1,1,1-Trichloroethane	1	0
Total xylene	5	86,250

Source: USEPA, 1997.

Notes: Refer to Section 3.2 for a discussion on the limitations of TRI data.
The TRI data in this table are for only those compounds that were identified by the VOC and carbonyl sampling and analytical methods; TRI data for other compounds are not included. Compounds not listed in the table either are not part of the TRI reporting requirements (e.g., *n*-octane) or were not reported by facilities in the vicinity of North Little Rock (e.g., benzene).
The facility that submitted a “Form R” for 1,1,1-trichloroethane indicated that it did not release any of this compound to the air in 1995.
The entry for “total xylene” is the sum of releases reported as individual xylene isomers and releases reported as mixed xylene isomers.

Table 9-4
Pairs of Compounds with Pearson Correlation Coefficients Greater Than 0.70
(Based on 23 Sampling Events)

Compounds		Pearson Correlation Coefficient
m,p-Xylene	*o*-Xylene	0.98
Ethylbenzene	*o*-Xylene	0.96
Ethylbenzene	*m,p*-Xylene	0.95
Benzene	*m,p*-Xylene	0.83
Benzene	*o*-Xylene	0.82
Benzene	Ethylbenzene	0.80
Acetaldehyde	Propionaldehyde	0.79
Ethylbenzene	Toluene	0.77
Benzene	Propylene	0.76
Acrolein	Methyl ethyl ketone	0.72
Formaldehyde	Isovaleraldehyde	0.71

Note: All of the Pearson correlation coefficients shown in the table were found to be statistically significant using a standard t-test—a statistical test commonly used for this purpose (Harnett, 1982).

10.0 Monitoring Results for Rutland, VT (RUVT)

This section summarizes and interprets ambient air monitoring data collected at the Rutland, Vermont (RUVT), monitoring station during the 1997 and earlier UATMPs. The RUVT monitoring station is located in a parking lot in downtown Rutland, which is a moderate-size city in central Vermont. As Figure 10-1 shows, a heavily traveled state highway and several busy city streets pass within 1 mile of the monitoring station. Approximately 39,000 people live within 10 miles of the monitoring station. Previous UATMP reports have attributed levels of air pollution measured at RUVT primarily to local emissions from industrial and motor vehicle sources. During the 1997 UATMP, 31 sampling events were attempted at RUVT. Valid carbonyl samples were collected on all 31 days, and valid VOC samples were collected on 30 days. Otherwise stated, the completeness of the carbonyl and VOC sampling at RUVT was 100 percent and 97 percent, respectively.

The remainder of this section summarizes the 1997 UATMP monitoring data for RUVT (Section 10.1), analyzes and interprets ambient air concentrations of selected nitriles and oxygenated compounds (Section 10.2), and describes how concentrations of certain compounds have changed at RUVT since the 1995 UATMP (Section 10.3). This section ends with a review of the most notable findings from the preceding subsections (Section 10.4).

10.1 Data Summary Parameters for the 1997 UATMP

Using the data summary parameters defined in Section 3.1, Tables 10-1 and 10-2 summarize the VOC and carbonyl monitoring data, respectively, collected at RUVT during the 1997 program. For consistency, the tables’ format is identical to that used in earlier UATMP reports.

10.1.1 Data Summary of VOC

Table 10-1 reveals the following notable trends regarding ambient air concentrations of VOC at Rutland, Vermont:

- *Prevalence.* According to the data in Table 10-1, only 18 of the 47 VOC considered in the 1997 UATMP were detected in more than half of the valid sampling events at RUVT. Summary statistics for these 18 compounds are believed to be most representative of actual air quality trends, because the statistics are least affected by nondetect observations, for which actual ambient air concentrations are not known. As a result, most of the analyses in this section focuses on these most prevalent compounds:

  Acetylene
  Benzene
  1,3-Butadiene
  Carbon tetrachloride
  Chloromethane
  Ethylbenzene
  Methylene chloride
  Methyl ethyl ketone
  Methyl *tert*-butyl ether
  n-Octane
  Propylene
  Styrene
  Tetrachloroethylene
  Toluene
  1,1,1-Trichloroethane
  m,p-Xylene
  o-Xylene

  Even though this section focuses primarily on the 18 most prevalent VOC, it should not be inferred that the other compounds were not present in ambient air at RUVT. Compounds with low prevalence, including those that were never detected during the program, might have been present in the air at RUVT, but at levels that the VOC analytical method could not measure.

- *Concentration Range.* Table 10-1 indicates the range of ambient air concentrations of VOC measured at Rutland. Of the 47 compounds, acetylene had the highest 24-hour average concentration during the program (5.84 ppbv), and eight other compounds had at least one 24-hour average concentration greater than 1.0 ppbv: benzene, chloromethane, methylene chloride, methyl ethyl ketone, propylene, toluene, and *m,p*-xylene. Since samples were not collected daily, however, it is very likely that ambient air concentrations rose to higher levels on days when samples were not collected. As a result, the concentration ranges in Table 10-1 should be viewed only as estimates of the actual span of ambient air concentrations of VOC at RUVT.

- *Central Tendency.* Table 10-1 also indicates three different measures commonly used to characterize central tendency concentrations: the median, the arithmetic mean, and the geometric mean. In the table, central tendency values for compounds shown in boldface are believed to be most accurate, since they represent compounds that were detected in more than 50 percent of the samples at RUVT. For the compounds not shown in boldface, the central tendency data are probably biased due to the higher frequency of nondetects, and they should be interpreted with caution. The six VOC with the highest geometric mean concentrations at RUVT were acetylene (1.90 ppbv), toluene (1.52 ppbv), propylene (0.93 ppbv), *m,p*-xylene (0.71 ppbv), and benzene (0.66 ppbv). All other compounds had geometric mean concentrations lower than 0.5 ppbv.

Figure 3-1, which compares geometric mean concentrations for selected VOC at the 12 UATMP air monitoring stations, shows that ambient levels of most VOC at RUVT were not unusually higher or lower than those at the other monitoring stations. The spatial profiles shown in Figure 3-1 are notably similar for eight compounds that are typically found in motor vehicle exhaust: acetylene, benzene, 1,3-butadiene, ethylbenzene, toluene, and the xylene isomers. For these eight compounds, the highest geometric mean concentrations were observed at EPTX, the second highest geometric mean concentrations were observed at BUVT, and the third highest geometric mean concentration were typically observed at RUVT. This spatial variation suggests that emissions from motor vehicles had the greatest impact at the EPTX monitoring station, the second greatest impact at the BUVT monitoring station, and the third greatest impact at the RUVT monitoring station.

Geometric mean concentrations of two other compounds at RUVT, acetonitrile and methyl *tert*-butyl ether, were also relatively higher than those at the other UATMP monitoring stations. Section 10.2 describes air quality trends for these compounds in greater detail.

Note: When interpreting the graphs in Figure 3-1, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban centers in the United States and only at discrete locations within selected cities. Thus, the fact that concentrations of certain VOC at RUVT ranked high among those at the other UATMP monitoring stations clearly does not imply that they would rank high among those at all cities in the United States. Moreover, the relatively high levels of certain compounds at RUVT may simply result from the monitors being placed in a heavily traveled part of town.

- *Variability.* With two exceptions, the coefficients of variation for the most prevalent VOC were less than 1.0, thus indicating that ambient air concentrations of most prevalent compounds exhibited comparable variability. The two exceptions were methylene chloride and styrene, which had coefficients of variation of 1.49 and 1.04, respectively. The greater variability for these two compounds suggests that their ambient air concentrations changed more significantly from one sampling date to the next than did concentrations of the other prevalent VOC. This greater variability is consistent with the compounds originating primarily from sources found at discrete locations in RUVT (e.g., industrial sources), because the monitors would probably detect higher levels of methylene chloride and styrene when emissions blew directly toward the station.

> Despite the consistency among the data, the relatively high coefficients of variation for methylene chloride and styrene do not necessarily prove that industrial emissions alone account for the levels of these compounds observed at RUVT.

To elaborate on trends and patterns for VOC, Section 10.2 interprets the 1997 UATMP monitoring data for nitriles and oxygenated compounds, and Section 10.3 evaluates how average concentrations of selected compounds have changed at RUVT since the 1995 UATMP.

10.1.2 Data Summary of Carbonyls

Table 10-2 reveals the following notable trends regarding ambient air concentrations of carbonyls at Rutland, Vermont:

- *Prevalence.* The prevalence data in Table 10-2 indicate that all 16 carbonyls considered in this program, except crotonaldehyde and 2,5-dimethylbenzaldehyde, were detected in at least 50 percent of the samples collected at RUVT. Thus, summary statistics for most of the carbonyls are not strongly affected by nondetect observations and are therefore expected to represent actual air quality trends in the Rutland area.

- *Concentration Range.* As Table 10-2 demonstrates, only 3 of the 16 carbonyls (acetaldehyde, acetone, and formaldehyde) were detected at RUVT at levels greater than 1.0 ppbv. In fact, formaldehyde had the highest ambient air concentration (27.82 ppbv) of all carbonyls and VOC sampled for at Rutland. As mentioned above, the concentration ranges shown in Table 10-2 only estimate the actual concentration ranges, since concentrations may have reached higher levels and lower levels on nonsampling days.

- *Central Tendency.* The central tendency data in Table 10-2 indicate that the highest geometric mean concentrations at RUVT were observed for formaldehyde (2.81 ppbv), acetaldehyde (1.20 ppbv), and acetone (1.11 ppbv). All other carbonyls had notably lower geometric mean concentrations (less than 0.15 ppbv). In fact, acetaldehyde, acetone, and formaldehyde accounted for over 90 percent of the total concentration of the carbonyls measured at RUVT—a trend that was observed at almost every UATMP monitoring station. Further, formaldehyde's geometric mean concentration was higher than that of any other compound measured at RUVT, carbonyl or VOC.

  As an indicator of spatial variations for carbonyls, Figure 3-2 shows how geometric mean concentrations of the most prevalent carbonyls varied among the

1997 UATMP monitoring stations. For each of the compounds shown in the figure, neither the highest or lowest geometric mean concentration was observed at the RUVT monitoring station. Therefore, ambient levels of carbonyls at RUVT do not appear to be notably higher or lower than those in a sampling of other urban locations. Compared to the other monitoring stations in Vermont, concentrations of most carbonyls at RUVT were generally similar to those at BUVT, slightly higher than those at BRVT, and notably higher than those at UNVT and WIVT, but this general trend does not apply to all of the carbonyls.

The spatial variations for acetaldehyde, acetone, and formaldehyde (i.e., the three carbonyls that were detected at highest levels at the Rutland station) are similar, in some ways, to the spatial variations for compounds found primarily in motor vehicle exhaust (see Section 10.1.1). For instance, the highest geometric mean concentration for acetaldehyde and formaldehyde was observed at EPTX, with the next highest levels observed at BUVT, CANJ, and RUVT. Similarly, relatively high levels of acetone were observed at the same group of stations, but the highest were measured at CANJ. Despite these basic similarities, the profiles of spatial variations for the three carbonyls (as shown in Figure 3-2) clearly differ from those for the VOC (as shown in Figure 3-2). For example, ambient air concentrations of acetone at the remote UNVT monitoring station ranked among the highest. In short, the spatial variations for the three carbonyls and for VOC found primarily in motor vehicle exhaust are similar in many ways, but exhibit notable differences. Thus, there is some evidence that emissions from mobile sources affect ambient levels of acetaldehyde, acetone, and formaldehyde at RUVT (and at the other UATMP monitoring stations), but there is also evidence that other factors likely influence ambient levels of these three carbonyls. Previous UATMP reports have noted that photochemical reactions probably play an important role as both a source and sink of airborne carbonyls.

Note: When interpreting the graphs in Figure 3-2, it is important to understand that the 1997 UATMP characterized air quality in a very small subset of urban centers in the United States and only at discrete locations within selected cities.

- *Variability*. As Table 10-2 shows, coefficients of variation for the most prevalent carbonyls at RUVT were less than 1.0, except for those for hexanaldehyde (1.88), formaldehyde (1.30), and benzaldehyde (1.28). Furthermore, coefficients of variation for the most prevalent carbonyls were, on average, higher than those for the most prevalent VOC. The reason for the relatively greater variability for the carbonyls at RUVT is not known.

Further information on air quality trends for carbonyls is included in Section 10.3, which reviews annual variations observed at RUVT, and in Section 12.1, which provides a general overview of carbonyl monitoring data collected at every station that participated in the 1997 UATMP.

10.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

As Section 2.2.1 described, the VOC analytical method used in the 1997 UATMP was capable of detecting nine compounds (all nitriles and oxygenated compounds) that could not be detected during earlier UATMPs. Detailed analyses of the ambient air monitoring data for these compounds follow:

- *Compounds that were rarely, if ever, detected.* Of the nine nitriles and oxygenated compounds measured during the 1997 UATMP, the following six were detected in fewer than 10 percent of the sampling events at RUVT: acrylonitrile, ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, methyl methacrylate, and *tert*-amyl methyl ether. Thus, all that can be said about these six compounds is that their ambient air concentrations at RUVT were consistently below their corresponding detection limits listed in Table 2-2. Consistent with this finding is the fact that no industrial facilities within 10 miles of RUVT reported air releases of these nitriles and oxygenated compounds to TRI.

- *Acetonitrile.* As Table 10-1 shows, acetonitrile was detected in 8 of the 30 samples collected at RUVT. The detections were only during January, late March through early May, and late July through early August, and thus did not exhibit a notable seasonal trend. No other compound exhibited similar monthly variations at RUVT. Though impossible to tell from Figure 3-1, the geometric mean concentration of acetonitrile at RUVT (0.36 ppbv) ranked third highest among the geometric mean concentrations at the 1997 UATMP monitoring stations. Several patterns among the data suggest that neither large industrial emissions sources nor motor vehicle sources explain the levels of acetonitrile measured at RUVT: no industrial facilities in the entire state of Vermont reported air releases of the compound to the 1995 TRI, and concentrations of acetonitrile were essentially uncorrelated with concentrations of every other compound at RUVT. Thus, the primary sources of the acetonitrile measured at this site during the 1997 UATMP are not known.

- *Methyl ethyl ketone.* According to Table 10-1, methyl ethyl ketone was detected in 29 of the 30 ambient air samples collected at RUVT during the 1997 UATMP. The geometric mean concentration of methyl ethyl ketone at RUVT (0.47 ppbv) ranked seventh among the levels measured at the 12 UATMP monitoring stations, but was the highest among the 5 monitoring stations in Vermont. The only potential temporal trend in the methyl ethyl ketone data is a slight increase in concentration over time, as shown in Figure 10-2. More specifically, ambient air concentrations from June 1998 to August 1998 were nearly 40 percent higher than those during other months of the year. This seasonal trend—higher concentrations of methyl ethyl ketone during the warmer summer months—was observed at most of the UATMP monitoring stations. However, analyses of future monitoring data should be performed to rule out the possibility that the increasing levels of methyl ethyl ketone at RUVT are part of a longer-term rise in ambient air concentrations of the compound.

Closer inspection of the 1997 UATMP monitoring data suggests that much of the methyl ethyl ketone detected at RUVT likely originated from nearby industrial sources or as the product of photochemical reactions. Even though motor vehicles are known to emit methyl ethyl ketone to the air, the fact that concentrations of methyl ethyl ketone at RUVT were essentially uncorrelated with concentrations of compounds typically found in motor vehicle exhaust (e.g., benzene, ethylbenzene, toluene, and the xylene isomers) strongly suggests that motor vehicles are probably not the primary source of this compound at RUVT. Releases from industrial sources may account for some fraction of the methyl ethyl ketone measured at RUVT, given that one facility located less than 2 miles from the monitoring station reported emitting 28,094 pounds of the compound to the air in the 1995 TRI. Though EPA has classified this facility as one of "Vermont's largest emitters of toxic chemicals" (USEPA, 1998), its emissions of methyl ethyl ketone are modest by national standards: of the 2,255 industrial facilities that submitted information on environmental releases of methyl ethyl ketone to the 1995 TRI, 500 facilities reported emitting more methyl ethyl ketone to the air than the facility near the Rutland monitoring station. Nonetheless, emissions from this industrial facility, as well as emissions from other local sources not subject to TRI reporting requirements, may best explain the levels of methyl ethyl ketone measured at RUVT during the 1997 UATMP.

- *Methyl tert-butyl ether*. As Table 10-1 shows, methyl *tert*-butyl ether was detected in 90 percent of the sampling events at RUVT during the 1997 UATMP. According to Figure 3-1, the geometric mean concentration of methyl *tert*-butyl ether at RUVT (0.18 ppbv) ranked fourth highest among the levels measured at the 12 monitoring stations that participated in this program. Not shown in the data summary tables is the fact that concentrations of methyl *tert*-butyl ether at RUVT had relatively weak seasonal variations: seasonal-average concentrations of the compound are no more than 30 percent greater or less than the annual average concentration.

  The air quality trends for methyl *tert*-butyl ether at RUVT are best explained by emissions from motor vehicles that use reformulated fuels. Since no industrial facilities in the entire state of Vermont reported emissions of methyl *tert*-butyl ether to the 1995 TRI, effects from industrial sources are expected to be minimal. The analyses in Section 6.2, which examine air quality trends in the Burlington metropolitan area, provide strong evidence that methyl *tert*-butyl ether in the Vermont air results primarily from local gasoline stations that sell reformulated fuels, even though the state does not require them to do so. The arguments presented in Section 6.2 generally apply to the monitoring data collected at RUVT. Ultimately, a detailed inventory of the different types of fuels sold at local gasoline stations would help pinpoint the actual sources of methyl *tert*-butyl ether in the Rutland air.

For information on concentrations of methyl *tert*-butyl ether observed in an area where EPA requires motor vehicles to use reformulated gasoline, refer to the analyses for the Camden monitoring station in Section 7.2.

10.3 Annual Variations

The RUVT monitoring station participated in the UATMP during program years 1995, 1996, and 1997. The following two subsections evaluate annual variations for the most prevalent VOC (Section 10.3.1) and carbonyls (Section 10.3.2). The least prevalent compounds are not considered here due to the uncertainty in their estimated annual average concentrations, which results from numerous nondetect observations.

Important things to remember when reading the following discussion are (1) that the UATMP years, which typically run from September to August, do not correspond with calendar years; (2) that changes in annual average concentrations from year to year are not necessarily statistically significant; (3) that statistically significant annual variations arise for a variety of reasons, such as decreases in emissions and changes in meteorological conditions; and (4) that air quality trends over a 3-year period do not imply trends over the longer term.

10.3.1 Annual Variations for VOC

Figure 10-3 shows how concentrations of the 15 most prevalent VOC at RUVT changed from the 1995 to the 1997 UATMP. Most VOC either had no notable changes in their annual average concentration over time, or gradual changes. As the exceptions, average concentrations of methylene chloride and *n*-octane had more dramatic changes: their average concentrations during the 1997 UATMP were more than twice as high, or twice as low, as those during the 1995 UATMP. More detailed evaluations of annual variations for different groups of VOC follows:

- *BTEX compounds.* Earlier UATMP reports have concluded that motor vehicle emissions appear to account for a large fraction of the airborne benzene, toluene, ethylbenzene, and xylene isomers (i.e., the so-called BTEX compounds) in urban areas. Thus, annual variations for these compounds should provide insight into the extent to which motor vehicle emissions have changed from one year to the next.

  As Figure 10-3 shows, annual variations for each the BTEX compounds were quite similar at RUVT: the annual average concentration for each compound did not increase or decrease by more than 30 percent from one year to the next. Further, for every BTEX compound, the 95-percent confidence intervals for each year shown in Figure 10-3 overlapped. Therefore, the small changes in annual average concentrations do not appear to be statistically significant. The absence of notable annual variations for the BTEX compounds suggests that emissions from motor vehicles in the Rutland area have not changed significantly since the 1995 UATMP.

