

# Passive Ozone Network of Dallas: A Modeling Opportunity with Community Involvement. 1

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Despite tremendous efforts toward regulating and controlling tropospheric ozone ( $O_3$ ) formation, a large portion of the U.S. population presently lives in environments where air quality exceeds both 1- and 8-h National Ambient Air Quality Standards (NAAQS) set for  $O_3$ . High  $O_3$  concentrations annually cost the United States billions of dollars in excessive human health costs, reduced crop yields, and ecological damage. This paper describes a regional networking of  $O_3$  monitoring sites, operated by the public, that used simplified passive sampling devices (PSDs). In collaboration with EPA Region 6, a lay network (i.e., Passive Ozone Network of Dallas, acronym POND), consisting of 30 PSD sites in the Dallas-Fort Worth (DFW) Metroplex, a region representing 16 counties, successfully measured daily ozone during 8 weeks of the 1998 high ozone season. It was demonstrated that the concerned public, when properly trained, could successfully operate a large PSD network that requires daily sample handling and weekly mailing procedures, even from remote sites. Data treatment of the 2880 POND measurements included (i) high correlations with collocated continuous monitoring data [ $r$  range = 0.95-0.97], (ii) daily  $O_3$  contour mapping of the 24 000 km<sup>2</sup> area, and (iii) a ranking of  $O_3$  severity in 12 peri-urban counties for guidance in siting additional monitors. With a new 8-h NAAQS standard now in place, a cost-effective network such as POND could aid regional airshed models in generating meaningful guidance for  $O_3$  state implementation plans (SIPs) by providing input that is representative of both rural and urban sites.

## Introduction

Tropospheric ozone is the most pervasive air pollution problem nationally and directly impacts human health, agriculture, and ecosystems (1, 2). Despite concerted efforts to regulate and control ground-level ozone ( $O_3$ ) formation, over 70 million people reportedly live in U.S. counties that still exceed the National Ambient Air Quality Standard

(NAAQS) set for  $O_3$  (3). The NAAQS for tropospheric ozone for the past 20 yr, as designated by the U.S. Environmental Protection Agency (EPA), is based upon a short-term one-h maximum of 0.12 ppm (235  $\mu\text{g}/\text{m}^3$ ); nonattainment is stipulated for a geographical area when four daily exceedances above 0.12 ppm are measured over a 3-yr period. The obstacles to effective ozone management are many because the photochemistry of its formation is complex. The proper choice of emission controls for ozone's precursor classes, i.e., the volatile organic compounds (VOCs) and the oxides of nitrogen ( $\text{NO}_x$ ), is dependent upon the relative spatial contribution of their anthropogenic and natural sources. Seasonal variation in temperature, relative humidity, and wind patterns can also defeat a local attainment strategy or can create additional exceedances regionally when preformed ozone and its precursors are dispersed by long-range transport (4).

Since setting the NAAQS for ozone in 1971, overwhelming evidence (2, 5, 6) has demonstrated that adverse health effects, such as impaired lung function, occurred in both healthy and sensitive segments of the population when exposed for several hours at  $O_3$  concentrations below the 0.12 ppm guideline. In response to a higher need of protection, the EPA subsequently issued both the primary and secondary NAAQSs for ozone (7, 8) in 1997 to a permitted concentration of 0.08 ppm averaged over 8 h. Attainment is now based upon a 3-yr average of the annual fourth-highest daily maximum 8-h average  $O_3$  concentrations measured in an area. U.S. counties that have not previously incurred a 1-h 0.12 ppm violation, i.e., representing over 90% of the total, will be subject to the 8-h standard beginning in 2000 (9, 10), whereas the 1-h standard will continue to apply for the remaining counties until their attainment is achieved.

Control strategies for ozone pollution or state implementation plans (SIPs) under the 1-h standard have evolved from the nesting of both urban and regional airshed models (11). Such modeling has focused largely upon urban abatement using the combined data from the Photochemical Assessment Monitoring Stations (PAMS), a Federal network created out of the 1990 Clean Air Act Amendments (CAAA), along with the established Aerometric Information Retrieval System (AIRS) database; however, present or near-future SIP development must adjust to the implications of adding the new 8-h NAAQS  $O_3$  standard. On the basis of the EPA's 1996-1998 air quality monitoring data (12), about 300 counties had annual fourth highest 8-h  $O_3$  maxima greater than the 8-h NAAQS. Noncompliance in the rural areas was expected to appreciably increase with the revised  $O_3$  standard, e.g., 30-50% of the rural eastern United States may be noncompliant using 1993-1995 data from the rural AIRS sites in that region (13). It was well-documented over 20 yr ago that  $O_3$  in nonurban areas tends to persist longer than in urban environments (14-16). A balance of both rural and urban data may be equally important to high  $O_3$  regions since their respective SIPs are evaluated by their performance in 8-h NAAQS models. However, obtaining vital data from large geographical areas with sufficient resolution by conventionally instrumented monitoring, especially during a significant portion of the ozone season, quickly becomes exhaustive in terms of budget and trained personnel. Furthermore, additional siting or its avoidance by rural criteria a priori, such as by land usage or population density, may be complicated by nearby anthropogenic sources and  $O_3$  transport patterns in general (17, 18). Broadening the paradigm of existing technologies, e.g., passive sampling, may help overcome the

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present constraints in actualizing a comprehensive air quality network.

Since the first passive sampling device (PSD) was reported in the mid-1970s (19) for indoor monitoring, the design has been modified to measure a plethora of inorganic and organic pollutants. These devices rely upon simple air diffusion and have the advantages of being inexpensive, reusable, easy to deploy, unobtrusive, and not requiring a source of power. The EPA has supported the development of passive sampling technology for various pollutants since 1983 (20–22) and successfully expanded PSD usage from personal exposure/indoor air applications to the monitoring of criteria pollutants (e.g.,  $O_3$ ,  $NO_2$ ,  $SO_2$ ) in ambient air. Several recent studies have used the PSD advantages to successfully monitor ozone in remote sites in protected ecosystems, national parks, forests, and mountainous areas (23–26) as well as in community activity studies (27, 28): sampling times per device represented integrated exposure data encompassing one to several weeks.

The work reported herein describes the daily operation of an extensive ozone-passive monitoring network (> 24 000  $km^2$ ) in and surrounding the Dallas–Fort Worth (DFW) Metroplex in Texas that was operated by public volunteers during 8 weeks of the 1998 high  $O_3$  season. An EPA laboratory in North Carolina supplied and analyzed the networked PSDs on a weekly basis. The work had the following objectives: (i) to determine the precision of networked PSDs when daily (24 h) exposures were taken under both urban and rural conditions (unpublished 1997 daily data from collocated PSD-continuous monitoring of  $O_3$  in Dallas was highly correlated,  $r = 0.97$ ); (ii) to assess the added value of the POND data to the existing Metroplex continuous monitoring system; (iii) to evaluate the ability of the volunteering public to perform as network site operators; and (iv) to determine if current mail handling practices could effectively move PSD packages across the country on a weekly basis, especially to the more remote network sites.

## Study Area

The DFW Metroplex population, occupying 16 counties in North Central Texas, grew 19% since 1990 and is predicted to reach 5 million by the 2000 census (29). This rate of growth doubled the national average of 8.7%, and this region is now more populous than several states. The EPA reclassified the DFW ozone compliance area, an urban core of four counties, from the “moderate” to “serious” category in 1998 because of nonattainment under the 1-h 0.12 ppm NAAQS guidelines (30). This core, having the majority of the region’s growth and economic activity, also encompasses the DFW International Airport, one of the world’s busiest airports in terms of both passenger and cargo flights. Over 60% and 80%, respectively, of the region’s VOC and  $NO_2$  emissions, the major precursors inventoried for  $O_3$  control, have been attributed to mobile sources for the past decade. The public is aware of this pollutant and had been asked to respond to an annual average of 25 ozone-action days since 1994 (31).

## Experimental Section

**Analytical, Sampling, and Data Handling.** The passive sampling devices (PSDs) and coated disks used to collect ozone were obtained from Ogawa & Co., Inc., Pompano Beach, FL. The Ogawa PSD consists of a solid cylindrical polymeric body (2 cm diameter  $\times$  3 cm long) housing a coated glass fiber disk at each end for sampling. Ozone, upon diffusion into the PSD, oxidizes the nitrite coated on the disk to nitrate on an equimolar basis:



The theoretical collection rate of the Ogawa PSD is 21.8  $cm^3/min$  for ozone (22). After PSD exposure, the sorbent disks were extracted with ultrapure water and the micrograms of  $NO_3^-$  formed were analyzed by ion chromatography. Our minimum detection limit for the Ogawa PSD was approximately 10 ppb  $O_3$  for 24 h. For improved quality control, the coated sampling disks were specified prepared as one lot and in sufficient quantity for the entire 8-week study. Only the disk quantity needed to reload the PSDs for the following week’s mailing to the POND were removed from  $-20^\circ C$  storage each week. The disks were exposed to ambient temperatures, i.e., from PSD reloading to analysis, for a maximum of 10 days.

Four of the 30 POND sites were collocated with ozone sites equipped with Dasibi model 1008 continuous monitors. The Dasibi 1008 instruments, having a minimum detection level of 1 ppb  $O_3$ , were calibrated at least every 2 weeks. Each of the 30 sites received a mailer containing 12 PSDs every week for an 8-week period (July 13–September 3). Two 24-h PSDs were deployed daily (Monday–Thursday) plus two 96-h PSDs were deployed on Monday and removed on Thursday as a quality control check on the 24-h PSDs. If the sum of the four 24-h concentrations agreed with the 96-h concentration, the PSDs and site operators were judged to be performing satisfactorily. Two unopened PSD controls also accompanied the round-trip mailing.

The PSD pole assembly as shown at POND sites in Figure 1 consisted of two 100-cm (40-in.) sections of 2.2 cm (0.87 in.) o.d. aluminum conduit piping held together by a sleeve and two set screws. The lower section was driven into the ground about 30 cm (12 in.) with a furnished 1.36-kg (3-lb) hammer and a wooden block to protect the sleeve. Four rain shelters for the PSDs were attached at 15-cm (6-in.) intervals on the upper pole section with large adjustable hose clamps; this section could be easily removed for changing the PSDs inside the home during inclement weather. Site instructions were to erect the pole assemblies in open ground away from trees, livestock, and nearby major traffic or industrial influences.

POND daily contour maps were prepared using ARCVIEW (GIS) Spatial Analyst software (32) with application of the inverse distance weighted (IDW) method for surface interpolation. The IDW method determines values using a linearly weighted combination of sample points. County boundaries and major highway depictions were gathered from the 1992 Census Bureau TIGER/Line files.

Meteorological data were downloaded from the EPA AIRS database for the Arlington site (AIRS site 48-439-0057 and stipulated collocated POND site 6). Available parameters included resultant wind speed and direction and hourly temperatures from 6 AM to 8 PM local daylight time.

**Networking Considerations.** The passive network (30 POND sites in 16 counties) was designed to be operated by volunteers living in the three following DFW areas: (i) the 4-county urban core under NAAQS regulation (totaling 17 POND sites including 4 collocated with continuous  $O_3$  monitors); (ii) all the immediate 8 counties touching the NAAQS core (totaling 9 POND sites); and (iii) the most northern counties subject to  $O_3$  transport by the prevailing southern winds (totaling 4 POND sites in 4 rural counties bordering Oklahoma). The location of the sites within the monitored counties are shown on the map in Figure 1. GPS coordinates were measured for each site.

Site operators included volunteers from EPA Region 6 personnel, service organizations such as the 4-H Club and Master Gardeners, and farm retirees recommended by county extension agents. No effort was made to specifically enlist people of any defined background or age bracket.