- *Halogenated hydrocarbons.* Five of the most prevalent VOC at RUVT are halogenated hydrocarbons. Previous UATMP reports have shown that factors other than motor vehicle emissions (e.g., industrial emissions and natural sources) appear to affect ambient air concentrations of these compounds most significantly. As Figure 10-3 shows, annual average concentrations of carbon tetrachloride, chloromethane, and tetrachloroethylene did not change significantly over the last 3 UATMPs. In fact, annual average concentrations of each of these compounds changed by less than 20 percent from one year to the next. The absence of notable spatial variations for these compounds suggests that their emissions probably changed little during this time.

  Monitoring data for methylene chloride at RUVT have much more pronounced annual variations than the three halogenated hydrocarbons discussed previously. From the 1995 to the 1996 UATMP, the annual average concentration of methylene chloride decreased by more than a factor of five—a decrease that appears to be statistically significant. The annual average concentration then increased by a factor of two from the 1996 to the 1997 UATMP, but this change does not appear to be statistically significant. The annual variations for methylene chloride at RUVT are most likely unrelated to motor vehicle emissions, since the BTEX compounds did not experience similar trends. In fact, *none* of the VOC shown in Figure 10-3 exhibited trends similar to those for methylene chloride, thus suggesting that the factors predominantly affecting concentrations of methylene chloride in the Rutland area are unique.

Though the relatively high coefficient of variation for methylene chloride during the 1997 UATMP suggests that the compound originated primarily from industrial emissions sources, no industrial facilities in Rutland County reported releasing methylene chloride to the air to the 1995 TRI. However, one industrial facility in Rutland reportedly emitted nearly 15,000 pounds of methylene chloride to the air during TRI reporting years 1987, 1988, and 1989. It is not known if this facility continues to use methylene chloride (but presumably at levels below the reporting thresholds) or if it has stopped using the compound altogether. In either case, it is likely that changing levels of emissions from nearby industrial facilities, including those not subject to TRI reporting requirements, contributed to the annual variations for methylene chloride shown in Figure 10-3.

According to Figure 10-3, average concentrations of 1,1,1-trichloroethane have decreased steadily from the 1995 to the 1997 UATMP, and the average concentration observed during the 1997 program is approximately half that found during the 1995 program. Reasons for this statistically significant decrease over the 3-year period are not known, but are probably linked to decreasing emissions from local industrial sources. Only one industrial facility in Rutland County has reported releases of 1,1,1-trichloroethane to TRI since reporting year 1987. According to the TRI database, air emissions from this facility were roughly 100,000 pounds from 1987 to 1991, 59,000 pounds during 1992, and 23,000 pounds during 1993. The facility has not reported releases of 1,1,1-trichloroethane during 1994 or 1995, indicating that it may have stopped using the compound altogether or it may now use the compound at levels below the reporting threshold. Since emissions data are not available for 1996, 1997, or 1998, it is unclear whether emissions from this one facility account for the annual variations of 1,1,1-trichloroethane shown in Figure 10-3.

- *Other compounds.* Besides showing annual variations for BTEX compounds and halogenated hydrocarbons, Figure 10-3 illustrates annual variations for five other compounds that were detected in more than half of the samples at RUVT during the 1997 UATMP: acetylene, 1,3-butadiene, *n*-octane, propylene, and styrene. Of these five compounds, annual average concentrations for three (1,3-butadiene, propylene, and styrene) changed by less than 25 percent from one UATMP to the next. This means that emissions from the sources for these compounds, whether industry, motor vehicles, or nature, probably did not vary greatly between program years 1995 and 1997.

The remaining two compounds, acetylene and *n*-octane, exhibited unique annual variations at RUVT, most of which appear to be statistically significant. First, as shown in Figure 10-3, the annual average concentration of acetylene at RUVT decreased by 41 percent from the 1995 to 1996 UATMPs, and by 13 percent from the 1996 to the 1997 UATMPs—the net effect being that the annual average concentration during the 1997 program was almost exactly half of that during the 1995 program. Based on findings from previous air quality analyses, these variations are difficult to explain: some researchers have reported that emissions from motor vehicles account for much of the acetylene found in ambient air (Main et al., 1996), yet the annual variations for acetylene at RUVT are clearly different from those observed for the BTEX compounds. Further research is encouraged to determine whether emissions from other sources (e.g., home heating) might account for the unique annual variations observed for acetylene.

Of the 15 VOC considered in Figure 10-3, *n*-octane had the greatest increase in average concentration at RUVT from the 1995 to the 1997 UATMP: its average concentration almost exactly doubled over this period. The reason for this statistically significant increase is not known. Even though motor vehicles emit *n*-octane, the 1997 monitoring data indicate that concentrations of *n*-octane at RUVT were very weakly correlated with concentrations of other compounds typically found in motor vehicle exhaust (e.g., the BTEX compounds). Thus, the higher concentrations of the compound in Rutland during the 1997 UATMP probably resulted from several factors, but the annual variations cannot be explained by changing levels of motor vehicle emissions alone.

10.3.2 Annual Variations for Carbonyls

Figure 10-4 shows how concentrations of the 14 most prevalent carbonyls changed at RUVT since the 1995 UATMP. In general, annual average concentrations of the selected carbonyls gradually decreased over the 3-year period. A more detailed analysis of the annual variations for the carbonyls follows:

- *Overall trends.* For every carbonyl shown in Figure 10-4, the annual average concentration during the 1997 UATMP was notably lower than that during the 1995 UATMP, and most of the decreasing concentrations appear to be statistically significant. More specifically, 1997 levels of the carbonyls were between 32 percent lower (for hexanaldehyde) and 83 percent lower (for tolualdehydes) than the 1995 levels. The lack of industrial emissions data for most carbonyls and the fact that several different factors affect their ambient air concentrations complicate efforts to understand these annual variations. Except for acetylene, none of the VOC had annual variations similar to those for the carbonyls. It is not clear why the air quality trends for acetylene and carbonyls are similar, but this finding may simply be anomalous. Analyses of additional air monitoring data collected at RUVT may help explain the factors causing the annual variations for carbonyls.

- *Trends for acetaldehyde, acetone, and formaldehyde.* As Section 10.1.2 noted, acetaldehyde, acetone, and formaldehyde accounted for over 90 percent of the carbonyls measured at RUVT during the 1997 UATMP. Therefore, annual variations in these three compounds largely determine how the overall magnitude of carbonyl concentrations changed since the 1995 UATMP. Though not shown directly in Figure 10-4, the total concentrations of acetaldehyde, acetone, and formaldehyde during the 1995, 1996, and 1997 UATMPs were 13.25 ppbv, 7.41 ppbv, and 6.39 ppbv, respectively. Therefore, annual variations for these three compounds alone amount to a decrease of nearly 7.0 ppbv in potentially toxic air pollution at RUVT over a 3-year period. Given the notable and apparently statistically significant decrease in concentrations for these carbonyls, further research is warranted to identify the factors that contributed to the notable decreases in concentration and additional monitoring is encouraged to determine whether this 3-year trend is part of a longer term improvement in the air quality at Rutland.

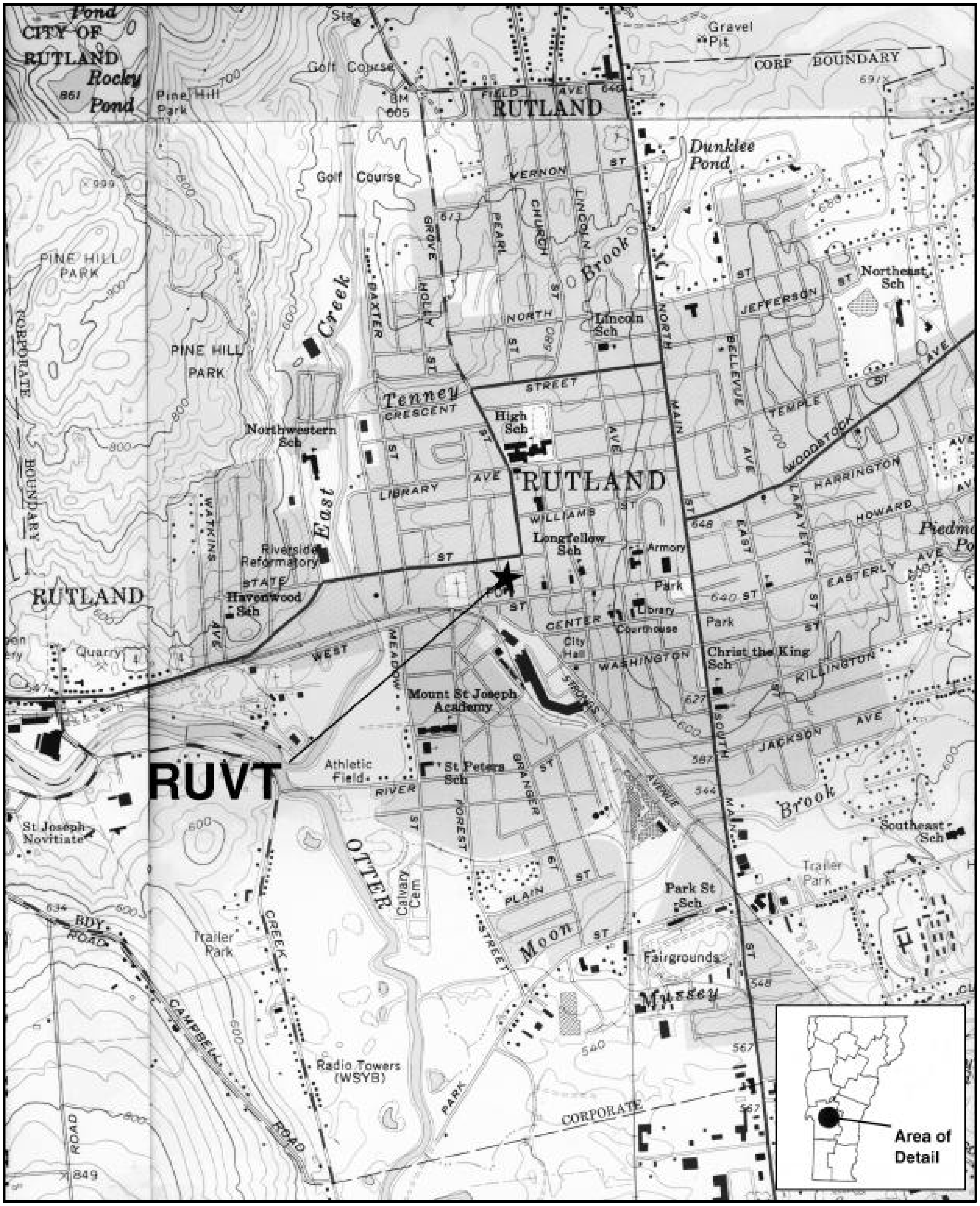
10.4 Summary

During the 1997 UATMP, ambient air concentrations of VOC and carbonyls at RUVT exhibited many trends consistent with previous monitoring efforts. For example, 18 VOC and 14 carbonyls were detected in over half of the samples, suggesting that these compounds are some of the most prevalent components of air pollution in Rutland. Of these compounds, acetaldehyde, acetone, acetylene, formaldehyde, and toluene consistently had higher ambient air concentrations than those of other compounds. Analyses of the data indicate that a variety of factors (e.g., mobile source emissions, industrial emissions, photochemical reactions) affected ambient air concentrations of these pollutants at RUVT.

The 1997 UATMP was the first year in which air samples were analyzed for concentrations of nine nitriles and oxygenated compounds. Only two of these compounds, methyl ethyl ketone and methyl *tert*-butyl ether, were detected in over half of the samples collected in Rutland. Trends in the monitoring data suggested that emissions from industrial sources and photochemical reactions primarily account for ambient levels of methyl ethyl ketone at RUVT and emissions from motor vehicles using reformulated fuels best explain the levels of methyl *tert*-butyl ether. Acetonitrile was detected in roughly 25 percent of the samples at Rutland, but likely sources of this compound were not identified.

With one exception, annual average concentrations for the 18 most prevalent VOC at RUVT either decreased or did not exhibit statistically significant variations between the 1995 and the 1997 UATMP; concentrations of *n*-octane increased during this period, but the reasons for this increase were not known. Unlike the trends for VOC, annual variations for almost every carbonyl were identical: steadily decreasing concentrations between the 1995 and the 1997 programs. Given the notably different annual variations for these two groups of compounds, the factors that predominantly influence air concentrations of VOC in Rutland probably differ from those that predominantly influence levels of carbonyls.

Figure 10-1
Rutland, Vermont (RUVT), Monitoring Station



Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

Figure 10-2
All Valid Samples of Methyl Ethyl Ketone During the 1997 UATMP

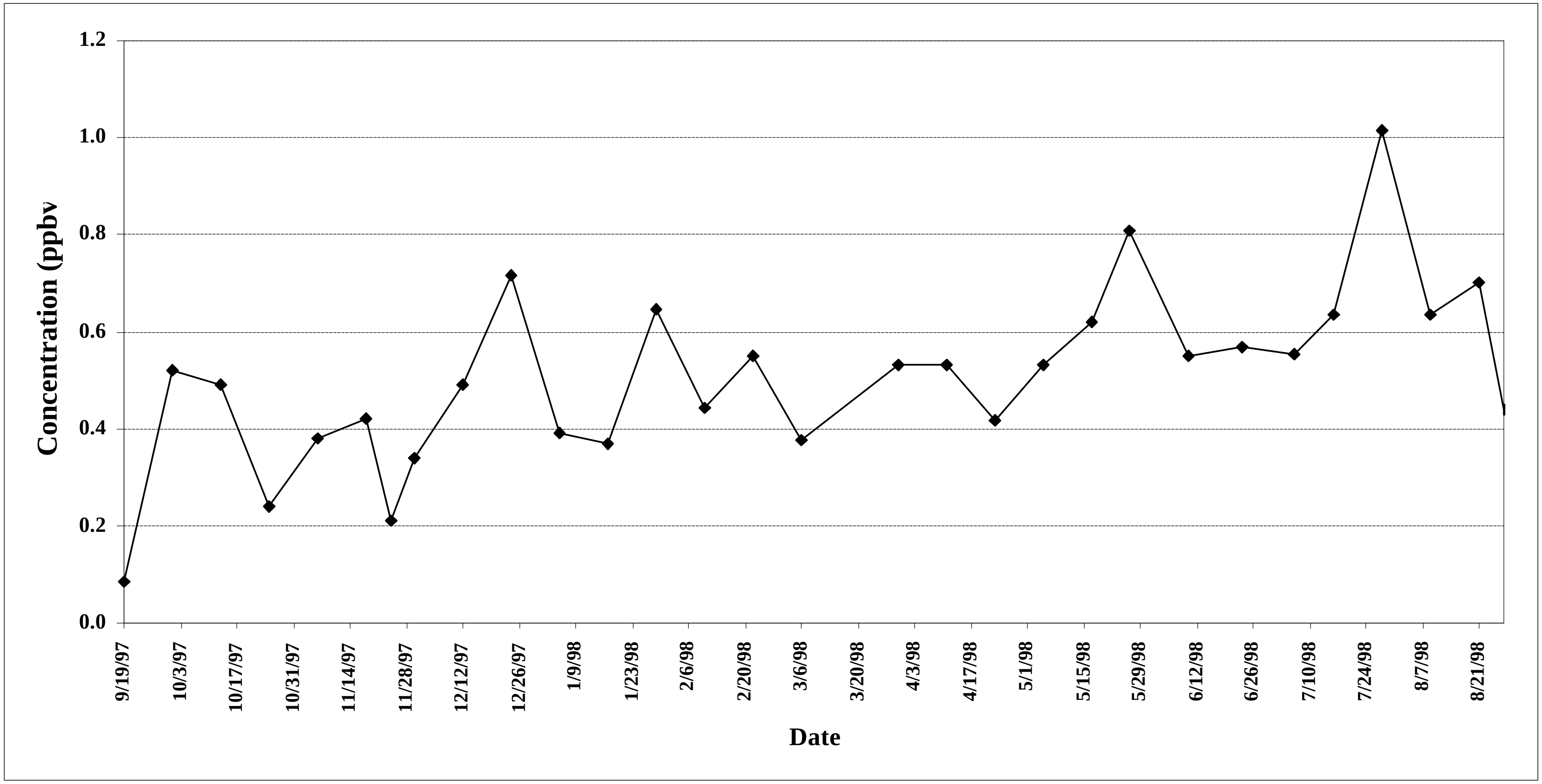
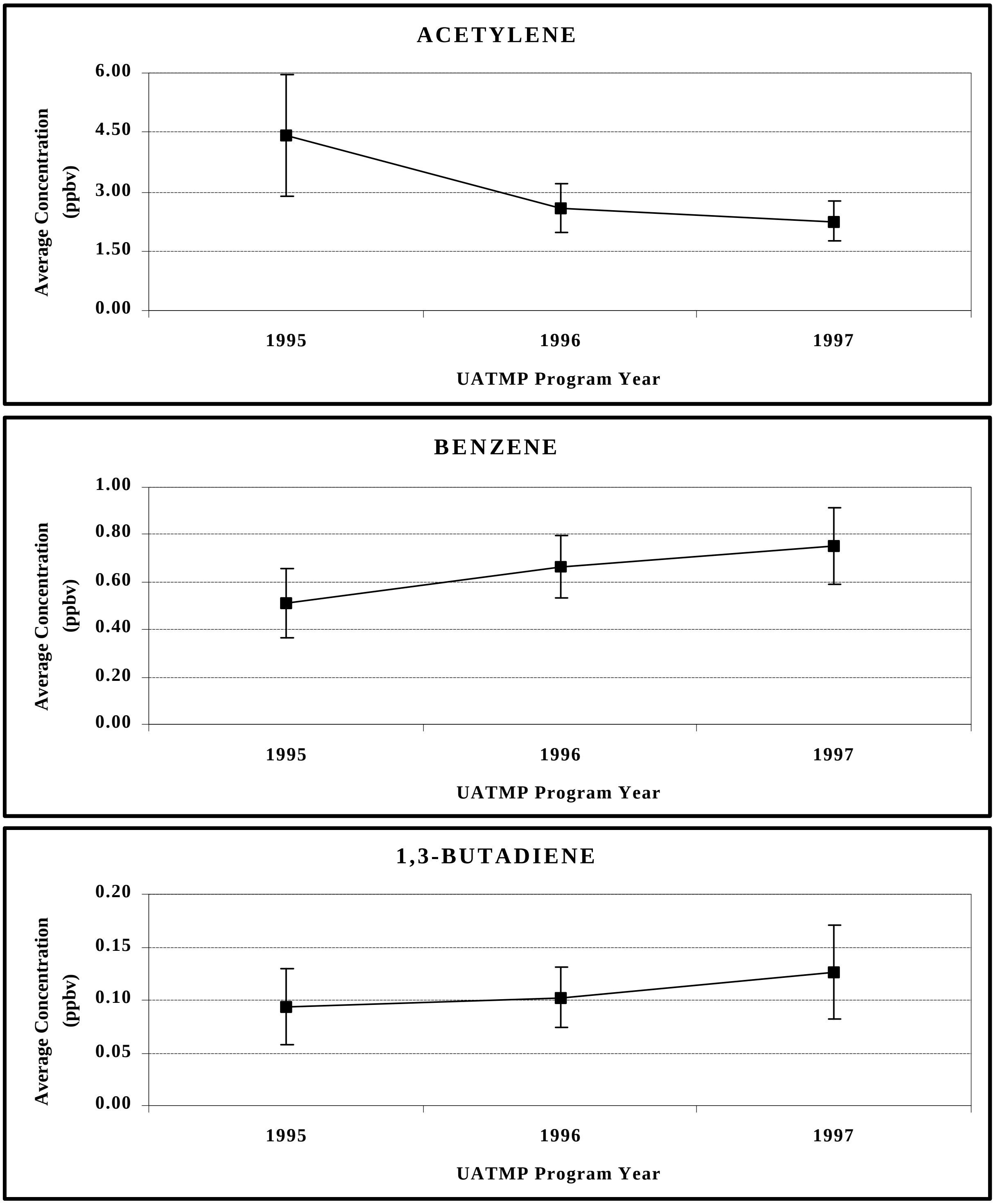
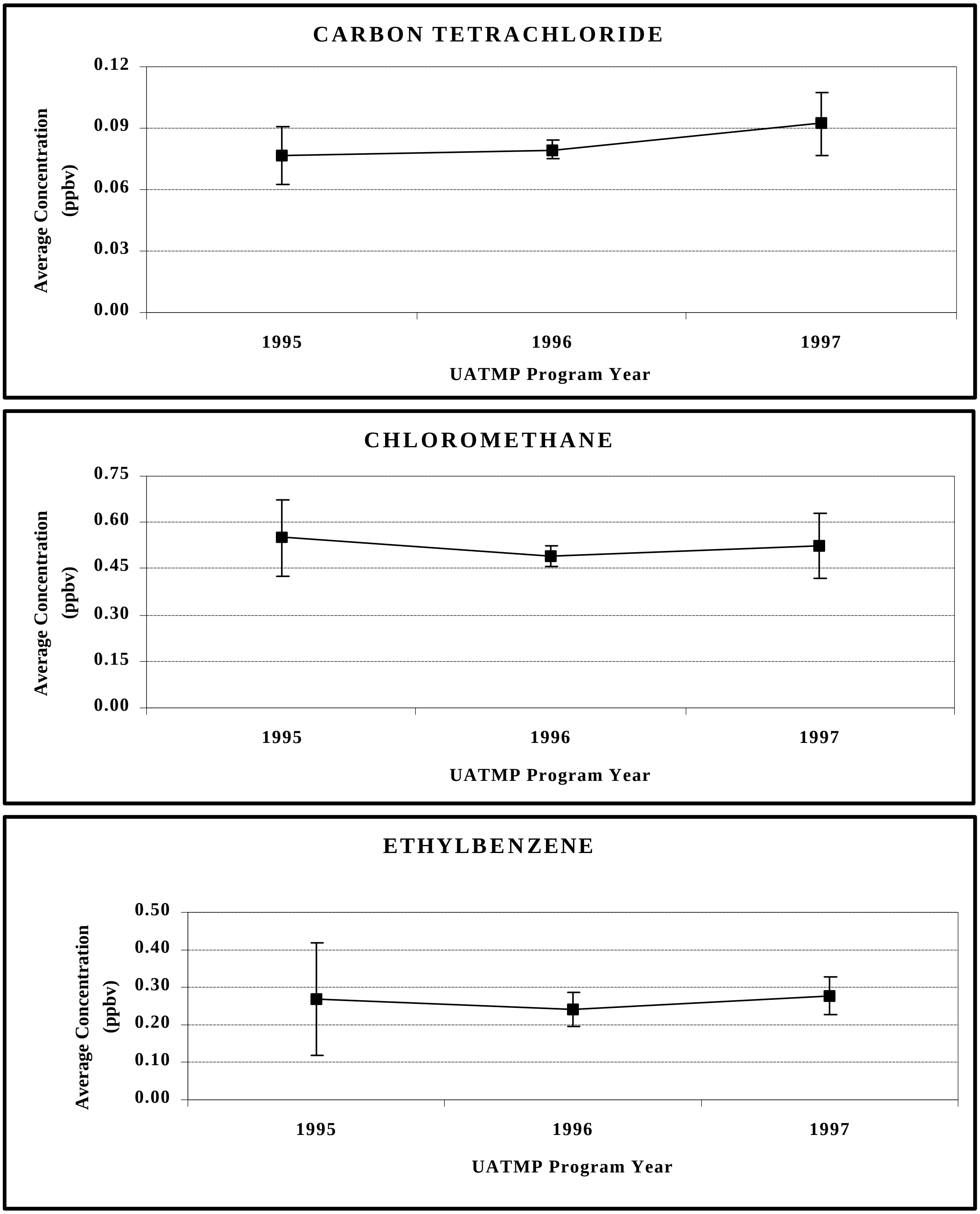