The PSDs were directly mailed to the 30 POND operators via Federal Express (FedEx) on a weekly basis. Each site





FIGURE 1. 30-site map of the Passive Ozone Network of Dallas (POND) with surrounding pictures of representative sites, sampling assemblies, and their operators.

operator received their week's supply of ozone PSDs in a 33 cm × 46 cm × 7.6 cm deep (13 in. × 18 in. × 3 in. high) mailing carton available from the U.S. Postal Service. Each carton contained a rigid block of polystyrene with cylindrical holes that held the vials containing the PSDs for each week's ozone collection. Each carton also contained a sampling log sheet, written instructions for the week, and a FedEx air bill to return the exposed PSDs (Friday pickup) to the EPA laboratory for analyses the following week. The PSDs were kept in the site operator's refrigerator both before and after deployment. Also, at the end of each week, the site operator received a new set of PSDs to be deployed the following week. In order to sample for 8 weeks without missing any sampling opportunities, a minimum of 1080 PSDs were in operation, i.e., each week 360 PSDs were sampling at the POND sites, 360 PSDs from the previous week were being analyzed at the laboratory, and 360 PSDs were being cleaned and reloaded for the following week's mailing.

The success of this study depended upon quality training, encouragement, and tools for the wide spectrum of lay operators. These volunteers were tasked to handle daily sampling, to complete logging routines, and to meet critical mailing schedules. For quality assurance, the following POND tools and procedures were prepared and used:

A network graphic identifier, i.e., the POND icon

A 3-week prescreening of PSD pole locations with telephone follow-up

A 12-min orientation and training video (33)  
 Logging forms and instructions with multi-colored zones  
 A toll-free trouble-shooting phone number  
 Prior visitation of many urban and rural network sites  
 Pretesting of FedEx timing to and from the POND sites with mailer and PSD conditions monitored  
 Special operator clock alarm as a PSD exchange reminder (before 8 AM)  
 "Keep up the good work" correspondence during the 8 weeks

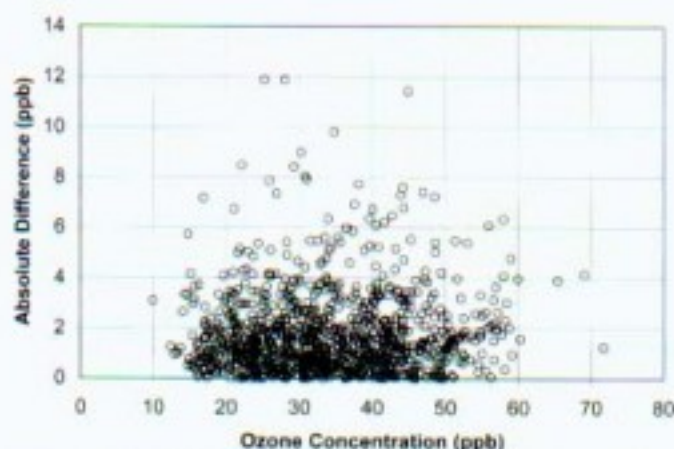
A follow-up written survey for operator feedback and suggestions for improvement

Final mailing of each site operator's data as initially promised

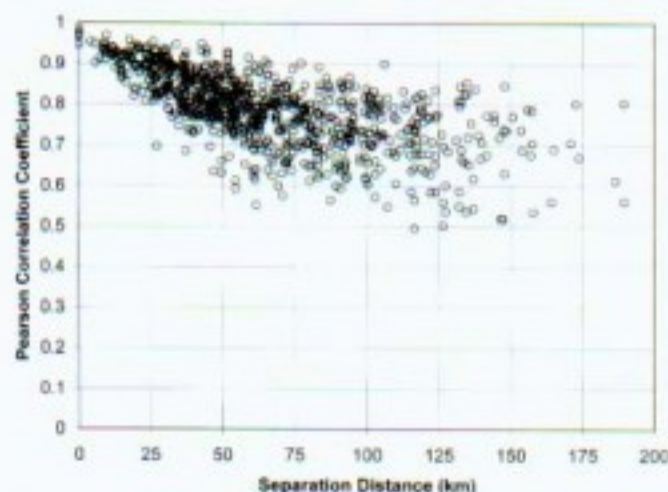
## Results and Discussion

**Precision and Accuracy.** The precision for the 8-week POND data was checked by analyses of all differences between the 24-h site duplicates (912 data pairs were analyzed from a possible 960 pairs at the 30 sites) and is presented in Figure 2. The absolute difference between the 24-h duplicates had a mean of 1.83 ppb O<sub>3</sub>, a median of 1.38 ppb, and was less than 4 ppb in 90% of the cases; furthermore, the precision was independent of the level of ozone concentration. Earlier (unpublished) data indicated this degree of precision at short exposures of 24 h and less was not achievable without taking





**FIGURE 2.** Precision of the ozone passive samplers by demonstrating the absolute difference between 24-h replicates (912 pairs) during the network study.



**FIGURE 3.** Correlation between all paired passive samplers versus their respective distances of site separation.

inventory and storage precautions with the coated disks. All disks for this study were prepared only several weeks before needed from a common source of  $\text{NaNO}_2$  and stored at  $-20^\circ\text{C}$ . A subplot of disks, stored at ambient temperature and analyzed monthly in pairs over a 3-month period, indicated a linear formation of  $0.043 \mu\text{g}$  of  $\text{NO}_3^-/\text{week}$  ( $r = 0.99$ ;  $p < 0.01$ ). No detectable disk (blank) change was measured after 6 months storage at  $-20^\circ\text{C}$ .

The correlation between 24-h  $\text{O}_3$  site data and the distance between sites was high, as shown in Figure 3. Correlations averaged  $>0.80$  at a 50-km separation,  $>0.70$  at a 100-km separation, and consistently exceeded 0.50 even when 200 km apart. These relatively high values would support minimal kriging errors given the relatively flat, prairie-like topography of this PSD-networked region. The high correlation measured between sites by the POND should be considered optimal and would not normally occur at such distances in regions having diverse physiographies (4); in these latter cases, network siting becomes more challenging, but there would be the opportunity to locate ample PSD sites throughout affected communities to define spatial and temporal  $\text{O}_3$  shifts under a myriad of meteorological conditions.