Figure 10-3 (Page 1 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at RUVT



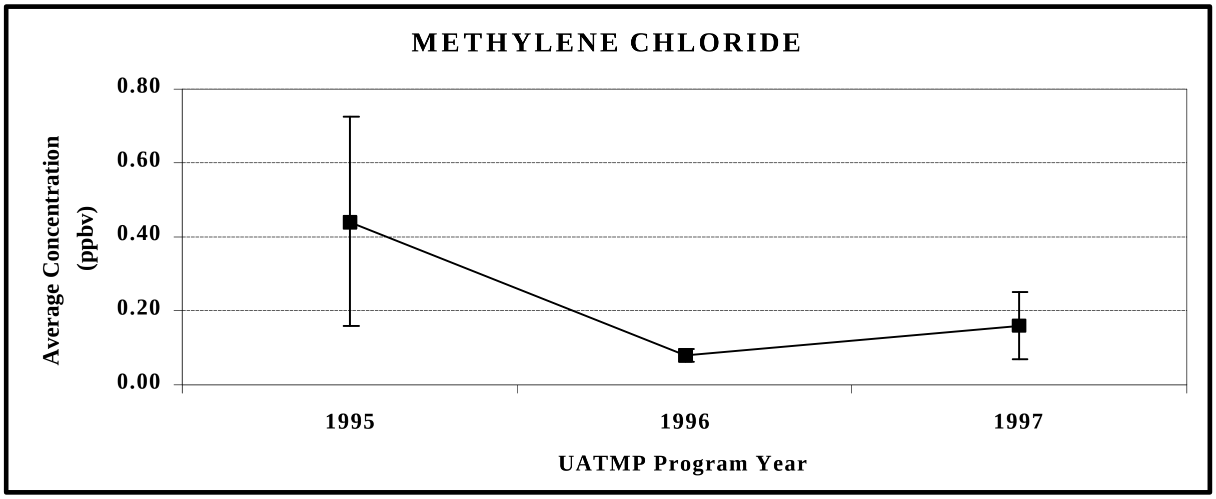
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

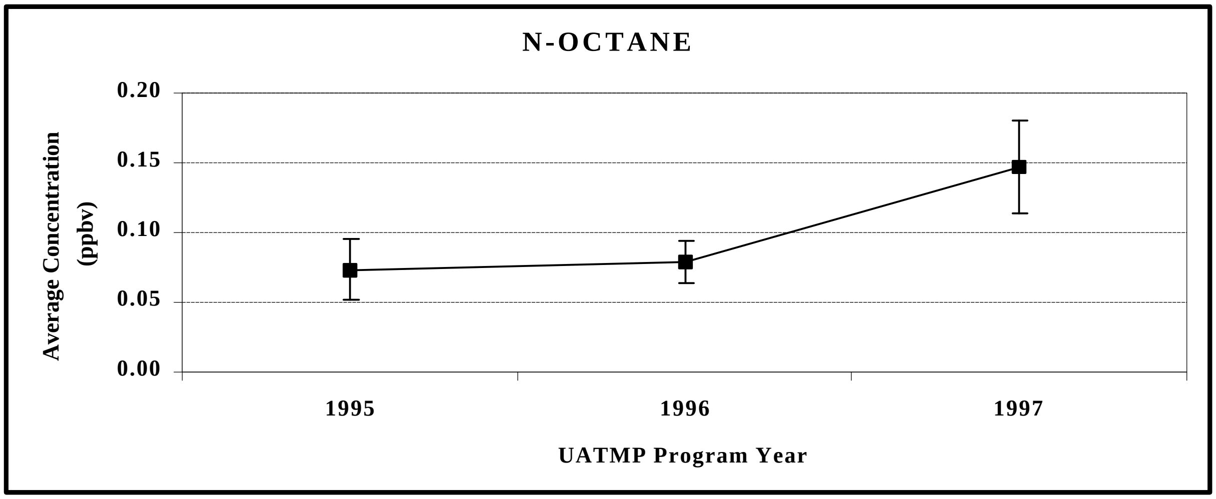
Figure 10-3 (Page 2 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at RUVT

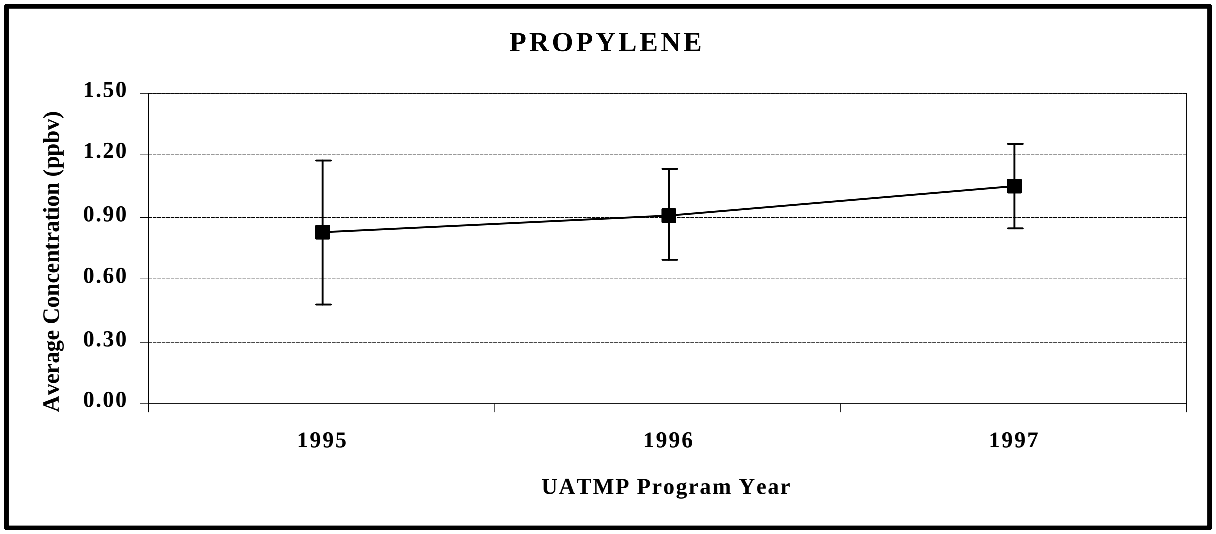


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 10-3 (Page 3 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at RUVT

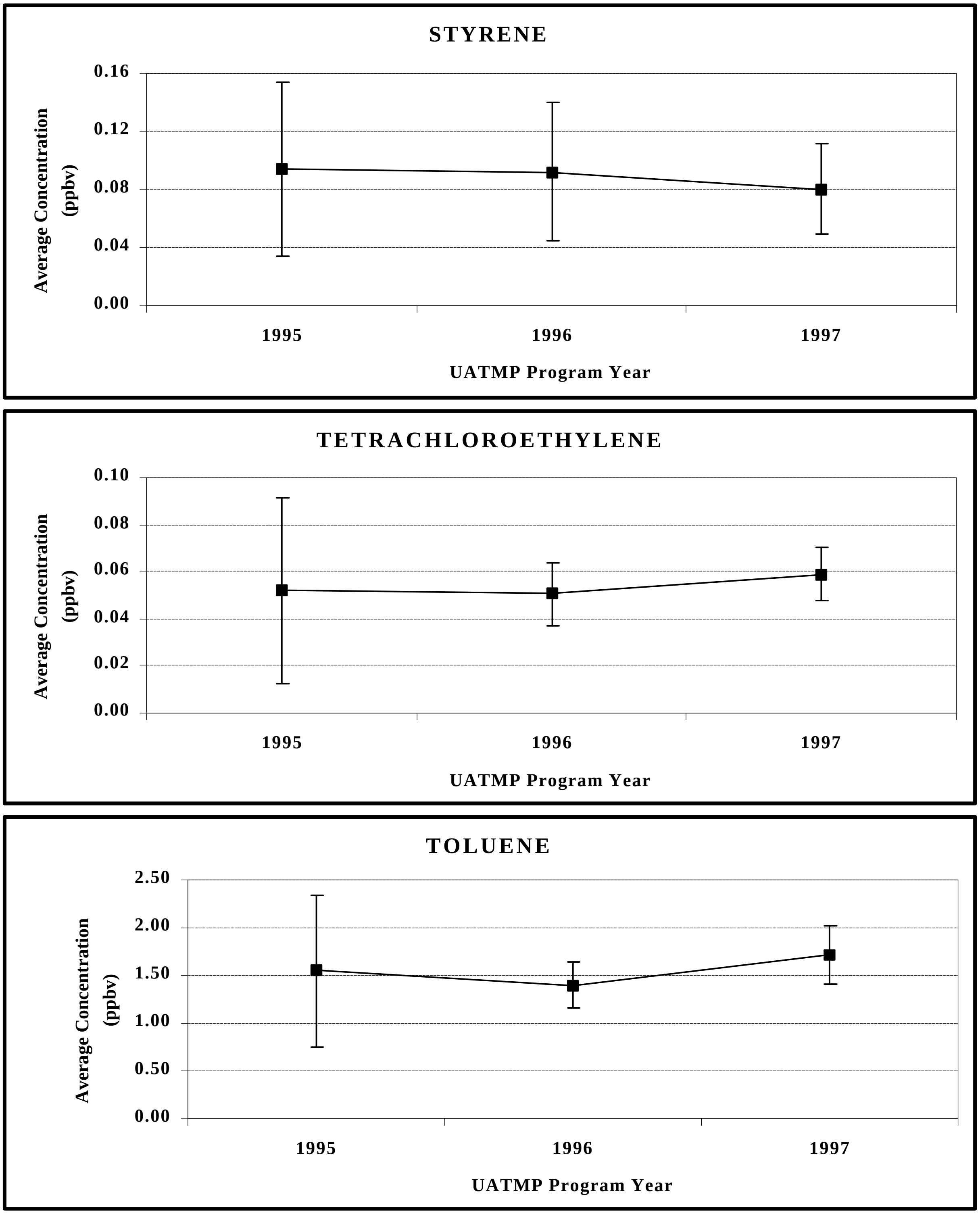






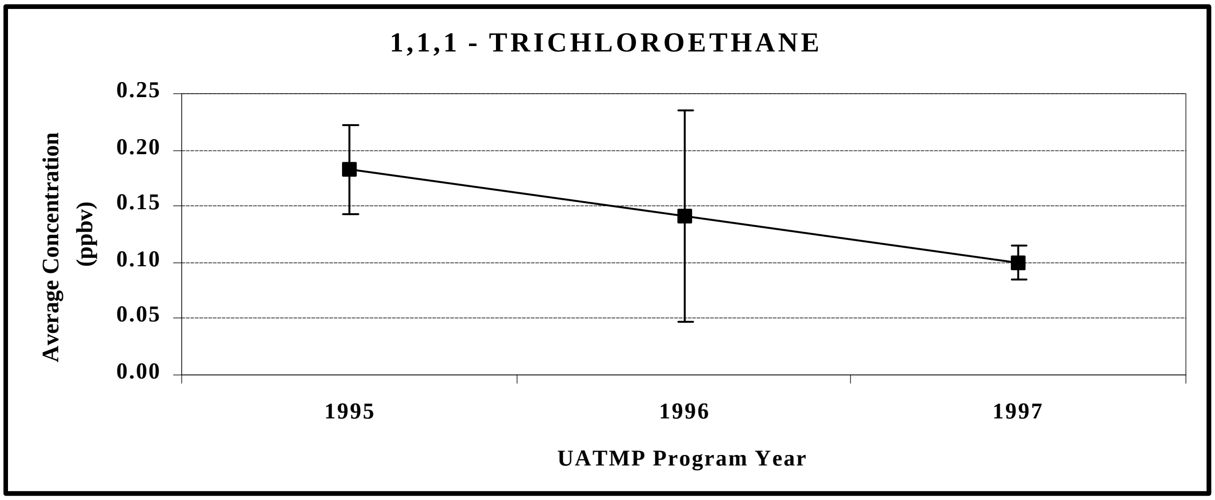
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

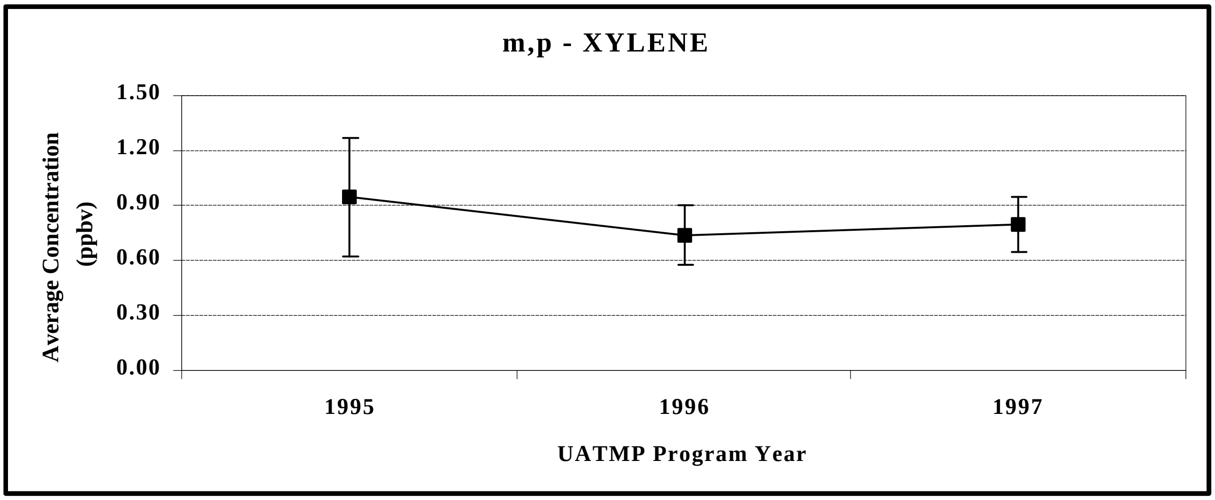
Figure 10-3 (Page 4 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at RUVT

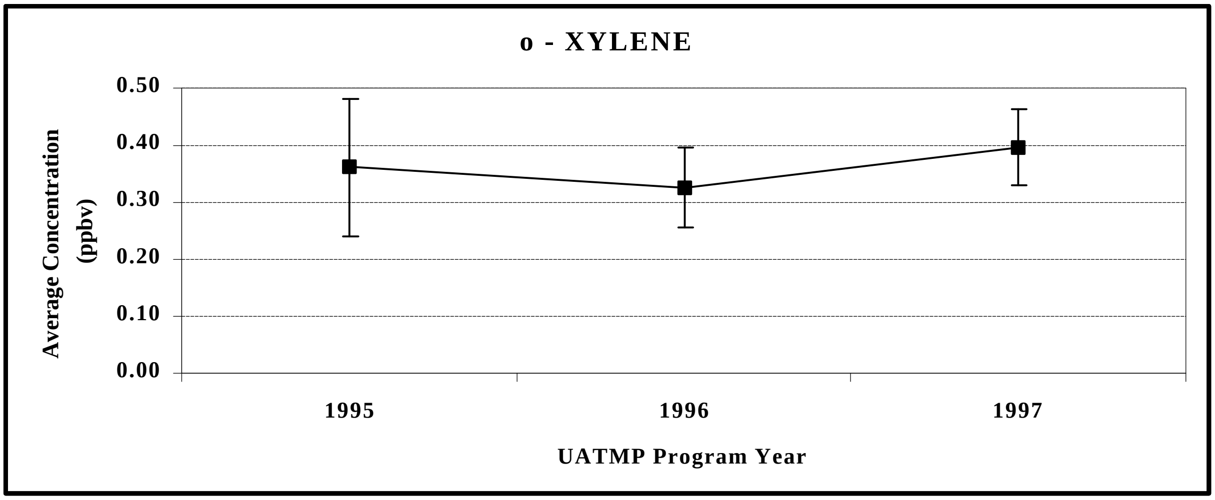


Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 10-3 (Page 5 of 5)
Annual Variations in Average Concentrations of the Most Prevalent VOC at RUVT