To validate overall siting accuracy, four POND sites were collocated at four continuous monitoring sites within the regulated four-county core for comparison of data. Their comparisons of 24-h data, as shown in Figure 4a–d, demonstrated excellent positive correlations ranging from 0.95 to 0.97. Figures 4a–d suggest a slight bias of the PSDs relative to the continuous monitors. In three cases, the continuous monitors are generally higher, while at the Keller

site (Figure 4c) the PSDs reported higher values. The mean absolute differences ( $n = 32$ ) at the four collocated sites were: 2.7, 3.4, 3.5, and 4.7 ppb, respectively. These values were considered small enough to proceed with the analysis of the total PSD network.

#### Maximizing Regional $\text{O}_3$ Information from the POND.

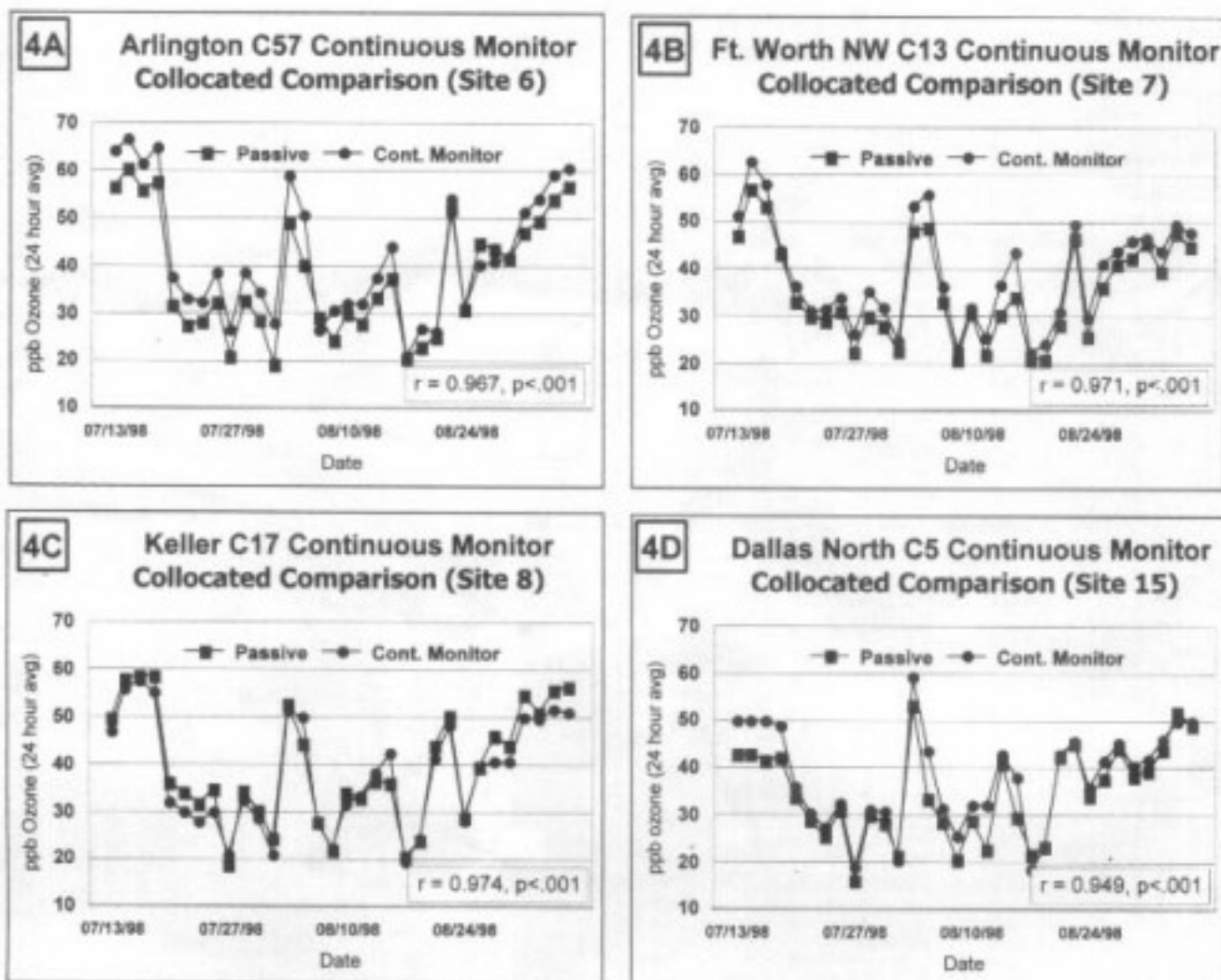
In 1998, the POND offered the only  $\text{O}_3$  monitoring sites in 12 counties that surrounded the 4 urban counties (i.e., Dallas, Tarrant, Denton, and Collin Counties) being continuously monitored. These 12 counties are now subject to the 8-h  $\text{O}_3$  NAAQS whereas the above 4 core counties will be regulated by the 1-h NAAQS until their attainment is reached. Therefore, we took the following steps to determine if a relative ranking of  $\text{O}_3$  severity within the 12 counties, as solely monitored by POND, could be achieved. Such information would help define the added value of a passive network in general and specifically provide the DFW Metroplex with air quality data previously unavailable.

*The 8–24-h Comparisons (Step 1).* Since the above 12 counties are subject to the 8-h NAAQS, a linear regression of the 24-h continuous daily averages on the 8-h maximum for the 4 collocated sites was calculated to obtain a predicted reference 24-h value when the 8-h value reached 85 ppb  $\text{O}_3$ . The reference 24-h value was 47.6 with a 95% prediction interval of 36.1–59.1 ( $p < 0.05$ ;  $r^2 = 0.76$ ) for the 8-week test period (examination of the data and regressions on a site-by-site basis indicated that pooling the data across the four collocated sites was appropriate). The 24-h PSD average value was also calculated from the 4 collocated data for only those days when continuous 8-h daily averages were 85 ppb and above. On the basis of 11 such days (85–126 ppb  $\text{O}_3$  range; see map dates in Figure 5a–k), the actual 24-h PSD value was  $49.6 \pm 9.7$  ppb ( $p < 0.05$ ;  $r^2 = 0.81$ ). The minimum PSD or continuous 24-h ozone concentration recorded on an ozone exceedance day in the region was 40 ppb. With these statistics in mind, an observer could generally scan the PSD data in the 12 counties for values of 50 ppb or greater for possible exceedances but would also recognize that a 24-h deviation of about  $\pm 10$  ppb could also encompass an 8-h exceedance; in addition, any ranking of  $\text{O}_3$  severity would be of limited value without examining the meteorological criteria, such as wind direction, for the test period.