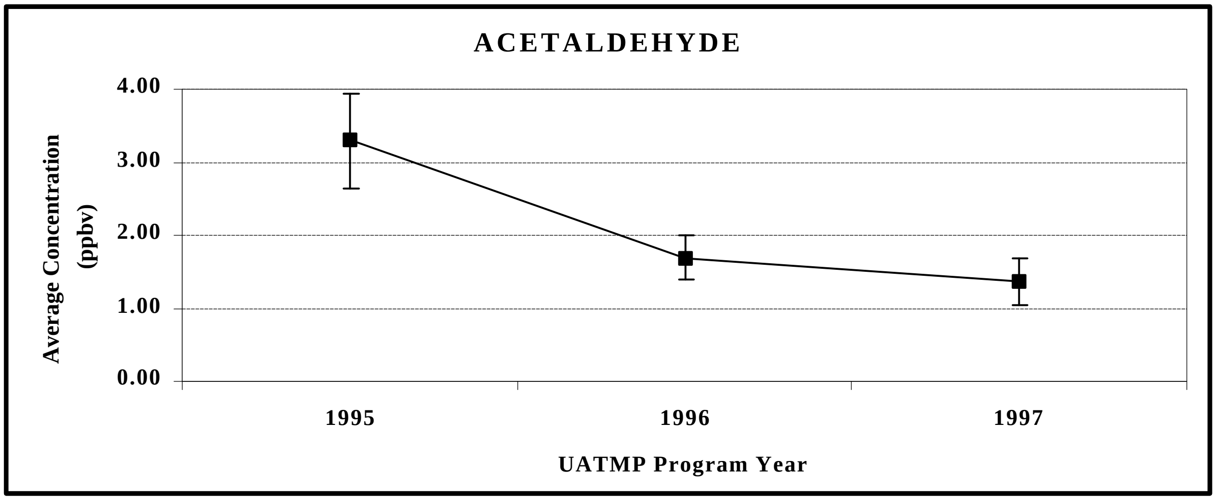


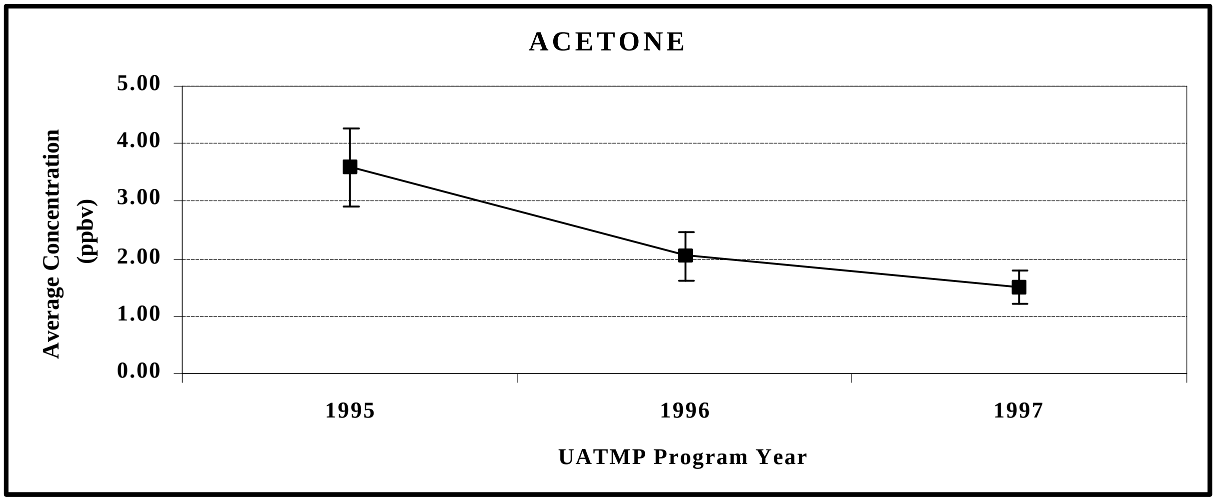


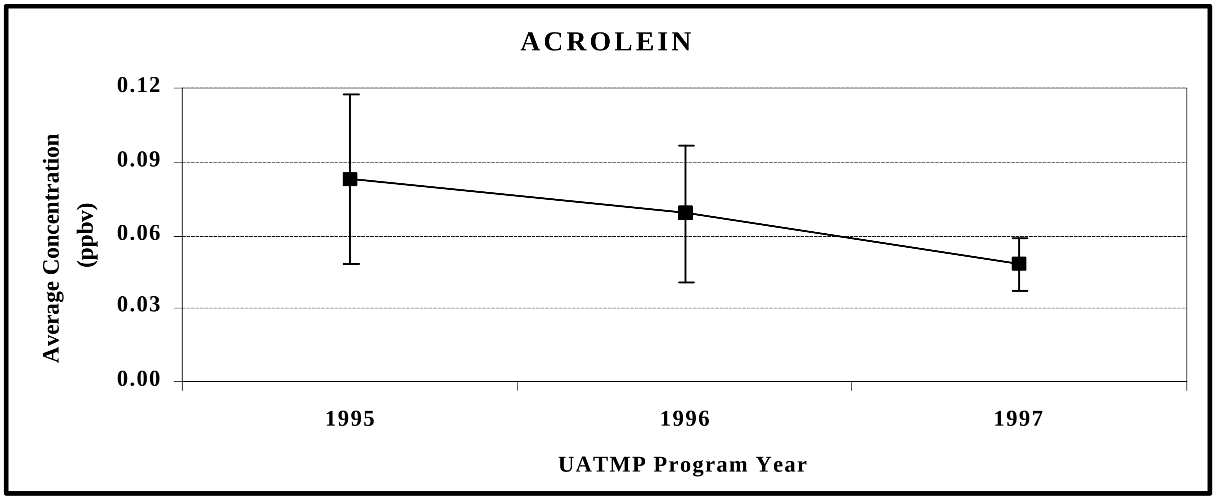


Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

Figure 10-4 (Page 1 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at RUVT

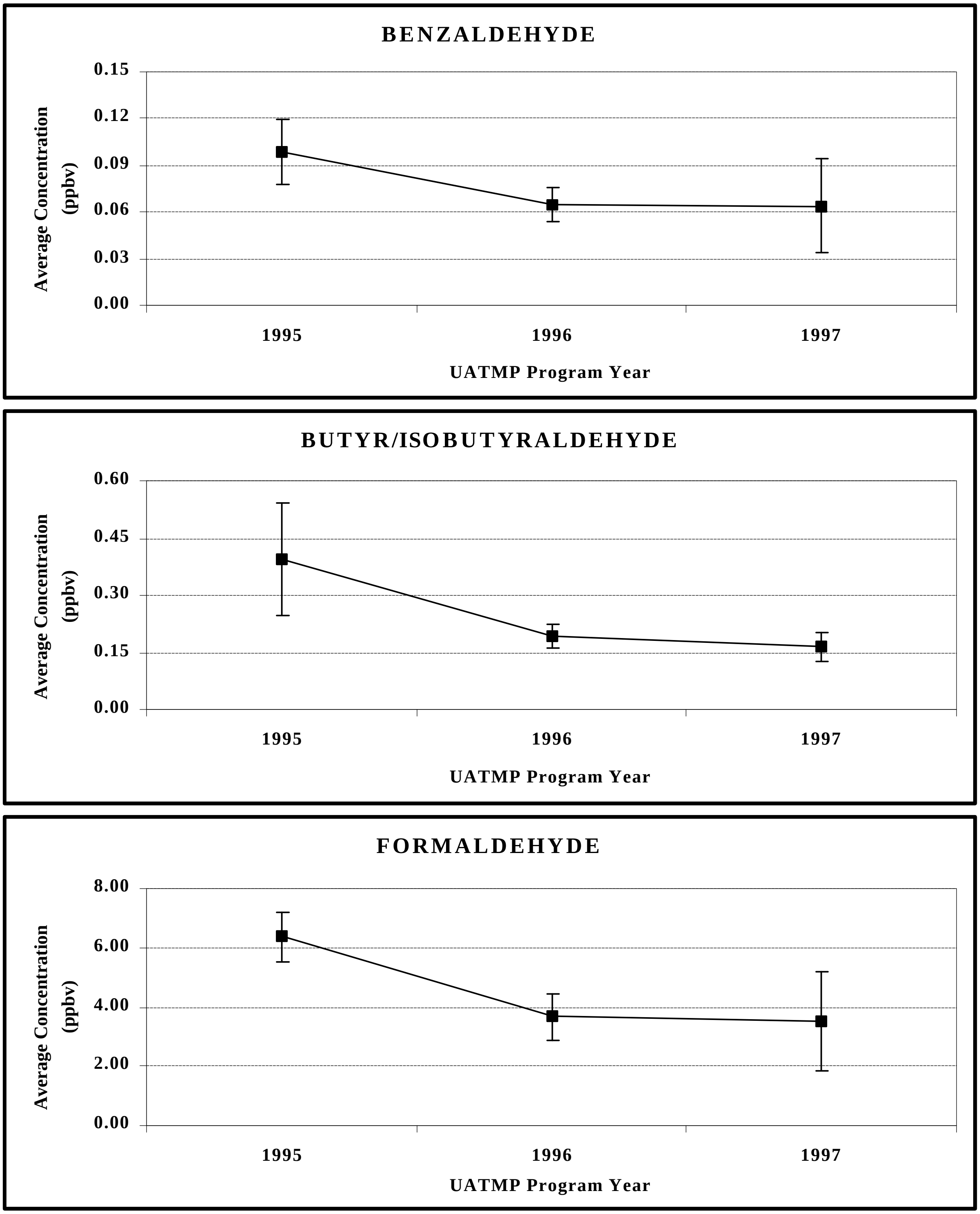






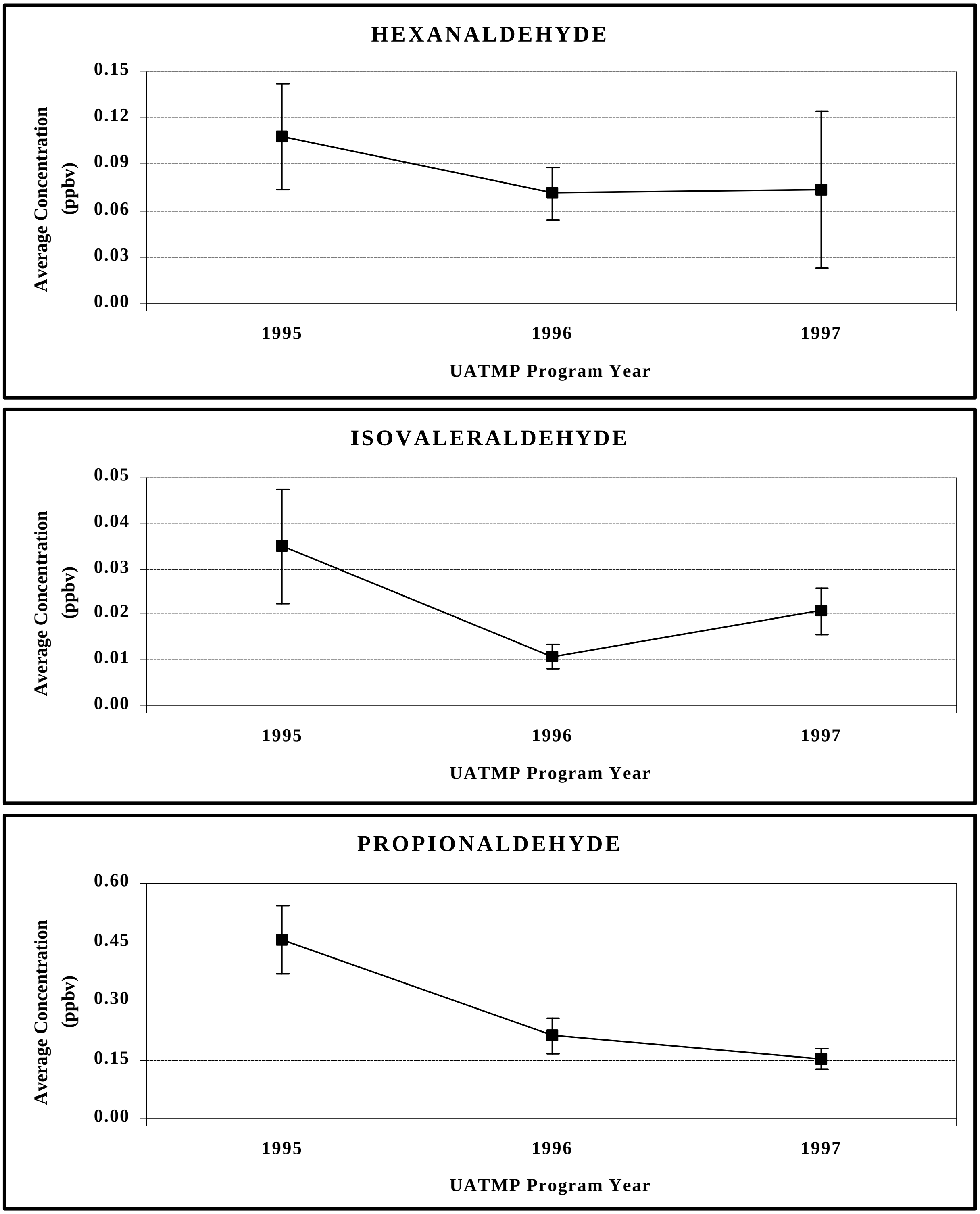
Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 10-4 (Page 2 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at RUVT



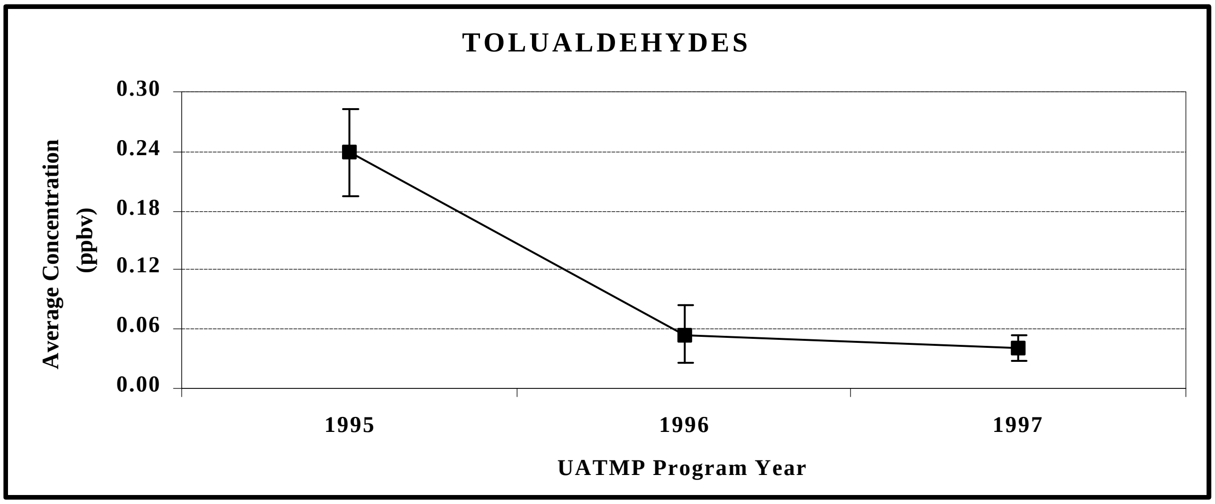
Note: Every plot on this page is shown on a different scale; “error bars” indicate the 95-percent confidence interval of the average concentration.

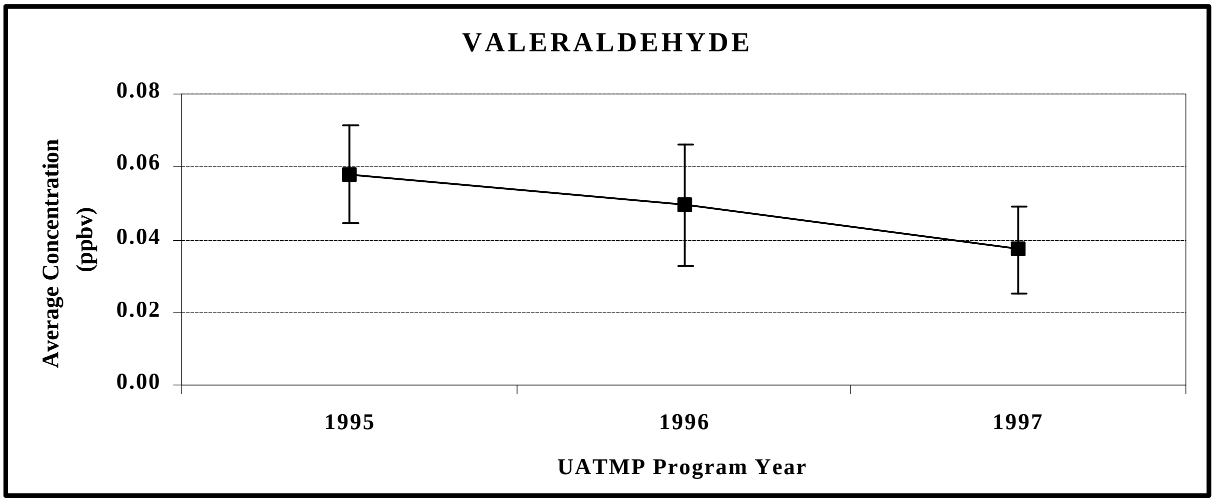
Figure 10-4 (Page 3 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at RUVT



Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Figure 10-4 (Page 4 of 4)
Annual Variations in Average Concentrations of the Most Prevalent Carbonyls at RUVT





Note: Every plot on this page is shown on a different scale; "error bars" indicate the 95-percent confidence interval of the average concentration.

Table 10-1
Summary Statistics for VOC Concentrations Measured at Rutland, Vermont (RUVT)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	22	27%	ND	3.06	0.29	0.65	0.36	0.79	1.22
Acetylene	**0**	**100%**	**0.75**	**5.84**	**1.79**	**2.25**	**1.90**	**1.35**	**0.60**
Acrylonitrile	30	0%	ND	ND	0.11	0.08	0.07	0.03	0.42
Benzene	**0**	**100%**	**0.31**	**2.09**	**0.60**	**0.75**	**0.66**	**0.43**	**0.57**
Bromochloromethane	30	0%	ND	ND	0.05	0.04	0.04	0.01	0.31
Bromodichloromethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	29	3%	ND	1.07	0.08	0.10	0.08	0.18	1.75
Bromomethane	30	0%	ND	ND	0.07	0.06	0.05	0.02	0.42
1,3-Butadiene	**11**	**63%**	**ND**	**0.48**	**0.08**	**0.13**	**0.08**	**0.12**	**0.93**
Carbon tetrachloride	**0**	**100%**	**0.06**	**0.90**	**0.09**	**0.09**	**0.09**	**0.04**	**0.45**
Chlorobenzene	30	0%	ND	ND	0.04	0.03	0.03	0.01	0.23
Chloroethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	26	13%	ND	0.04	0.03	0.03	0.03	0.00	0.17
Chloromethane	**1**	**97%**	**ND**	**1.64**	**0.58**	**0.52**	**0.44**	**0.28**	**0.53**
Chloroprene	30	0%	ND	ND	0.05	0.04	0.03	0.02	0.41
Dibromochloromethane	30	0%	ND	ND	0.08	0.06	0.05	0.03	0.44
m-Dichlorobenzene	30	0%	ND	ND	0.08	0.07	0.06	0.01	0.21
o-Dichlorobenzene	30	0%	ND	ND	0.08	0.07	0.07	0.01	0.20

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 10-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Rutland, Vermont (RUVT)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	28	7%	ND	0.03	0.07	0.05	0.05	0.01	0.25
1,1-Dichloroethane	30	0%	ND	ND	0.05	0.04	0.03	0.02	0.41
1,2-Dichloroethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.14
trans-1,2-Dichloroethylene	30	0%	ND	ND	0.06	0.05	0.05	0.02	0.33
1,2-Dichloropropane	30	0%	ND	ND	0.02	0.03	0.03	0.01	0.42
cis-1,3-Dichloropropylene	30	0%	ND	ND	0.03	0.03	0.02	0.01	0.27
trans-1,3-Dichloropropylene	30	0%	ND	ND	0.06	0.04	0.04	0.02	0.43
Ethyl acrylate	30	0%	ND	ND	0.05	0.04	0.04	0.01	0.34
Ethylbenzene	**1**	**97%**	**ND**	**0.66**	**0.25**	**0.28**	**0.24**	**0.13**	**0.48**
Ethyl *tert*-butyl ether	30	0%	ND	ND	0.04	0.03	0.03	0.00	0.15
Methylene chloride	**4**	**87%**	**ND**	**1.39**	**0.11**	**0.16**	**0.11**	**0.24**	**1.49**
Methyl ethyl ketone	**1**	**97%**	**ND**	**1.01**	**0.53**	**0.51**	**0.47**	**0.18**	**0.36**
Methyl isobutyl ketone	30	0%	ND	ND	0.04	0.04	0.04	0.00	0.00
Methyl methacrylate	30	0%	ND	ND	0.04	0.03	0.03	0.00	0.07
Methyl *tert*-butyl ether	**3**	**90%**	**ND**	**0.64**	**0.21**	**0.23**	**0.18**	**0.14**	**0.62**
***n*-Octane**	**5**	**83%**	**ND**	**0.47**	**0.13**	**0.15**	**0.13**	**0.09**	**0.61**
Propylene	**0**	**100%**	**0.34**	**2.64**	**0.98**	**1.05**	**0.93**	**0.55**	**0.52**
Styrene	**9**	**70%**	**ND**	**0.50**	**0.06**	**0.08**	**0.07**	**0.08**	**1.04**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 10-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Rutland, Vermont (RUVT)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
tert-Amyl methyl ether	28	7%	ND	0.04	0.04	0.03	0.03	0.00	0.08
1,1,2,2-Tetrachloroethane	30	0%	ND	ND	0.09	0.07	0.06	0.03	0.42
Tetrachloroethylene	**13**	**57%**	**ND**	**0.11**	**0.05**	**0.06**	**0.05**	**0.03**	**0.51**
Toluene	**0**	**100%**	**0.54**	**3.53**	**1.57**	**1.71**	**1.52**	**0.80**	**0.47**
1,1,1-Trichloroethane	**0**	**100%**	**0.04**	**0.20**	**0.09**	**0.10**	**0.09**	**0.04**	**0.41**
1,1,2-Trichloroethane	30	0%	ND	ND	0.06	0.04	0.04	0.02	0.43
Trichloroethylene	30	0%	ND	ND	0.02	0.02	0.02	0.00	0.20
Vinyl chloride	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.07
***m,p*-Xylene**	**0**	**100%**	**0.31**	**1.93**	**0.74**	**0.80**	**0.71**	**0.41**	**0.51**
***o*-Xylene**	**0**	**100%**	**0.14**	**0.83**	**0.41**	**0.40**	**0.36**	**0.18**	**0.45**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Table 10-2
Summary Statistics for Carbonyl Concentrations Measured at Rutland, Vermont (RUVT)
(Based on 31 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.46**	**5.31**	**1.17**	**1.36**	**1.20**	**0.86**	**0.63**
Acetone	**1**	**97%**	**ND**	**3.93**	**1.26**	**1.51**	**1.11**	**0.82**	**0.54**
Acrolein	**1**	**97%**	**ND**	**0.11**	**0.04**	**0.05**	**0.04**	**0.03**	**0.61**
Benzaldehyde	**4**	**87%**	**ND**	**0.48**	**0.05**	**0.06**	**0.04**	**0.08**	**1.28**
Butyr/Isobutyraldehyde	**0**	**100%**	**0.06**	**0.58**	**0.14**	**0.16**	**0.14**	**0.10**	**0.62**
Crotonaldehyde	20	35%	ND	0.16	0.00	0.02	0.01	0.03	2.06
2,5-Dimethylbenzaldehyde	21	32%	ND	0.02	0.00	0.01	0.00	0.00	0.97
Formaldehyde	**0**	**100%**	**1.25**	**27.82**	**2.52**	**3.51**	**2.81**	**4.57**	**1.30**
Hexanaldehyde	**0**	**100%**	**0.01**	**0.80**	**0.05**	**0.07**	**0.05**	**0.14**	**1.88**
Isovaleraldehyde	**4**	**87%**	**ND**	**0.05**	**0.02**	**0.02**	**0.02**	**0.01**	**0.66**
Propionaldehyde	**0**	**100%**	**0.05**	**0.40**	**0.13**	**0.15**	**0.14**	**0.07**	**0.47**
Tolualdehydes	**3**	**90%**	**ND**	**0.20**	**0.03**	**0.04**	**0.03**	**0.03**	**0.85**
Valeraldehyde	**0**	**100%**	**0.01**	**0.19**	**0.03**	**0.04**	**0.03**	**0.03**	**0.88**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

11.0 Monitoring Results for Texarkana, AR (GREY)

This section interprets ambient air monitoring data collected at the Texarkana, Arkansas (GREY), monitoring station during the 1997 UATMP. The monitoring station is actually located about 10 miles south of Texarkana, and less than 1 mile east of the Texas–Arkansas border. Figure 11-1 indicates the exact location of the monitoring station, which is in a cow pasture. The features that distinguish land use near GREY from land use near almost every other UATMP monitoring station are the low population density and the minimal effects of motor vehicle traffic at GREY: no interstate highways, and very few heavily traveled roadways pass in the immediate vicinity of the monitors. Another distinguishing feature is that some large industrial facilities, including a paper mill and a natural gas purification plant, are located within several miles of the monitors. Throughout this section, the air quality trends at GREY are shown to be largely consistent with the fact that the monitors are in a remote area, yet near some significant industrial emissions sources.

As Table 2-1 indicated, the monitors at GREY began sampling ambient air on a weekly basis in February, 1998, and collected only 7 months of monitoring data (i.e., from February to August) during the 1997 UATMP. The station has not participated in earlier UATMPs. During the current program, sampling was attempted on 38 days; valid VOC samples were collected on 30 days, and valid carbonyl samples were collected on 34 days. In other words, the completeness of the VOC and carbonyl sampling at GREY was 79 percent and 89 percent, respectively.

The remainder of this section puts the 1997 UATMP monitoring data from GREY into perspective: Section 11.1 presents data summary parameters and comments on their significance; Section 11.2 analyzes in greater detail air quality trends for selected nitriles and oxygenated compounds detected at GREY; Section 11.3 identifies and interprets other notable characteristics of the 1997 monitoring data; and Section 11.4 summarizes the main findings of the preceding subsections. This section does not consider annual variations in ambient air concentrations at GREY, since the monitoring station did not participate in earlier UATMPs.

11.1 Data Summary Parameters for the 1997 UATMP

Using the data summary parameters defined in Section 3.1, Tables 11-1 and 11-2 provide a succinct but thorough overview of the VOC and carbonyl monitoring data, respectively, that were collected at GREY during the 1997 UATMP. For purposes of comparison, these summary tables have the same format as those prepared for the other monitoring stations.

11.1.1 Data Summary of VOC

Table 11-1 reveals the following characteristics of ambient air concentrations of VOC at GREY:

- *Prevalence*. According to Table 11-1, 15 of the 47 VOC considered in the 1997 UATMP were detected in more than half the samples collected at the GREY monitoring station. These most prevalent compounds are:

  Acetylene
  Benzene
  Carbon tetrachloride
  Chloromethane
  Ethylbenzene
  Methylene chloride
  Methyl ethyl ketone
  n-Octane
  Propylene
  Styrene
  Toluene
  1,1,1-Trichloroethane
  m,p-Xylene
  o-Xylene

  The remainder of the VOC were detected in less than one-third of the sampling events at GREY, and 21 of these were never detected at GREY during the 1997 UATMP.

  Since summary statistics for the most prevalent compounds are least affected by nondetects, which are assigned estimated concentrations of one-half the detection limit, most of the analyses in this section focuses on the 15 most prevalent VOC. The accuracy of the summary statistics for the least prevalent VOC is unknown, but is likely low due to the large number of nondetect observations. However, it should not be inferred that the least prevalent VOC are not present in ambient air near GREY: they may be present at varying concentrations over time or they may be consistently present, but at levels that the VOC sampling and analytical method cannot measure.

- *Concentration Range*. As the concentration range data in Table 11-1 show, the highest concentrations of VOC observed at GREY were 302.00 ppbv of acetonitrile, 8.33 ppbv of methyl ethyl ketone, and 4.79 ppbv of styrene. Not shown in Table 11-1 is the fact that the highest concentrations for these three compounds were higher than those observed at almost every UATMP monitoring station: for acetonitrile, only the ambient air concentrations observed at B2LA exceeded those observed at GREY; for methyl ethyl ketone, only one other ambient air concentration observed during the 1997 UATMP (33.33 ppbv at GALA) exceeded the highest levels observed at GREY; and, for styrene, the two highest ambient air concentrations of the compound observed during the entire 1997 UATMP were from samples collected at GREY. In short, levels of acetonitrile, methyl ethyl ketone, and styrene measured at the remote GREY station were notably higher than those measured at the other UATMP monitoring stations, some of which are located in densely populated urban environments. This finding suggests that emissions sources near GREY are probably releasing these three compounds to the air in quantities greater than the emissions from sources near the other UATMP monitoring stations. The analyses of central tendency data (below) support this hypothesis.

Also not shown in Table 11-1 is evidence that the peak concentrations for acetonitrile, methyl ethyl ketone, and styrene typically occurred on the same days at GREY. For instance, the highest concentrations for methyl ethyl ketone and styrene were both observed on May 11, 1998. Further, the sample collected on March 30, 1998, had the second highest concentrations of acetonitrile, methyl ethyl ketone, and styrene. The timing of the elevated concentrations for these compounds suggests that all three may have originated from the same local source (or sources). Sections 11.2 and 11.3 and the following discussion on central tendency revisit this issue.

As Table 11-1 indicates, several other VOC measured at GREY had at least one ambient air concentration greater than 1.0 ppbv: acetylene, acrylonitrile, benzene, chloromethane, methylene chloride, propylene, and toluene. However, the highest concentrations for these compounds were all notably lower than those discussed previously for acetonitrile, methyl ethyl ketone, and styrene.

Further interpretations of the concentration ranges in Table 11-1 should acknowledge the fact that the UATMP data only estimate the actual span of ambient air concentrations at GREY, since higher or lower levels may have occurred on nonsampling days.

- *Central Tendency*. Table 11-1 presents three different measures of central tendency concentrations at GREY. As noted earlier, these measures are believed to be least uncertain for the most prevalent VOC. Because high numbers of nondetect observations bias central tendency calculations, the data presented for the least prevalent compounds should be interpreted with caution. Overall, Table 11-1 shows that none of the VOC considered in the 1997 UATMP had geometric mean concentrations greater than 1.0 ppbv at GREY. The five compounds with the highest geometric mean concentrations were methyl ethyl ketone (0.90 ppbv), chloromethane (0.74 ppbv), acetylene (0.51 ppbv), propylene (0.50 ppbv), and acetonitrile (0.43 ppbv). All other VOC at GREY had geometric mean concentrations less than or equal to 0.35 ppbv.

The five compounds with the highest central tendency values at GREY differed from those typically observed at the other monitoring stations. More specifically, at almost every UATMP monitoring station, toluene had geometric mean concentrations ranking among the five highest; and, at several stations, benzene, methyl *tert*-butyl ether, and *m,p*-xylene had concentrations that also ranked among the five highest. At GREY, however, none of these compounds had concentrations ranking among the five highest. This dissimilarity suggests that the factors most affecting air quality in urban centers (i.e., at the other UATMP monitoring stations) differ from those most affecting air quality at GREY. Because mobile source emissions are believed to account for much of the benzene, methyl *tert*-butyl ether, toluene, and *m,p*-xylene in urban air, the relatively low concentrations of these compounds at GREY is best explained by the site being located in a remote area, far from heavily traveled roadways.

Figure 3-1, which illustrates the spatial variations in ambient air concentrations observed during the 1997 UATMP, indicates two notable instances where ambient air concentrations of VOC at GREY differ from those at the other UATMP monitoring stations. First, the geometric mean concentrations of VOC typically found in motor vehicle exhaust—acetylene, benzene, 1,3-butadiene, ethylbenzene, toluene, and the xylene isomers—were either lowest or second lowest at the GREY monitoring station during the 1997 program. This trend further emphasizes the relative impacts of mobile source emissions in urban and rural locations.

Second, the spatial variations provide additional evidence that emissions sources near GREY contributed to relatively high levels of acetonitrile, methyl ethyl ketone, and styrene. For instance, the geometric mean concentrations of acetonitrile and styrene at GREY were the second highest of those observed during the 1997 UATMP (next to the concentrations observed at B2LA); and the geometric mean concentration of methyl ethyl ketone at GREY was the highest of those observed during the 1997 program (with the concentration at B2LA being second highest). The relatively high geometric mean concentrations of acetonitrile, methyl ethyl ketone, and styrene at GREY provide further evidence that they originate from local emissions sources that probably are not found in most urban environments. The similarity between the levels observed at GREY and at B2LA, however, suggests that a particular type of emissions source for these compounds might be found in the immediate vicinity of both stations, but not near the other UATMP monitors. Sections 11.2 and 11.3 comment further on the unique air quality trends observed at GREY for acetonitrile, methyl ethyl ketone, and styrene.

Note: It is important to interpret the graphs in Figure 3-1 in proper context: the 1997 UATMP characterized air quality in a very small subset of urban areas in the United States. Therefore, even though concentrations of methyl ethyl ketone at GREY were higher than those at the other UATMP monitoring stations, the 1997 UATMP monitoring data are insufficient for evaluating how the levels observed at GREY rank among those throughout the United States.

- *Variability*. Table 11-1 lists standard deviations and coefficients of variation as absolute and relative indicators, respectively, of variability among the ambient air monitoring data collected at GREY. Ten of the most prevalent VOC had coefficients of variation less than 1.0, and five had coefficients of variation greater than or equal to 1.0. The most prevalent compounds with the greatest variability, on a relative scale, were styrene (coefficient of variation, 2.70), ethylbenzene (1.34), methyl ethyl ketone (1.27), methylene chloride (1.08), and toluene (1.00). By definition, ambient air concentrations of these compounds changed the most from sample to sample. Such variability is typical for compounds originating primarily from emissions sources at discrete locations (e.g., not mobile sources), since the concentrations measured by the monitors would change primarily with fluctuating wind patterns. However, the variability data alone are not sufficient for reaching this conclusion. Nonetheless, the variability data are consistent with several of the findings of Sections 11.2 and 11.3.

As noted earlier, Section 11.2, which interprets the 1997 UATMP monitoring data for nitriles and oxygenated compounds, and Section 11.3, which identifies and interprets other notable trends and patterns among the data, provide further insight into the VOC monitoring data collected at GREY.

11.1.2 Data Summary of Carbonyls

Table 11-2 reveals the following characteristics of ambient air concentrations of carbonyls measured at GREY:

- *Prevalence*. As Table 11-2 shows, the 16 carbonyls considered in the 1997 UATMP, except for crotonaldehyde and 2,5-dimethylbenzaldehyde, were detected in at least half of the samples collected at GREY. Therefore, summary statistics for most of the carbonyls likely represent actual air quality trends in the vicinity of the Texarkana, Arkansas, monitoring station.

- *Concentration Range*. Of the 16 carbonyls considered in the 1997 UATMP, 12 were not detected at levels greater than 1.0 ppbv during the 7 months of sampling at GREY. The maximum concentrations of acetaldehyde (4.05 ppbv), acetone (4.01 ppbv), formaldehyde (13.22 ppbv), and hexanaldehyde (1.02 ppbv) all exceeded this level. In fact, concentrations of formaldehyde were greater than 1.0 ppbv in over 85 percent of the samples. The discussion on central tendency (below) comments further on the relative concentrations of carbonyls measured at GREY. As noted earlier, concentration ranges derived from the UATMP monitoring data only estimate the actual span of ambient air concentrations, because concentrations may reach higher or lower levels on nonsampling days.

- *Central Tendency*. According to Table 11-2, geometric mean concentrations of carbonyls at GREY were highest for formaldehyde (2.59 ppbv), acetaldehyde (0.93 ppbv), and acetone (0.89 ppbv). In fact, these three compounds, on average, accounted for nearly 90 percent of the carbonyls that were measured in the air at GREY. Every other carbonyl measured at GREY during the 1997 UATMP had geometric mean concentrations less than 0.15 ppbv—more than a factor of seven lower than the levels observed for acetaldehyde, acetone, or formaldehyde. It should also be noted that the geometric mean concentration of formaldehyde was higher than that for every other compound measured at GREY, including VOC.

  Figure 3-2, which illustrates how geometric mean concentrations of carbonyls varied from one monitoring station to the next, indicates that levels of carbonyls at GREY were not unusually higher or lower than those reported at the other monitoring stations that participated in the 1997 program. Nonetheless, two notable trends are apparent from these spatial variations. First, though difficult to tell from the figure, several carbonyls—acetaldehyde, acrolein, formaldehyde, hexanaldehyde, isovaleraldehyde, the tolualdehyde isomers, valeraldehyde—had geometric mean concentrations at GREY that ranked among the top five observed at the 12 UATMP monitoring stations. The fact that these compounds had relatively high concentrations in a rural area that is far from heavily traveled roadways suggests that motor vehicle emissions alone cannot explain the spatial variations. Second, it is interesting to note that geometric mean concentrations at GREY were quite similar to those measured at North Little Rock, the only other UATMP monitoring station in the state of Arkansas. For instance, the geometric means for acetaldehyde, acetone, and formaldehyde at GREY were no more than 20 percent different from the corresponding concentrations observed at PARR. In short, concentrations of carbonyls in the downtown area of Arkansas' largest city differ little from those in a remote field in the state. Emissions of carbonyls from nearby industrial sources might explain the relatively high levels observed at GREY, or ambient air concentrations of carbonyls may simply be affected by regional factors (e.g., long-range transport, photochemical reactivity). Further research is encouraged to explain this surprising trend.

Note: As mentioned earlier, the spatial variations illustrated in Figure 3-2 characterize air quality in a very small subset of urban centers in the United States, and the trends implied by the figure should be interpreted accordingly.

- *Variability*. Not surprisingly, the data variability for the most prevalent carbonyls measured at GREY differed from compound to compound. As Table 11-2 indicates, benzaldehyde and hexanaldehyde had the greatest variability, on a relative scale, and butyr/isobutyraldehyde and acetaldehyde had the lowest. The coefficients of variation for acetaldehyde (0.73), acetone (0.80), and formaldehyde (0.80) ranked among the lowest at GREY. Therefore, the three compounds that account for most of the airborne carbonyls measured during the 1997 UATMP were consistently present in the air at GREY, despite changing wind patterns from one sample to the next.

For further insight into the origins of airborne carbonyls, Section 11.3 interprets emissions data reported by facilities near the GREY monitoring station, and Section 12.1 reviews the most notable findings of the carbonyl monitoring data collected at all stations during the 1997 UATMP.