*Ranking of Peri-urban and Rural Networked Counties (Step 2).* Eleven 8-h exceedance days measured in the urban core occurred during 7 differing wind directions, and these days were selected for ranking the surrounding 12 POND-monitored counties for ozone severity in Table 1. This balanced array of wind directions provided greater credibility to a severity ranking of the 12 counties, and this information was linked to the number of peri-urban county days that measured PSD values  $\geq 50$  ppb  $\text{O}_3$ . The spatial relationship of these counties in the POND network may be seen in the ozone monitoring maps to be discussed. The Rockwall–Kaufman County area and Parker–Hood County area, each having 4 or 5 days of PSD values  $\geq 50$  ppb, are symmetrically located on the immediate east and west sides of the four-county urban core. Both county areas would be the suggested top sites for future monitoring based upon this ranking criterion; however, the maximum PSD values for Rockwall (69) and Kaufman (65 and 72) were both markedly higher than those of Parker (57) and Hood (58); thus, a further distinction is implied between these two areas. The four most northern counties (Montague, Cooke, Grayson, and Fannin) exhibited the lowest  $\text{O}_3$  concentrations during the 8-h exceedance days but also, as a group, experienced  $\text{O}_3$  measurements over 50 ppb on 5 urban core exceedance days. Further distinction between the northern county group can be seen in the frequency column of Table 1.

The nearly identical data obtained from two POND sites in Kaufman County suggested a site redundancy for this area;





**FIGURE 4.** (a–d) Comparison of daily ozone data from four continuous ozone monitoring sites (a–d) having collocated passive sampling devices (PSDs). The collocated monitoring sites were located in Tarrant and Dallas Counties, two of the four counties under NAAQS regulation.

however, such counties are large, and it is common for significant daily  $O_3$  gradients to occur within county boundaries (see  $O_3$  contour maps for examples). The placement of two PSD sites in similarly sized counties is prudent, particularly if the area is of special interest. For example, the only site out of 30 in our volunteer passive network that failed to provide sufficient data was located in Johnson County, an area that led all the peri-urban counties in population growth in 1999 (31). Two POND sites in such a county could have secured the  $O_3$  baseline for monitoring future growth effects upon air quality.

Table 1 points out that the 8-week duration of the POND monitoring was essential in disclosing additional regional information in 1998 that would have been missed by a highly instrumented intensive study covering only 1–2 weeks. For example, it required a monitoring period from July 13 through September 3 (see column 6; footnote e) for the 12 peri-urban counties to experience the 7 different wind directions creating the urban exceedances and record PSD values above 50 ppb in discerning frequencies for ranking (see column 2). Although 3 of the 11 urban 8-h exceedances were associated with ENE winds, Hood County did not record its maximum PSD value with this particular wind direction until September 1. Much earlier, Montague and Cooke Counties recorded their PSD maxima above 50 ppb on July 16, and both occurred with the urban exceedances linked to a NNW wind. Note that an urban exceedance occurred only once with a WNW wind on September 3, but on this day an aggregate high of four

counties recorded their maximum PSD measurements (see column 5).

Another method of ranking both POND and continuous monitored counties in the DFW metroplex region was developed as follows. A linear equation for predicting the 8-h maximum value from the 24-h POND value was determined. To address the fact that the predictor also contained error, the slope of the prediction equation was estimated by utilizing a method of moments estimator (34) that incorporated the error in the POND values obtained from the results of the duplicate sampling discussed above. The intercept was then calculated by forcing the predictive line through the point determined by the two mean values.

This equation was then used to estimate the 8-h maximum value at each POND site on each of the 11 days for which one of the continuous monitors recorded an 8-h maximum above 85 ppb. These estimated 8-h maxima were combined with the monitored ones to produce an interpolated map of the maximum 8-h ozone levels on each of the 11 days (inverse distance-squared weighting with 12 sites was used for the interpolation). For each day and county, the percentage of land area within the study region estimated to be above the 85 ppb level was determined. All 16 major counties in the metroplex area could then be ranked according to their average percentage of land area estimated to be above the 85 ppb level. The results of this ranking and the corresponding affected counties' areas are displayed in Table 2. It is interesting to note that many of the averages for the peri-