11.2 Analyses and Interpretations for Nitriles and Oxygenated Compounds

The following discussion analyzes and interprets air quality trends for the nine compounds (all nitriles and oxygenated compounds) that were measured during the 1997 UATMP, but not during previous program years. As discussed below, most of these compounds were rarely, if ever, detected at GREY:

- *Compounds that were rarely, if ever, detected*. Of the nine nitriles and oxygenated compounds that the VOC analytical method could measure, six—ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, methyl methacrylate, methyl *tert*-butyl ether, and *tert*-amyl methyl ether—were detected in none, or only one, of the samples collected at GREY during the 1997 UATMP. Thus, it is difficult to draw any conclusions about these compounds, except that they are rarely found at detectable levels. Consistent with the infrequent detections is the fact that no industrial facilities within 10 miles of GREY reported emitting ethyl acrylate, methyl isobutyl ketone, methyl methacrylate, or methyl *tert*-butyl ether to the 1995 TRI. Emissions data for ethyl *tert*-butyl ether and *tert*-amyl methyl ether are not readily available, since facilities were not required to disclose environmental releases of these compounds to the 1995 TRI. However, the fact that neither compound was detected at GREY suggests that their emissions from nearby industries are likely insignificant. A review of 1996, 1997, and 1998 TRI data, once available, is encouraged to verify these findings.

- *Acetonitrile.* Though it was detected in less than half of the samples in GREY, acetonitrile exhibited unique data trends. For instance, ambient air concentrations of acetonitrile had particularly strong seasonal variations at GREY: its average concentration during the first 4 months of sampling (i.e., from February to May) was over seven times higher than its average concentration during the last 3 months of sampling (i.e., from June to August). In fact, acetonitrile was not detected in the last 15 valid sampling events at the monitoring station. The reason for this seasonality is unknown, but it is interesting to note that ambient air concentrations of acetonitrile measured at the monitoring station in Baton Rouge exhibited similar seasonal variations (see Section 4.2). Furthermore, of the 1,360 ambient air concentrations of VOC measured at GREY during the 1997 UATMP, the four highest concentrations were all for acetonitrile: 302.0 ppbv, 70.7 ppbv, 58.4 ppbv, and 14.3 ppbv. Therefore, though not detected frequently, acetonitrile was often detected at extremely high levels at GREY.

  Several explanations are consistent with these unique data trends for acetonitrile at GREY (e.g., nearby industrial emissions sources periodically releasing the compound, detections of acetonitrile being linked to very specific meteorological conditions, and so on). However, it is difficult to confirm these explanations because no industrial facilities near the monitoring station reported releases of acetonitrile to the 1995 TRI. Review of more recent TRI reporting data, once available, might help identify the origin of acetonitrile at GREY. Further, given the similarities between the ambient air monitoring data for acetonitrile at B2LA and those at GREY, a detailed comparison of the industrial facilities near these two stations also might help identify the predominant sources of acetonitrile.

- *Acrylonitrile.* Like acetonitrile, acrylonitrile was detected in 8 of the 30 valid VOC sampling events at GREY during the 1997 UATMP. Unlike acetonitrile, however, acrylonitrile exhibited relatively weak seasonal variations and its ambient air concentrations were notably lower, never exceeding 1.13 ppbv. It is difficult to determine the origins of acrylonitrile at GREY, since no industrial facilities in the area reported emitting the compound to the 1995 TRI. Curiously, acrylonitrile was most prevalent at the only UATMP monitoring stations in rural areas (GREY and UNVT)—a trend that suggests natural emissions sources of acrylonitrile may be significant. However, more monitoring data are needed to confirm the association between land use and acrylonitrile in ambient air; and further research is needed to determine possible links between natural emissions sources and ambient air concentrations of acrylonitrile.

- *Methyl ethyl ketone*. As noted earlier, methyl ethyl ketone appears to be one of the principal components of air pollution at GREY: it was detected in every sample collected at the station, and its geometric mean concentration was higher than that of every other VOC at GREY. In fact, concentrations of methyl ethyl ketone at GREY were higher, on average, than those measured at every other station that participated in the 1997 UATMP. The fact that levels of methyl ethyl ketone were highest at the most remote monitoring station (GREY) suggests that emissions from motor vehicles were not the primary source of the compound measured during the 1997 program.

  Industrial emissions data, on the other hand, appear to be somewhat consistent with the methyl ethyl ketone monitoring data. According to the TRI, a paper mill near GREY reported releasing 13,000 pounds of methyl ethyl ketone to the air in 1995. These emissions likely accounted for some of the methyl ethyl ketone detected at the monitoring station. Without conducting a detailed atmospheric dispersion modeling analysis, which is not included in the scope of work for this report, it is impossible to determine whether emissions from this one facility are consistent with the measured concentrations. However, it is interesting to note that lower concentrations of methyl ethyl ketone were observed at monitoring stations that are near facilities that reportedly emitted at least 25,000 pounds of the compound (e.g., Baton Rouge, Camden, and Rutland). The analyses in Section 11.3 suggest that emissions sources near GREY other than the paper mill likely contributed to the relatively high concentrations of methyl ethyl ketone observed during the 1997 UATMP.

11.3 Other Notable Characteristics

Since no historical data are readily available for evaluating annual variations in air quality at GREY, this section instead presents additional detailed analyses of the monitoring data that were collected during the 1997 UATMP. More specifically, the following discussion addresses the composition of air samples collected at GREY, interprets correlations among the monitoring data, and revisits industrial emissions reported by facilities in the area:

- *Composition of air samples*. For further insight into the origins of air pollution at GREY, two different measures of the composition of air samples were evaluated. First, to illustrate the relative quantities of different groups of compounds, Figure 11-2 presents the composition of the most prevalent compounds at GREY, broken down by carbonyls, halogenated hydrocarbons, and hydrocarbons. The basis for this composition calculation was the geometric mean concentrations of the 29 compounds (15 carbonyls[1], 4 halogenated hydrocarbons, and 10 hydrocarbons) that were detected in at least half of the samples collected at GREY during the 1997 UATMP. As Figure 11-2 shows, carbonyls accounted for 64 percent of the total concentration of the most prevalent compounds at GREY, followed by hydrocarbons (24 percent) and halogenated hydrocarbons (12 percent). As can be seen by comparing Figures 9-2 and 11-2, air pollution at the rural GREY site contained more carbonyls relative to hydrocarbons than did air pollution at the urban PARR site. This difference likely results from several factors, but the absence of heavy motor vehicle traffic near GREY probably best explains the relatively lower levels of hydrocarbons at this station.

To characterize the impacts of mobile source emissions at GREY, Figure 11-3 compares concentration ratios of BTEX compounds calculated from the 1997 UATMP monitoring data to ratios reported in a recent roadside study (Conner et al., 1995). As is evident from this comparison, the relative concentrations of BTEX compounds at GREY do not resemble those measured at roadsides—a trend confirming that mobile source emissions probably do not account for a large portion of the BTEX compounds measured at GREY. It is likely, however, that emissions from industrial facilities near the monitoring station account for much of the airborne BTEX compounds at GREY. For purposes of comparison, Figure 11-4 clearly demonstrates how concentration profiles from other UATMP monitoring stations are strikingly similar to those from the roadside study.

- *Data correlations*. As Section 9.3 explained, the extent to which concentrations of different compounds are correlated is an important element for understanding the sources of urban air pollution, particularly when identifying emissions sources for selected compounds. As a general rule, pairs of compounds that originate from the same groups of sources usually have highly correlated ambient air monitoring data, though exceptions may exist. To quantify the correlations among the ambient air monitoring data collected at GREY, Pearson correlation coefficients were calculated for the nearly 300 different possible pairings of the most prevalent VOC and carbonyls. As a summary of the most notable correlations, Table 11-3 lists the 20 pairs of compounds that had Pearson correlation coefficients greater than 0.70. Though many interpretations can be made from these correlations, two important observations are highlighted below.

  First, concentrations of methyl ethyl ketone and styrene were shown to be very highly correlated with concentrations of other compounds at GREY. This finding,

---

[1] Though it is measured by the VOC analytical method, methyl ethyl ketone is technically a carbonyl and was classified as such for purposes of calculating composition data.

which was shown to be statistically significant, is noteworthy because it appears to be unique to GREY: at every other station, levels of methyl ethyl ketone and styrene were very weakly correlated, if not completely uncorrelated, with levels of the other most prevalent compounds. To illustrate the highly correlated data at GREY, Figure 11-5 indicates how concentrations of methyl ethyl ketone compared to those of ethylbenzene, *m,p*-xylene, and styrene. As the figure shows, when levels of methyl ethyl ketone were high at GREY, so were levels of ethylbenzene, *m,p*-xylene, and styrene; and vice versa. Emissions from one or more sources near the monitoring station most likely accounted for these unique correlations. More specifically, prevailing winds would either blow emissions of these compounds away from the monitors, causing the compounds' concentrations to be low, or blow the emissions toward the monitors, causing the compounds' concentrations to be high. As discussed in greater detail below, the emissions sources of these compounds are most likely nearby industrial facilities.

The second noteworthy observation from Table 11-3 is the relatively strong correlations that were observed for many different pairs of carbonyls. Both the 1995 and 1996 UATMP final reports also addressed data correlations, but neither report identified monitoring stations with similarly strong correlations for as many pairs of compounds. Thus, the limited monitoring data available for this station suggest that ambient air concentrations of many carbonyls tend to rise and fall in proportion. In addition to being highly correlated, ambient air concentrations of almost every carbonyl at GREY were notably higher during the summer (June to August) than during other months (February to May). This seasonal trend is consistent with the assumption that carbonyls at GREY originated, to a certain extent, as products of photochemical reactions, which reach their peak during the warmer summer months. The final report for the 1998 UATMP will provide more detailed analyses of the sources of carbonyls in ambient air.

- *Industrial emissions data*. With analyses throughout this section indicating that mobile source emissions have a relatively minor impact on air quality at GREY, the notably high concentrations of certain compounds (e.g., acetonitrile, methyl ethyl ketone, styrene) at this station appear to most likely originate from nearby industrial sources. Based on information included in the 1995 TRI and provided by the Arkansas Department of Pollution Control and Ecology, industrial emissions sources near the GREY monitoring station appear to be limited to a paper mill and a natural gas purification plant. Table 11-4 presents self-reported emissions data for the paper mill, but emissions data for the natural gas purification plant were not reported to the 1995 TRI, presumably because the facility was not required to do so.

  As Section 11.2 noted, the relatively high levels of methyl ethyl ketone at GREY may have been caused, to a certain extent, by the emissions reported by the paper mill. However, there are several reasons to believe that other sources in the area also emitted methyl ethyl ketone. First, the paper mill reportedly emitted almost six times as much acetaldehyde as methyl ethyl ketone, yet the geometric mean concentrations of acetaldehyde (0.93 ppbv) and methyl ethyl ketone (0.90 ppbv) at GREY were similar. The fact that the relative amounts of acetaldehyde and methyl ethyl ketone in the emissions differ from those measured at GREY suggests that there may be other sources of these compounds in the area.[2] Second, the ambient air concentrations of methyl ethyl ketone were very highly correlated with those for ethylbenzene, styrene, and the xylene isomers, yet the paper mill did not report releasing proportionate amounts of these compounds.

These and other inconsistencies between the ambient air monitoring data and the emissions data demonstrate several key limitations associated with using TRI in quantitative analyses. More specifically, since the reporting requirements do not apply to all industrial facilities, the TRI emissions data may not provide a complete account of major industrial emissions sources in a given area. Data from an extensive emissions inventory—one which accounts for all industrial sources near the monitors—would allow for a much more rigorous analysis of air pollution at GREY and might explain why concentrations of some compounds at this rural station were surprisingly high.

11.4 Summary

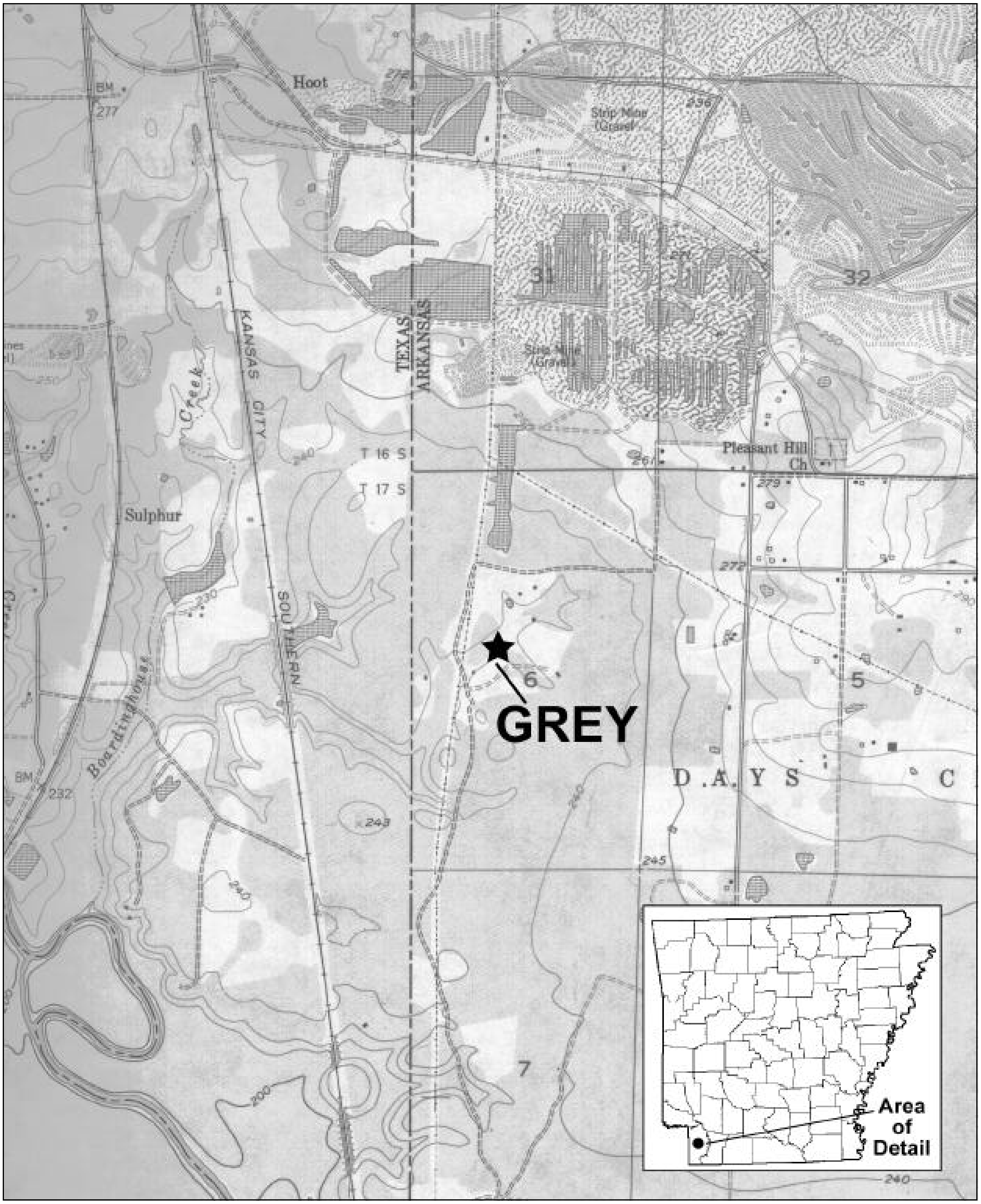
Of the 12 monitoring stations that participated in the 1997 UATMP, the GREY monitoring station was unique in several regards, mainly as a result of its location in a cow pasture far from heavily traveled roadways yet close to several industrial emissions sources. One unique feature for this site was that many different trends among the data suggested that mobile source emissions were relatively insignificant: the compounds with the highest concentrations at GREY did not include hydrocarbons typically found in motor vehicle exhaust, the concentration profile of BTEX compounds at GREY was notably different than that observed at other monitoring stations and in roadside studies, and the average concentrations of the BTEX compounds at GREY were lower than those observed at almost every other monitoring station.

---

[2] This argument assumes that the emissions data reported by the paper mill were accurate and reasonably representative of emissions during the 1997 UATMP.

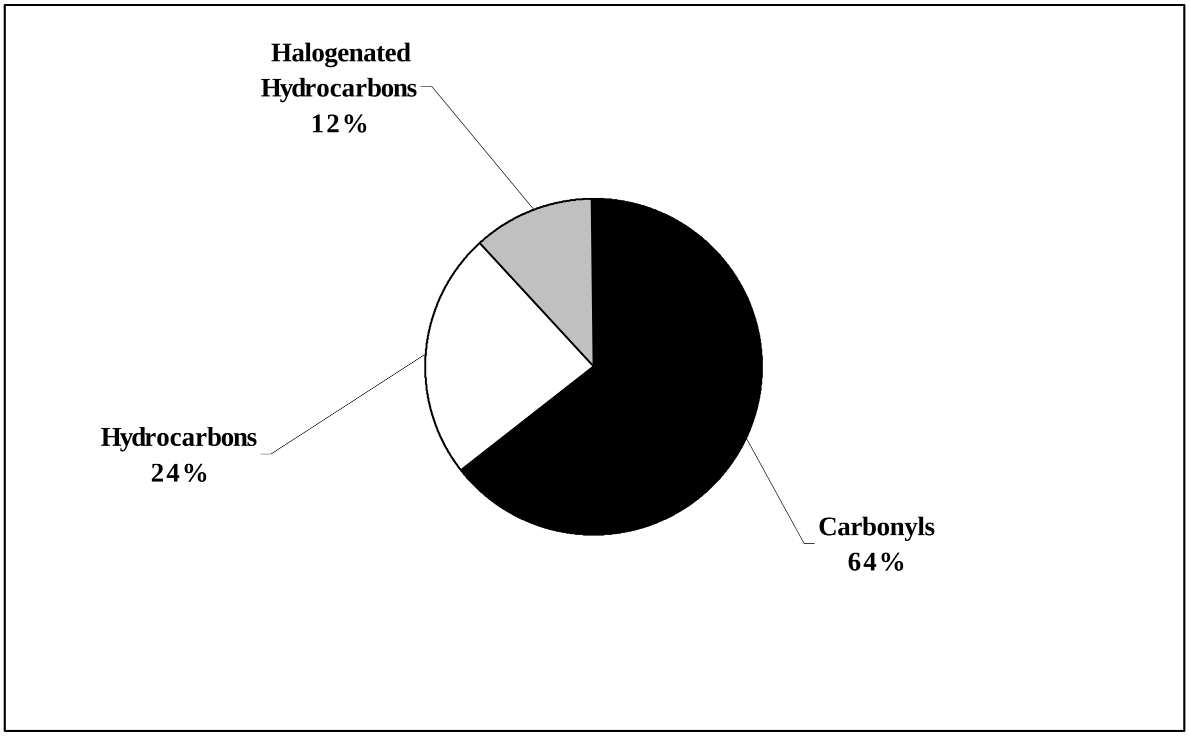
Another notable feature of the air monitoring data is the relatively high concentrations of acetonitrile, methyl ethyl ketone, and styrene. Given the minor influences from mobile source emissions at this station, these compounds probably originated, to a large extent, from nearby industrial emissions sources. The fact that the concentrations of these compounds were highly correlated suggests that they may have originated from the same source or possibly from a group of sources located in the same general area. Because comprehensive emissions data were not available for every industrial facility near this monitoring station, the exact sources of these compounds could not be determined. However, consistencies between the ambient air monitoring data collected at B2LA and those collected at GREY suggest that a similar type of emissions source may be near both monitoring stations and may account for much of the airborne levels of acetonitrile, methyl ethyl ketone, and styrene. Further research is encouraged to verify this hypothesis.