# POND 24-Hour Contours

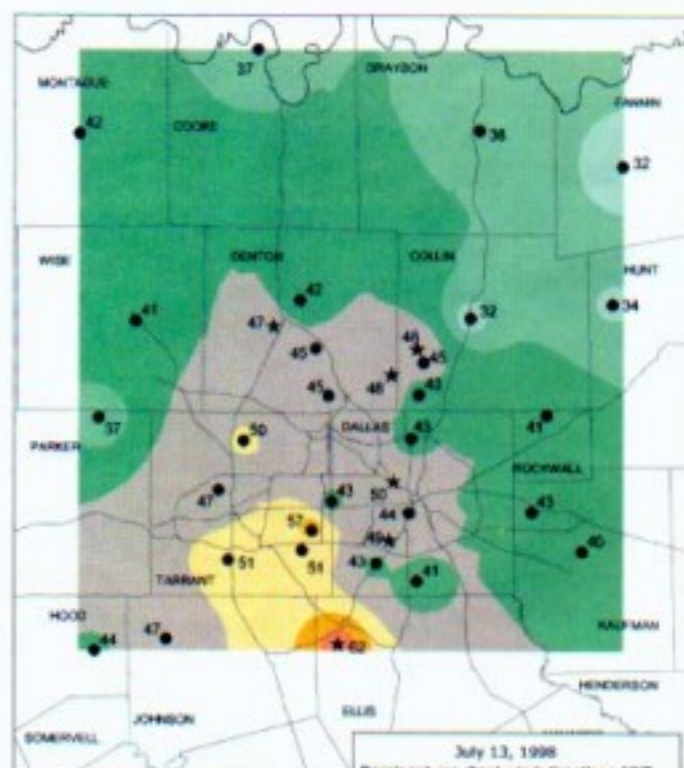


Figure 5a

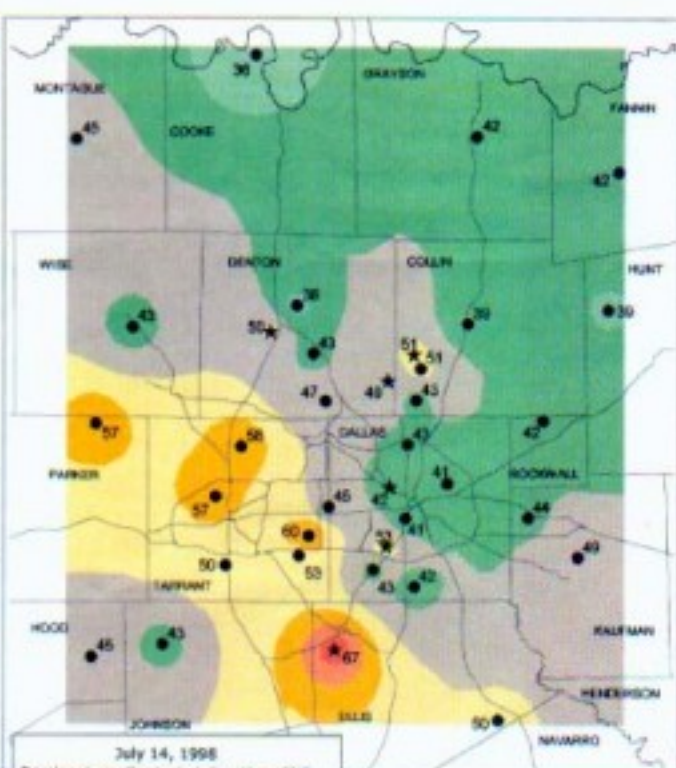
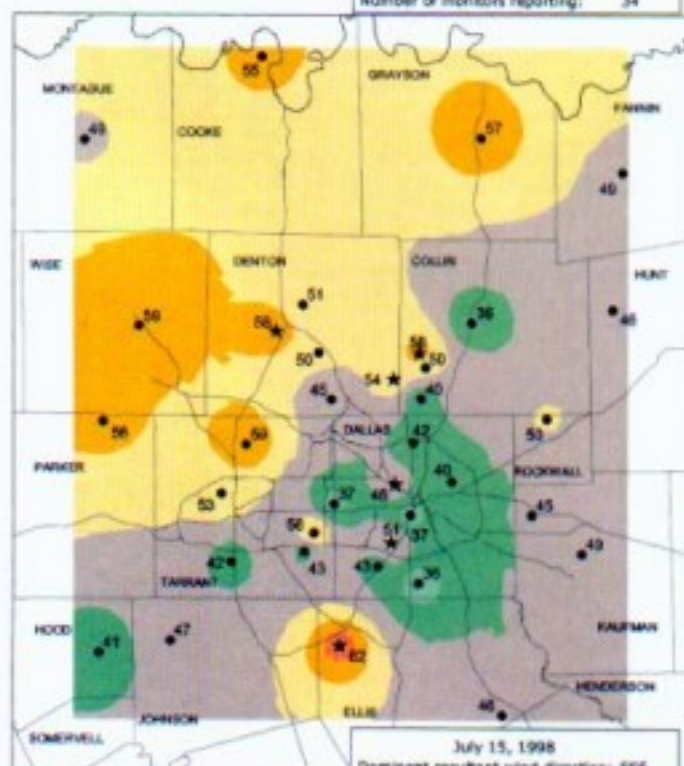


Figure 5b

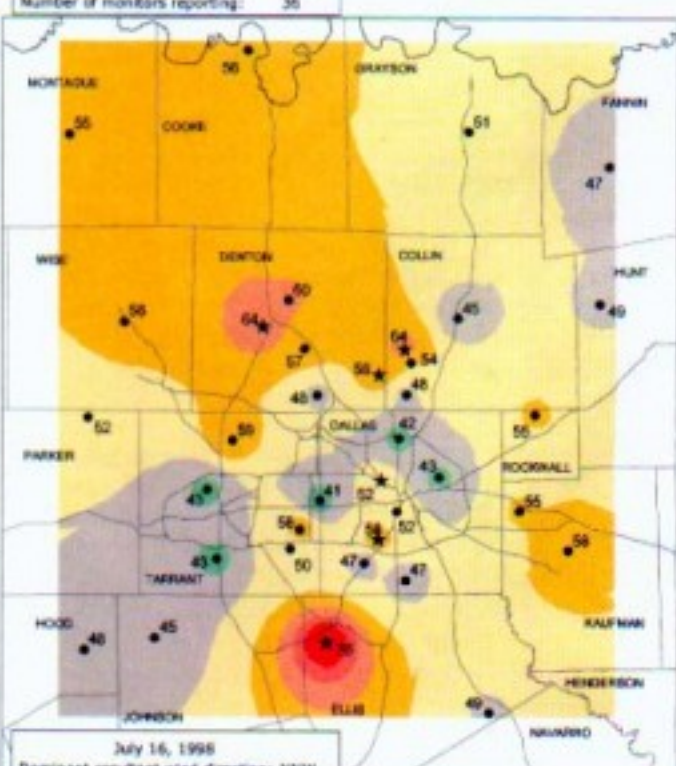


- ★ 40 Continuous Ozone Monitor  
24-Hour Value (ppb)
- ★ 40 Passive Ozone Monitor  
24-Hour Value (ppb)
- Interstate/Major Highway

**Value Ranges**  
 Less than 20 ppb  
 20 - 24 ppb  
 25 - 29 ppb  
 30 - 34 ppb  
 35 - 39 ppb  
 40 - 44 ppb  
 45 - 49 ppb  
 50 - 54 ppb  
 55 - 59 ppb  
 60 - 64 ppb  
 65 - 69 ppb  
 70 ppb or Greater



Sources:  
 AIRS Database  
 EPA Region 6 M2P2 and ORD  
 1992 Census Bureau TIGER/Line Files



Daily values rounded to the nearest integer.  
 Contours are shaded in ranges of 5 ppb.

All meteorological data analyzed from  
 5am to 8pm local daylight time from site #6  
 in Arlington. (AIRS# 48-439-0057)



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 GIS Support Team  
 March 20, 2000



Figure 5c

Figure 5d



# POND 24-Hour Contours

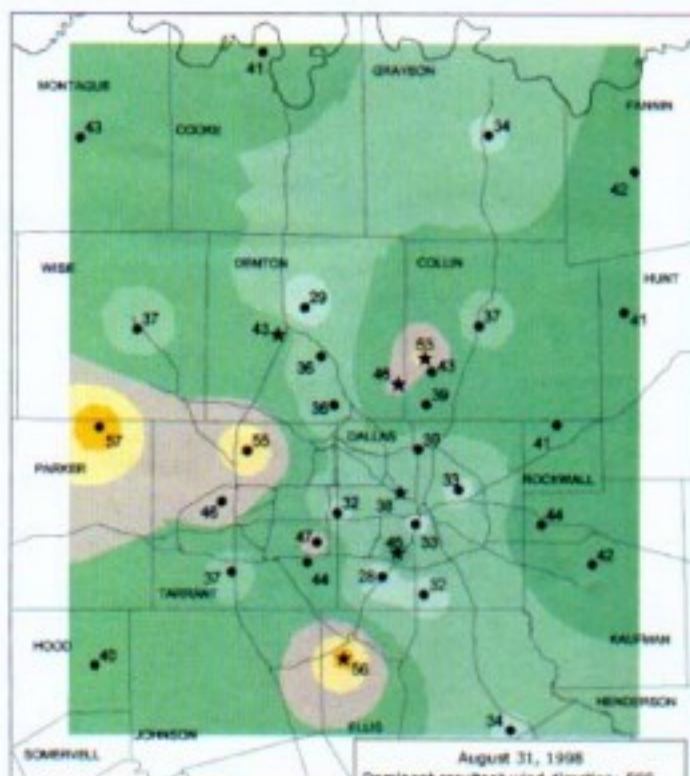


Figure 5e

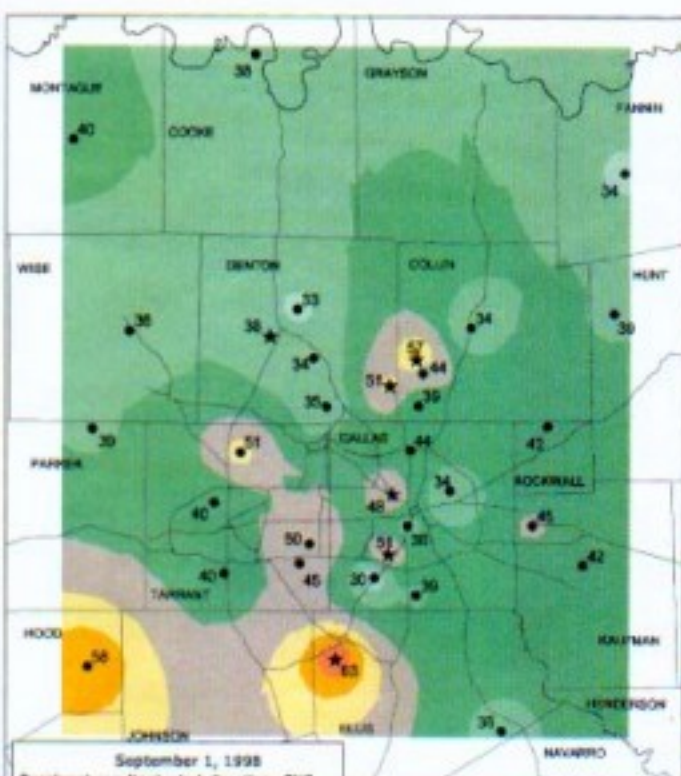


Figure 5f

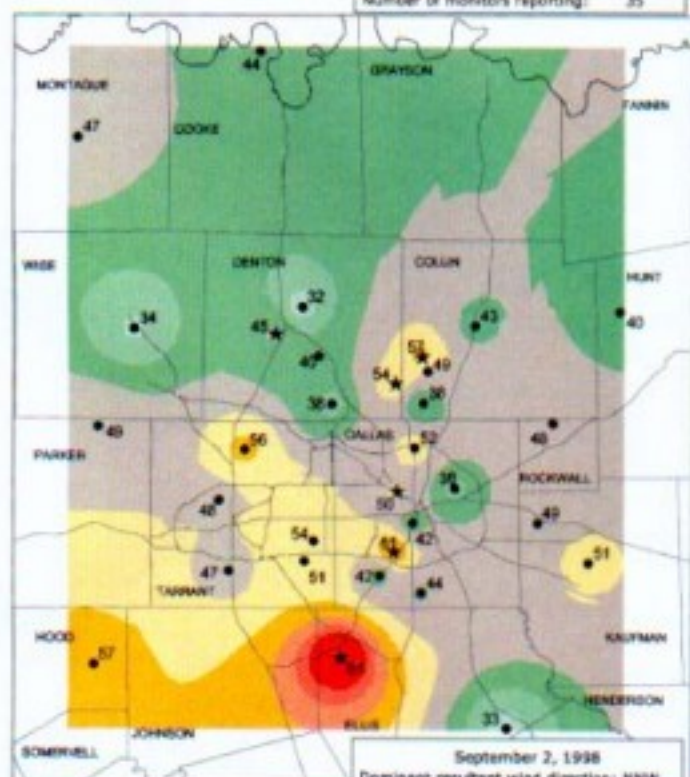


Figure 5g

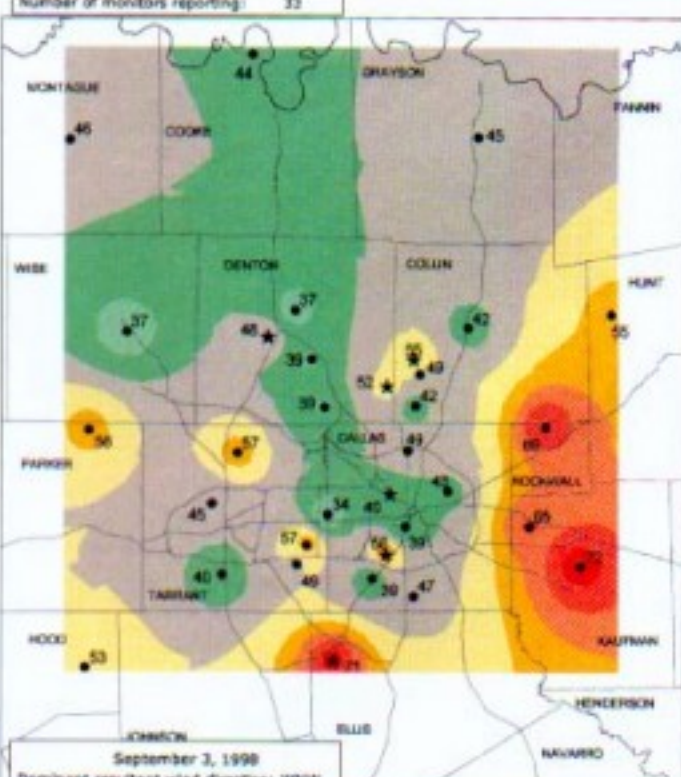


Figure 5h

**Value Ranges**  
 Less than 20 ppb  
 20 - 24 ppb  
 25 - 29 ppb  
 30 - 34 ppb  
 35 - 39 ppb  
 40 - 44 ppb  
 45 - 49 ppb  
 50 - 54 ppb  
 55 - 59 ppb  
 60 - 64 ppb  
 65 - 69 ppb  
 70 ppb or Greater