Figure 11-1
Texarkana, Arkansas (GREY), Monitoring Station



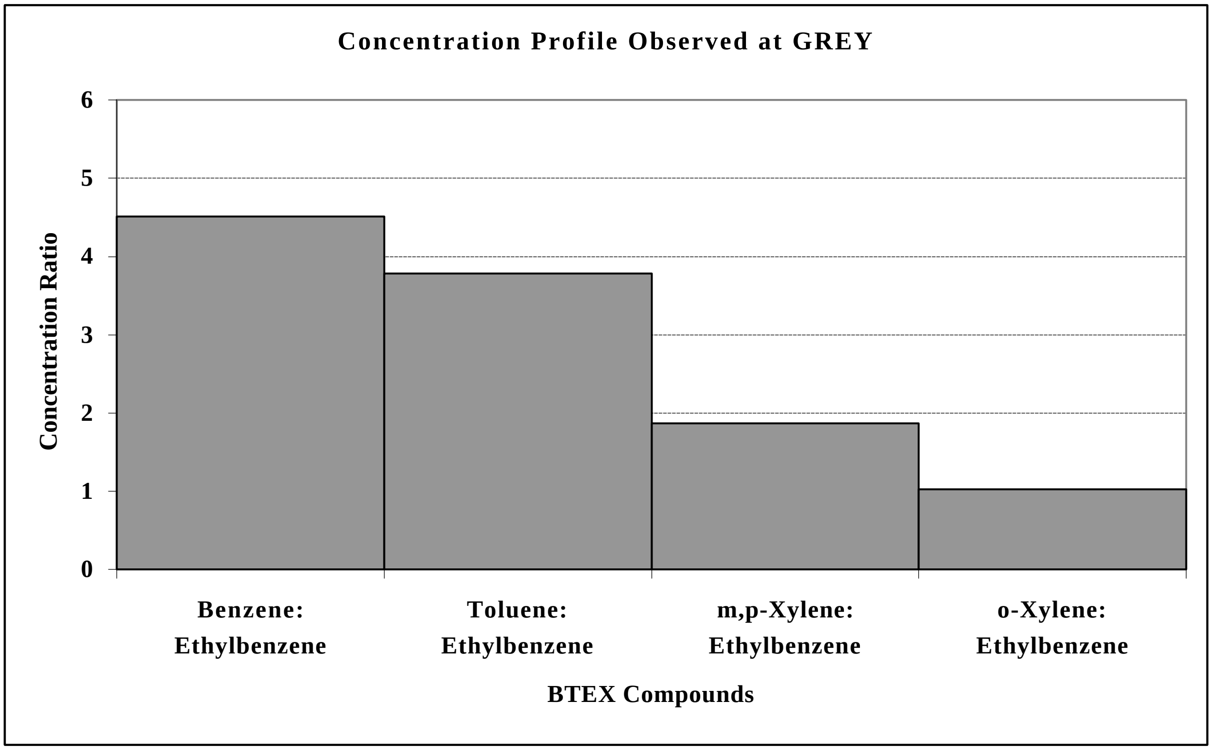
Source: USGS 7.5 Minute Series. Map Scale: 1:24,000.

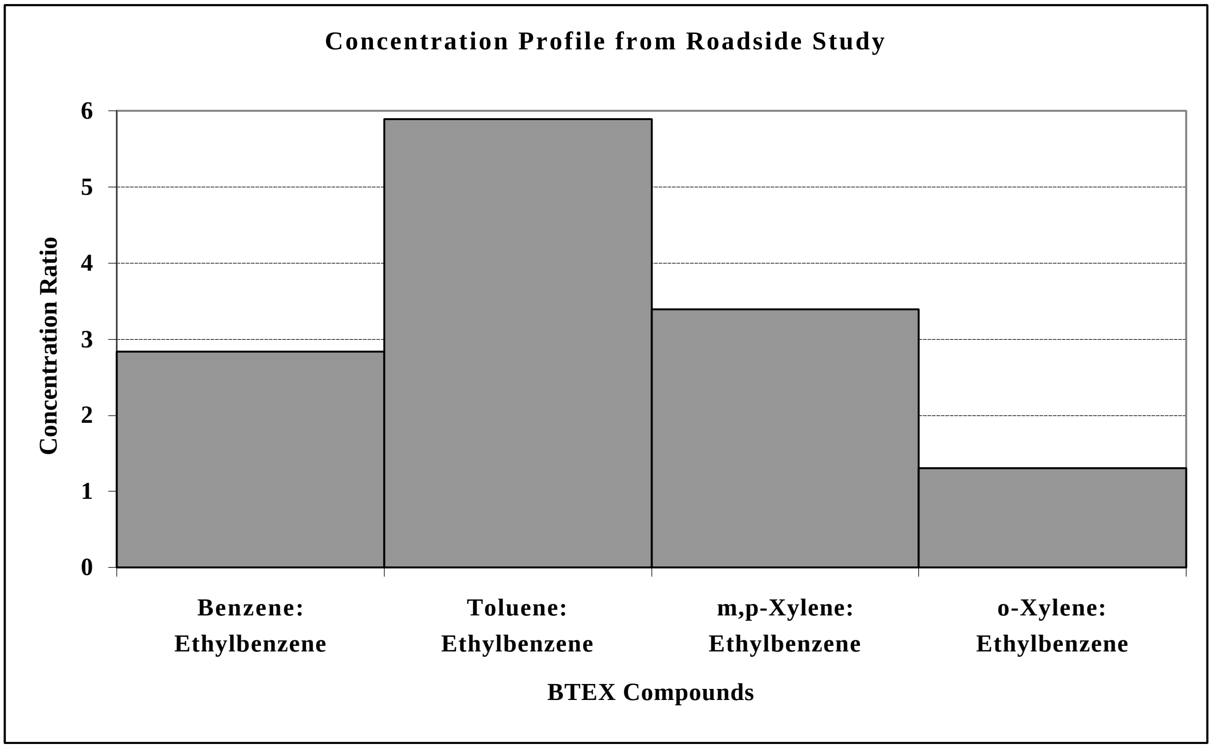
Figure 11-2
Composition of Air Samples at GREY



Note: As Section 11.3 explains, the composition data in this figure should be viewed only as an indicator of the actual composition of air pollution at GREY. Because this figure considers only the most prevalent compounds measured during the 1997 UATMP, and because the UATMP does not measure concentrations of every component of air pollution, this figure does not present the actual composition of air pollution at GREY.

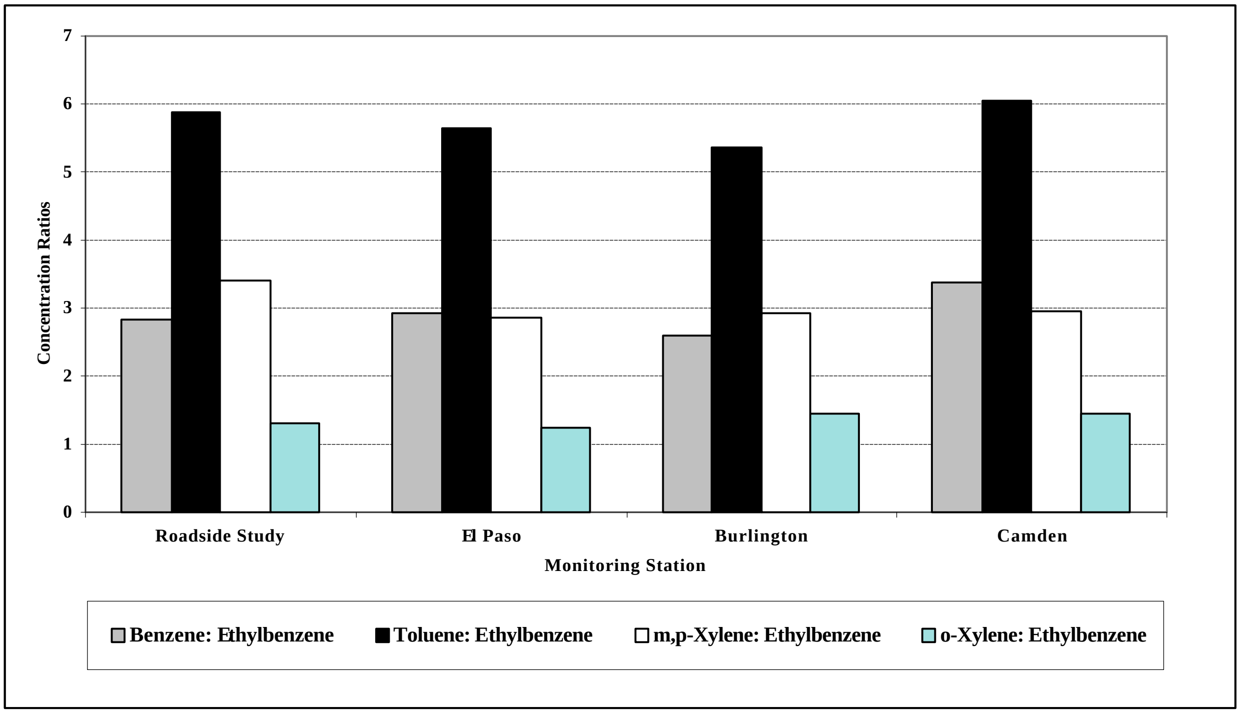
Figure 11-3
Comparison of BTEX Concentration Profile at GREY to Results from a Roadside Study





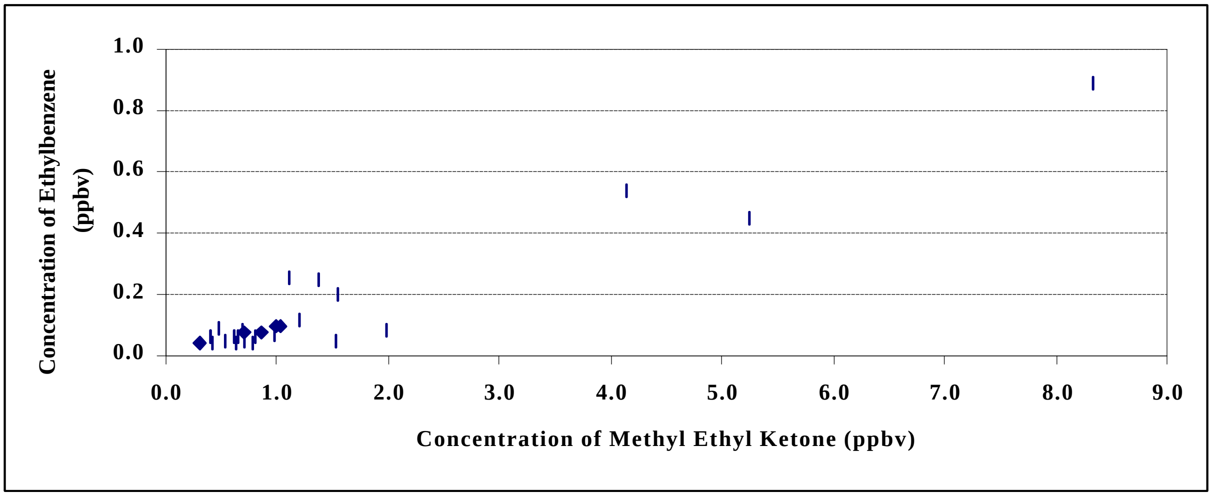
Note: Roadside data from Conner et al., 1995.

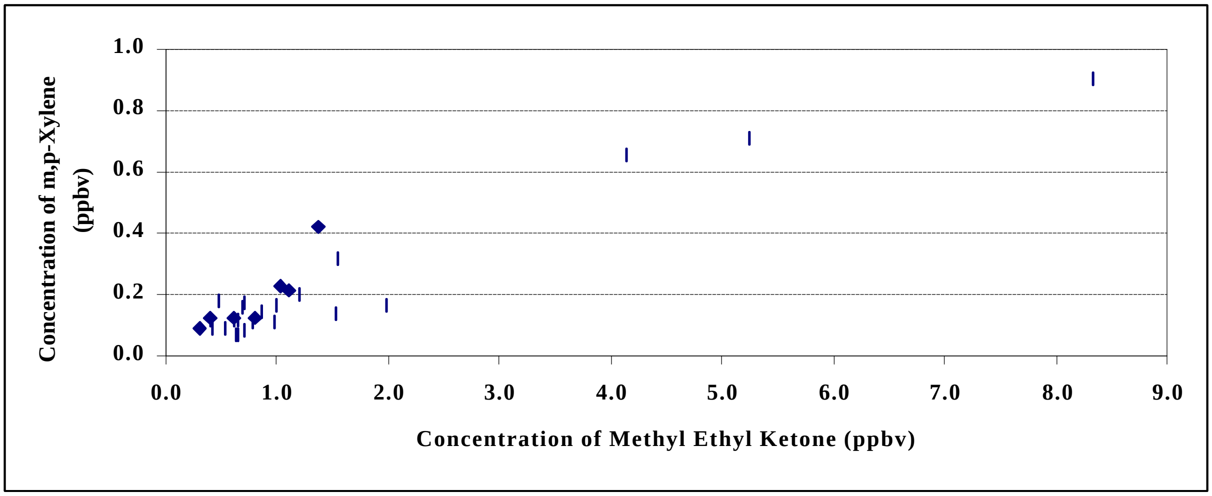
Figure 11-4
Comparison of BTEX Concentration Profile at Selected Monitoring Stations to Results from a Roadside Study



Note: Roadside data from Conner et al., 1995.

Figure 11-5
Data Correlations for Ambient Air Concentrations of Selected Compounds





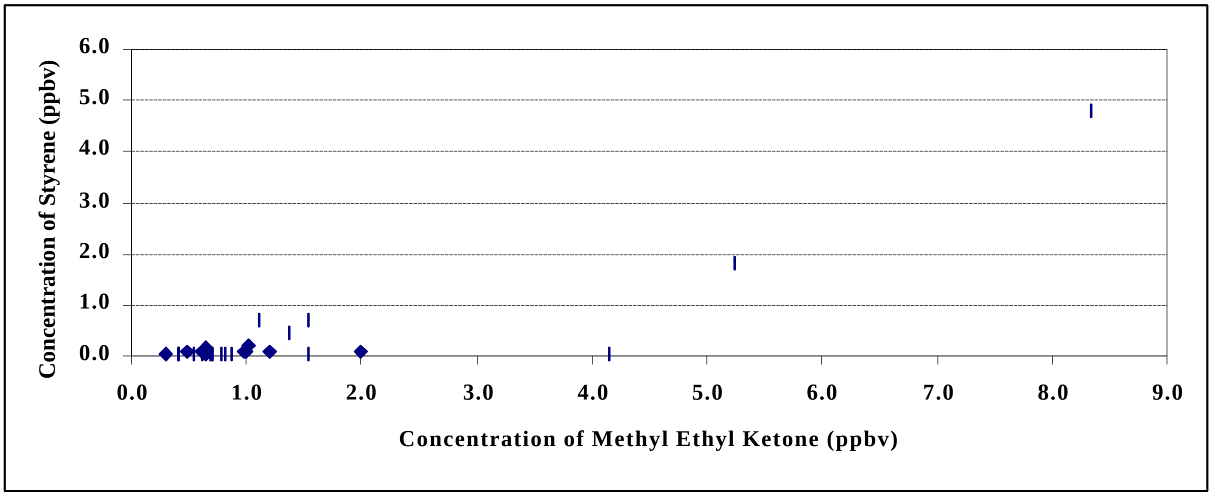


Table 11-1
Summary Statistics for VOC Concentrations Measured at Texarkana, Arkansas (GREY)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetonitrile	22	27%	ND	302.00	0.20	15.26	0.43	56.59	3.71
Acetylene	**0**	**100%**	**0.23**	**1.94**	**0.52**	**0.60**	**0.51**	**0.41**	**0.68**
Acrylonitrile	22	27%	ND	1.13	0.11	0.20	0.09	0.29	1.44
Benzene	**0**	**100%**	**0.16**	**2.16**	**0.33**	**0.41**	**0.35**	**0.35**	**0.87**
Bromochloromethane	30	0%	ND	ND	0.02	0.03	0.03	0.01	0.42
Bromodichloromethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Bromoform	30	0%	ND	ND	0.06	0.07	0.07	0.01	0.11
Bromomethane	28	7%	ND	0.03	0.02	0.04	0.03	0.02	0.62
1,3-Butadiene	29	3%	ND	0.43	0.03	0.05	0.03	0.07	1.59
Carbon tetrachloride	**0**	**100%**	**0.06**	**0.17**	**0.10**	**0.10**	**0.09**	**0.02**	**0.24**
Chlorobenzene	30	0%	ND	ND	0.02	0.03	0.03	0.01	0.29
Chloroethane	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.00
Chloroform	28	7%	ND	0.05	0.02	0.02	0.02	0.01	0.28
Chloromethane	**1**	**97%**	**ND**	**2.23**	**0.75**	**0.84**	**0.74**	**0.36**	**0.43**
Chloroprene	30	0%	ND	ND	0.02	0.03	0.02	0.02	0.60
Dibromochloromethane	30	0%	ND	ND	0.02	0.04	0.03	0.03	0.65
m-Dichlorobenzene	30	0%	ND	ND	0.05	0.06	0.06	0.01	0.26
o-Dichlorobenzene	30	0%	ND	ND	0.05	0.06	0.06	0.01	0.24

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 11-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Texarkana, Arkansas (GREY)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
p-Dichlorobenzene	29	3%	ND	0.38	0.04	0.06	0.05	0.06	1.02
1,1-Dichloroethane	30	0%	ND	ND	0.02	0.03	0.02	0.02	0.60
1,2-Dichloroethane	30	0%	ND	ND	0.04	0.04	0.04	0.00	0.14
trans-1,2-Dichloroethylene	30	0%	ND	ND	0.03	0.04	0.04	0.02	0.45
1,2-Dichloropropane	30	0%	ND	ND	0.05	0.04	0.03	0.01	0.36
cis-1,3-Dichloropropylene	30	0%	ND	ND	0.02	0.02	0.02	0.01	0.36
trans-1,3-Dichloropropylene	30	0%	ND	ND	0.02	0.03	0.03	0.02	0.64
Ethyl acrylate	30	0%	ND	ND	0.02	0.03	0.03	0.01	0.47
Ethylbenzene	**2**	**93%**	**ND**	**0.89**	**0.07**	**0.14**	**0.09**	**0.19**	**1.34**
Ethyl *tert*-butyl ether	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.17
Methylene chloride	**5**	**83%**	**ND**	**1.05**	**0.12**	**0.18**	**0.13**	**0.20**	**1.08**
Methyl ethyl ketone	**0**	**100%**	**0.30**	**8.33**	**0.74**	**1.33**	**0.90**	**1.70**	**1.27**
Methyl isobutyl ketone	29	3%	ND	0.13	0.04	0.04	0.04	0.02	0.47
Methyl methacrylate	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.08
Methyl *tert*-butyl ether	29	3%	ND	0.11	0.02	0.02	0.02	0.02	0.71
***n*-Octane**	**5**	**83%**	**ND**	**0.20**	**0.10**	**0.10**	**0.09**	**0.04**	**0.44**
Propylene	**0**	**100%**	**0.22**	**1.63**	**0.54**	**0.56**	**0.50**	**0.29**	**0.52**
Styrene	**12**	**60%**	**ND**	**4.79**	**0.06**	**0.34**	**0.10**	**0.91**	**2.70**
tert-Amyl methyl ether	30	0%	ND	ND	0.03	0.03	0.03	0.00	0.08

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 11-1 (Continued)
Summary Statistics for VOC Concentrations Measured at Texarkana, Arkansas (GREY)
(Based on 30 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
1,1,2,2-Tetrachloroethane	30	0%	ND	ND	0.03	0.05	0.04	0.03	0.61
Tetrachloroethylene	29	3%	ND	0.03	0.05	0.07	0.07	0.03	0.41
Toluene	**1**	**97%**	**ND**	**2.17**	**0.30**	**0.41**	**0.31**	**0.42**	**1.00**
1,1,1-Trichloroethane	**0**	**100%**	**0.05**	**0.20**	**0.08**	**0.09**	**0.08**	**0.03**	**0.38**
1,1,2-Trichloroethane	29	3%	ND	0.27	0.02	0.04	0.03	0.05	1.21
Trichloroethylene	28	7%	ND	0.18	0.03	0.03	0.03	0.03	0.93
Vinyl chloride	30	0%	ND	ND	0.04	0.03	0.03	0.00	0.08
***m,p*-Xylene**	**0**	**100%**	**0.07**	**0.90**	**0.13**	**0.21**	**0.16**	**0.20**	**0.96**
***o*-Xylene**	**1**	**97%**	**ND**	**0.55**	**0.08**	**0.12**	**0.09**	**0.12**	**0.99**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 11-2
Summary Statistics for Carbonyl Concentrations Measured at Texarkana, Arkansas (GREY)
(Based on 34 Days with Valid Samples)

Compound	Prevalence of Compound in Ambient Air		Range of Measured Concentrations		Central Tendency of Measured Concentrations			Variability in Measured Concentrations	
	Number of Non-detects	Frequency of Detections	Lowest (ppbv)	Highest (ppbv)	Median (ppbv)	Arithmetic Mean (ppbv)	Geometric Mean (ppbv)	Standard Deviation (ppbv)	Coefficient of Variation
Acetaldehyde	**0**	**100%**	**0.01**	**4.05**	**1.34**	**1.49**	**0.93**	**1.08**	**0.73**
Acetone	**0**	**100%**	**0.10**	**4.01**	**1.11**	**1.27**	**0.89**	**1.02**	**0.80**
Acrolein	**3**	**91%**	**ND**	**0.28**	**0.05**	**0.08**	**0.05**	**0.07**	**0.86**
Benzaldehyde	**16**	**53%**	**ND**	**0.33**	**0.01**	**0.05**	**0.01**	**0.09**	**1.69**
Butyr/Isobutyraldehyde	**2**	**94%**	**ND**	**0.44**	**0.17**	**0.18**	**0.12**	**0.11**	**0.64**
Crotonaldehyde	27	21%	ND	0.11	0.00	0.01	0.00	0.02	2.18
2,5-Dimethylbenzaldehyde	29	15%	ND	0.04	0.00	0.01	0.00	0.01	1.55
Formaldehyde	**0**	**100%**	**0.04**	**13.22**	**3.41**	**4.40**	**2.59**	**3.51**	**0.80**
Hexanaldehyde	**3**	**91%**	**ND**	**1.02**	**0.06**	**0.15**	**0.06**	**0.25**	**1.66**
Isovaleraldehyde	**8**	**76%**	**ND**	**0.12**	**0.02**	**0.03**	**0.02**	**0.03**	**1.02**
Propionaldehyde	**1**	**97%**	**ND**	**0.78**	**0.16**	**0.19**	**0.11**	**0.16**	**0.88**
Tolualdehydes	**7**	**79%**	**ND**	**0.33**	**0.10**	**0.10**	**0.06**	**0.08**	**0.80**
Valeraldehyde	**1**	**97%**	**ND**	**0.34**	**0.05**	**0.08**	**0.05**	**0.08**	**1.08**

ND = Nondetect

Note: Data for compounds detected in more than 50 percent of the samples are presented in boldface. Data for the other compounds should be interpreted with caution, since their summary statistics may be biased by nondetects (see Section 3.1).

Because only 7 months of monitoring data were collected at this site, the central tendency estimates may not reflect annual-average concentrations.

Table 11-3
Pairs of Most Prevalent Compounds with Pearson Correlation Coefficients Greater Than 0.70
(Based on 26 Sampling Events)

Compounds		Pearson Correlation Coefficient
m,p-Xylene	*o*-Xylene	0.99
Ethylbenzene	*o*-Xylene	0.98
Ethylbenzene	*m,p*-Xylene	0.97
Ethylbenzene	Methyl ethyl ketone	0.96
Methyl ethyl ketone	*m,p*-Xylene	0.95
Methyl ethyl ketone	*o*-Xylene	0.94
Hexanaldehyde	Valeraldehyde	0.92
Acetaldehyde	Tolualdehydes	0.89
Methyl ethyl ketone	Styrene	0.89
Acetaldehyde	Propionaldehyde	0.88
Ethylbenzene	Styrene	0.87
Formaldehyde	Tolualdehydes	0.85
Styrene	*o*-Xylene	0.82
Propionaldehyde	Tolualdehydes	0.81
Styrene	*m,p*-Xylene	0.81
Formaldehyde	Valeraldehyde	0.78
Acetaldehyde	Formaldehyde	0.78
Acetylene	Benzene	0.78
Acetaldehyde	Butyr/Isobutyraldehyde	0.77
Formaldehyde	Propionaldehyde	0.70

Note: All of the Pearson correlation coefficients shown in the table were found to be statistically significant using a standard t-test—a statistical test commonly used for this purpose (Harnett, 1982).

Table 11-4
Total Air Releases of VOC Reported to TRI by Facilities Within 10 Miles of the GREY Monitoring Station

Compound	Number of Facilities Within 10 Miles of GREY That Reported Air Releases of the Compound to TRI in 1995	Total Pounds of Air Releases of the Compound Reported by These Facilities in 1995
Acetaldehyde	1	74,000
Formaldehyde	1	21,000
Methyl ethyl ketone	1	13,000

Source: USEPA, 1997.

Notes: Refer to Section 3.2 for a discussion on the limitations of TRI data.
The table does not include emissions data for compounds not considered during the 1997 UATMP.
Compounds not listed in the table either are not part of the TRI reporting requirements (e.g., *n*-octane) or were not reported by facilities in the vicinity of the GREY monitoring station (e.g., benzene).

12.0 Conclusions and Recommendations

As noted throughout this report, the UATMP monitoring data offer a wealth of information for evaluating the nature and magnitude of air pollution in, or near, urban centers. The following discussion reviews the main conclusions of this report and presents recommendations for future UATMPs and other air monitoring efforts.

12.1 Conclusions

Sections 4 through 11 of this report identify numerous site-specific trends and patterns among the ambient air monitoring data collected during the 1997 UATMP. Many of these data trends, however, were observed at most, if not all, of the 12 monitoring stations that participated in the current program. Examples of such trends, as well as particularly noteworthy site-specific trends, are summarized as follows:

- *Summary statistics.* Four data summary parameters were used to characterize general features of the large volume of monitoring data collected during the 1997 UATMP. Data on prevalence indicated that, to a certain extent, certain VOC and carbonyls appear to be ubiquitous to the ambient air in urban environments, regardless of geographical location. The concentration range and central tendency data indicate that a subset of these most prevalent compounds were found at elevated concentrations at most every monitoring station. More specifically, Sections 4 through 11 noted that the following VOC and carbonyls generally had the highest concentrations at all 12 monitoring stations, though there were exceptions: acetaldehyde, acetone, acetylene, benzene, chloromethane, formaldehyde, methyl ethyl ketone, propylene, toluene, and xylenes. Data correlations suggested that benzene, toluene, ethylbenzene, and xylenes (i.e., BTEX compounds) originated primarily from motor vehicle exhaust. Although there also was evidence that emissions from cars affected air concentrations of acetaldehyde, acetylene, formaldehyde, and propylene, data trends for these compounds were not quite as consistent as those for the BTEX compounds. In other words, factors other than motor vehicle emissions seemed to have relatively small effects on air concentrations of BTEX compounds, but relatively greater effects on air concentrations of other compounds.

- *Ambient air monitoring data for nitriles and oxygenated compounds.* Much attention in this report was given to the nine nitriles and oxygenated compounds that were measured during the 1997 UATMP, but not during earlier programs. Of these nine compounds, four (ethyl acrylate, ethyl *tert*-butyl ether, methyl isobutyl ketone, and methyl methacrylate) were rarely detected at all 12 monitoring stations. Not surprisingly, very few facilities in the vicinity of these stations reported emitting any of these compounds to the air. Overall, few conclusions could be drawn for these four compounds, except for the fact that they do not appear to be major components of air pollution in most urban centers.

The data trends for the five other nitriles and oxygenated compounds exhibited notable and unique spatial variations that revealed important insight into the factors most affecting their ambient air concentrations. Acetonitrile was not detected at most of the monitoring stations, but was often measured at extremely high levels (greater than 100.0 ppbv) at B2LA, at moderately high levels at GREY, and at lower levels at RUVT. The ambient air concentrations of acetonitrile at B2LA were often greater than the combined concentration of all other compounds measured at that station. The unique spatial variations for this compound—geometric mean concentrations at B2LA were roughly 100 times higher than those at other stations—strongly suggested that major emissions sources of acetonitrile were present near B2LA and, to a lesser extent, near GREY, but not near the other UATMP monitoring stations. Because the seasonal variations in acetonitrile concentrations were nearly the same at both B2LA and GREY, further research is encouraged to determine if a particular type of emissions source common to these two areas might explain the compounds' unique air quality trends.

At all 12 monitoring stations that participated in the 1997 UATMP, acrylonitrile was detected in fewer than one-third of the sampling events, but it was detected most frequently at the rural GREY and UNVT monitoring stations. The higher prevalence figures at these two distinctly different rural areas provided some evidence that natural emissions sources of the compound may be important, but the scientific literature suggested that most airborne acrylonitrile originates from selected industrial processes. Analyses of monitoring data currently being collected as part of the 1998 UATMP should help determine if the higher prevalence of acrylonitrile in rural areas is a data trend or simply an artifact of the 1997 UATMP monitoring results.

Of the nine nitriles and oxygenated compounds considered during the 1997 program, methyl ethyl ketone was detected most frequently: at almost every station, at least 90 percent of the samples had measurable levels of the compound. Even though motor vehicles are known to emit the compound, the air quality trends for methyl ethyl ketone were largely inconsistent with the assumption that it originated primarily from mobile source emissions. For instance, the highest geometric mean concentration of methyl ethyl ketone was detected at GREY, the monitoring station located furthest from heavily traveled roadways. Further, at most stations, ambient air concentrations of methyl ethyl ketone were essentially uncorrelated with concentrations of compounds typically found in motor vehicle exhaust. The TRI emissions data, on the other hand, were much more consistent with the methyl ethyl ketone monitoring data. In TRI reporting year 1995, industrial facilities near almost every monitoring station emitted methyl ethyl ketone, thus providing evidence that industrial emissions sources of the compound may be significant. The consistency between TRI data and the ambient air monitoring data are not sufficient, however, to confirm the predominant sources of airborne methyl ethyl ketone. At almost every monitoring station, concentrations of methyl ethyl ketone were, on average, notably higher during the warmer summer months than during other times of the year. This observation suggested that photochemical reactions, which peak during the summer, may be an important factor affecting the compounds' ambient air concentrations. The 1998 UATMP will include similar analyses to determine whether industrial emissions or photochemical reactions more strongly influence ambient air concentrations of methyl ethyl ketone.

Methyl *tert*-butyl ether was detected in over 90 percent of the samples collected at BRVT, BUVT, CANJ, and RUVT—the only monitoring stations located in areas where motor vehicles use reformulated gasoline. Concentrations of methyl *tert*-butyl ether at Camden were shown to be highly correlated with concentrations of compounds typically found in automobile exhaust. This result was not surprising, given the fact that EPA requires all gas stations in the Camden–Philadelphia area to sell only reformulated fuels. Industrial sources of methyl *tert*-butyl ether were identified near the CANJ monitoring stations, but emissions from these facilities seemed to be relatively insignificant when compared to the levels emitted by mobile sources. Concentrations of methyl *tert*-butyl ether at the three Vermont monitoring stations (BRVT, BUVT, RUVT) were notably lower than those measured at Camden, but much higher than those observed at the monitoring stations in Arkansas, Louisiana, and Texas. A series of data analyses in Section 6.2 demonstrated that the levels of methyl *tert*-butyl ether measured in Vermont were consistent with emissions from motor vehicles traveling on local roadways—an interesting result considering that gasoline stations in Vermont are not required to sell reformulated fuels. It is suspected that several distributors sell reformulated fuels to gas stations in Vermont, even though they are not required to do so.

tert-Amyl methyl ether was detected in over half of the samples collected at CANJ, but was rarely detected at the other monitoring stations. This spatial variation clearly suggests that an emissions source specific to the Camden area likely accounted for the compounds' observed concentrations. Though the compound is used as an additive to reformulated fuels, the monitoring data for *tert*-amyl methyl ether at CANJ were weakly correlated with other compounds found in motor vehicle exhaust in the area, including methyl *tert*-butyl ether. The weak correlations suggested that industrial sources (as opposed to motor vehicle sources) might have contributed more significantly to the observed concentrations of the compound at CANJ, but it is difficult to confirm this hypothesis because facilities were not required to report releases of *tert*-amyl methyl ether to the 1995 TRI, the most comprehensive emissions inventory available for the area at the writing of this report.

- *Annual variations.* The annual variations discussed in Sections 4 through 11 characterize site-specific changes in air quality over a 3-year period. Not surprisingly, levels of air pollution at some stations decreased, while levels at other stations increased or remained relatively unchanged. Further, at each monitoring station, air quality trends tended to differ for individual compounds. Nonetheless, some general trends emerged from the analyses of annual variations. First, at almost every station, the air quality trends for carbonyls almost always differed from those for VOC. The absence of parallel trends for these two sets of compounds is an important finding because it further emphasizes that the factors that seem to affect ambient air concentrations of VOC differ from those that seem to affect ambient air concentrations of carbonyls. Second, though many exceptions exist, decreasing or unchanging levels of air concentrations for the most prevalent compounds were far more prevalent than increasing levels. Though this general observation suggests that air quality may be steadily improving at the UATMP monitoring stations, analyses of several more years of monitoring data are needed to verify this apparent trend.

12.2 Recommendations

Based on lessons learned from analyzing the 1997 UATMP monitoring data, a number of improvements are recommended for future programs:

- *Continue to identify and implement improvements to the sampling and analytical methods.* The improvements made to the VOC analytical method prior to the 1997 UATMP allowed for measurement of ambient air concentrations of nine compounds (all nitriles and oxygenated compounds) that were not measured during previous programs. As demonstrated in Sections 4 through 11, this single improvement has provided sponsoring agencies with important information about air quality within their jurisdictions. For example, the concentrations of methyl ethyl ketone in some areas were shown to rank among the highest concentrations observed for VOC, and the concentrations of methyl *tert*-butyl ether provided useful insight into the effects of motor vehicles using reformulated fuels. Given these and other benefits associated with the improvement to the VOC analytical method, further research is encouraged to identify other method improvements that would allow the UATMP to characterize a wider range of components in urban air pollution.

- *Investigate the feasibility of offering additional monitoring options.* Discussions throughout this report acknowledge that the UATMP currently identifies a large number of, but certainly not all, components of urban air pollution. To characterize levels of urban air pollution more completely, the scope of the UATMP should be reviewed to determine if offering monitoring options for particulate matter, inorganic acids, or other groups of pollutants might be cost-effective and appealing to sponsoring agencies. Options for continuous monitoring, which would almost certainly reveal notable air quality trends that cannot be identified by biweekly sampling, should also be investigated.

- *Coordinate data analyses with sponsoring agencies.* This report, as well as that for the 1995 and 1996 UATMPs, was prepared entirely from the monitoring data, TRI emissions data, and U.S. Census data. The analyses in Sections 4 through 11 cited numerous examples where more detailed and comprehensive information was needed to understand the air quality trends observed during the 1997 UATMP. Examples of such information include local inventories of industrial emissions sources, studies of motor vehicle traffic patterns, site-specific surveys of gasoline usage, local meteorological data, and implementation dates of relevant pollution control regulations. Since these reference materials are critical to understanding complex air quality trends, analyses in future reports should be based on detailed site-specific information that sponsoring agencies provide, if such information is readily available.

- *Encourage continued participation in the UATMP.* Although UATMP monitoring data thoroughly characterize levels of air pollution in or near urban centers, state and local agencies can assess long-term trends in air quality only through continued monitoring at fixed locations. These long-term trends not only are important for identifying and controlling sources of potentially toxic air pollution, but they serve as an effective performance measure for important pollution control initiatives. As a result, sponsoring agencies are encouraged to develop thorough monitoring programs or continue participating in the UATMP. With more cities participating in this program over longer time frames, the UATMP will continue to answer important questions regarding urban air pollution.

13.0 References

Conner et al., 1995. "Transportation-Related Volatile Hydrocarbon Source Profiles Measured in Atlanta." Teri L. Conner, William A. Lonneman, Robert L. Seila. Journal of the Air and Waste Management Association, 45: 383-394. 1995.

ERG, 1998. "1996 Urban Air Toxics Monitoring Program (UATMP): Final Report." Eastern Research Group, Inc. Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. October, 1998.

Harnett, 1982. "Statistical Methods." Donald L. Harnett, Addison-Wesley Publishing Company, Third Edition. 1982.

Howard, 1989. "Handbook of Environmental Fate and Exposure Data for Organic Chemicals." Volumes I through IV. Philip H. Howard (editor), Lewis Publishers. 1989.

Kirk Othmer, 1985. "Kirk Othmer Concise Encyclopedia of Chemical Technology." John Wiley and Sons, New York. 1985.

Mackay et al., 1992. "Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals." Volume 3. Donald Mackay, Wan Ying Shiu, Kuo Ching Ma. Lewis Publishers. 1992.

Main et al., 1996. "PAMS Data Analysis Workshop: Illustrating the Use of PAMS Data to Support Ozone Control Programs." Hilary H. Main, Paul T. Roberts, Marcelo E. Korc. Prepared for U.S. Environmental Protection Agency. October, 1996.

Main et al., 1998. "Analysis of Photochemical Assessment Monitoring Station (PAMS) Data to Evaluate a Reformulated Gasoline (RFG) Effect." Hilary H. Main, Paul T. Roberts, Richard Reiss. Prepared for U.S. Environmental Protection Agency, Office of Mobile Sources. April, 1998.

Scranton, 1999. Personal communication between John Wilhelmi (ERG) and Eric Scranton (State of Vermont Agency of Natural Resources, Air Pollution Control Division, Mobile Sources Section). February 16, 1999.

USEPA, 1984. "Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography." U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory. June, 1984.

USEPA, 1988. "Data Quality Objectives for the Urban Air Toxics Monitoring Program (Stages I and II)." U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. June, 1998.

USEPA, 1989. "Risk Assessment Guidance for Superfund: Volume I: Human Health Evaluation Manual (Part A)." Interim Final Report. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. December, 1989.

USEPA, 1996. "PAMS Data Analysis Workshop: Illustrating the Use of PAMS Data to Support Ozone Control Programs." Prepared by Sonoma Technology, Inc., for U.S. Environmental Protection Agency. October, 1996.

USEPA, 1997a. "Compendium Method TO-14A: Determination of Volatile Organic Compounds (VOC) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography." U.S. Environmental Protection Agency, Center for Environmental Research and Information. EPA/625/R-96/010b. January, 1997.

USEPA, 1997b. "Toxics Release Inventory 1987–1995 CD-ROM." United States Environmental Protection Agency, Office of Pollution Prevention and Toxics. EPA 749-C-97-003. August, 1997.

USEPA, 1998a. "Questions and Answers About Methyl Tertiary Butyl Ether (MTBE)." U.S. Environmental Protection Agency, Office of Mobile Sources. July 29, 1998.

USEPA, 1998b. "Vermont Companies Reduce Toxic Releases by 22.7% in Single Year, EPA Names Ten Largest Pollution Emitters." EPA Press Release #98-6-14. June 18, 1998.