★ 40 Continuous Ozone Monitor  
 24-Hour Value (ppb)  
 ● 40 Passive Ozone Monitor  
 24-Hour Value (ppb)  
 --- Interstate/Major Highway



**Sources**  
 AIRS Database  
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Daily values rounded to the nearest integer.  
 Contours are shaded in ranges of 5 ppb.

All meteorological data analyzed from  
 6am to 8pm local daylight time from site #6  
 in Arlington. (AIRS# 45-439-0057)

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 March 20, 2000  
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# POND 24-Hour Contours

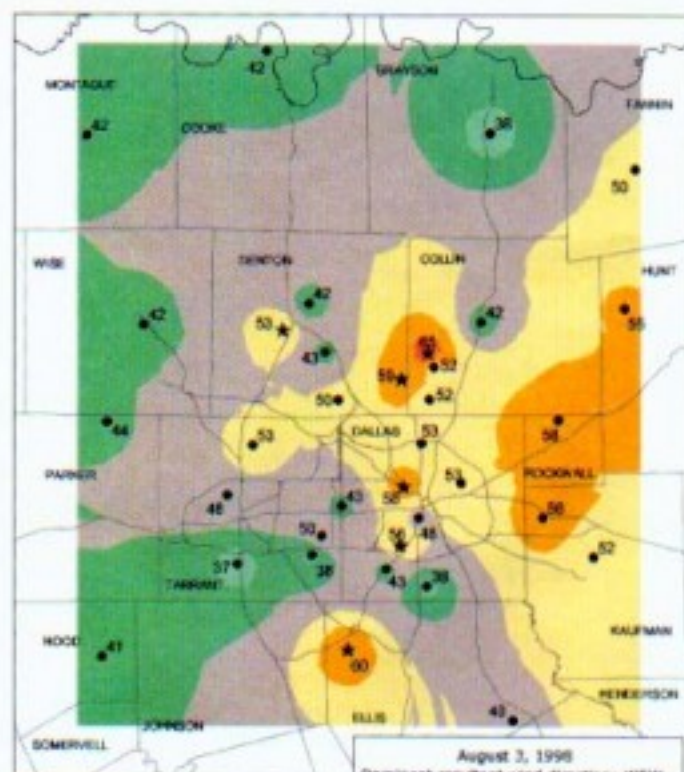


Figure 5i

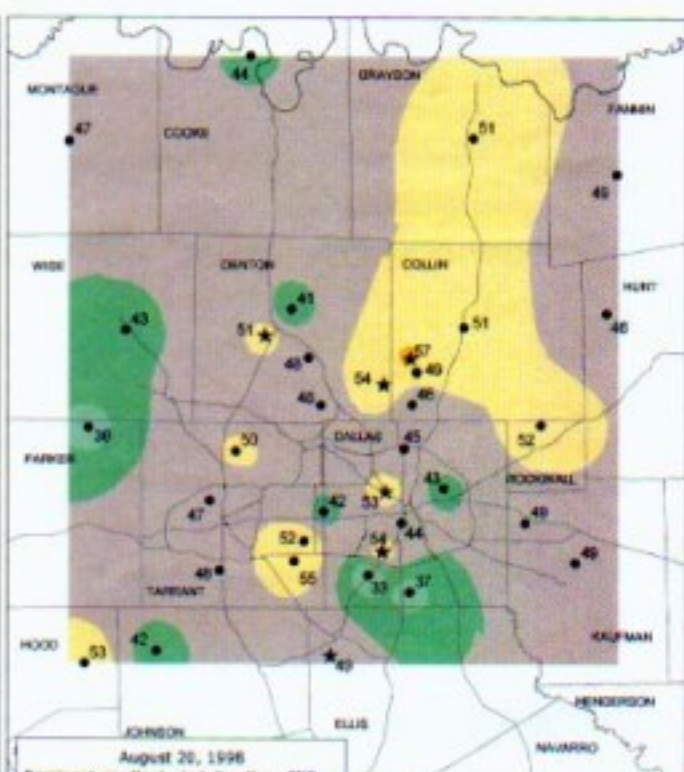
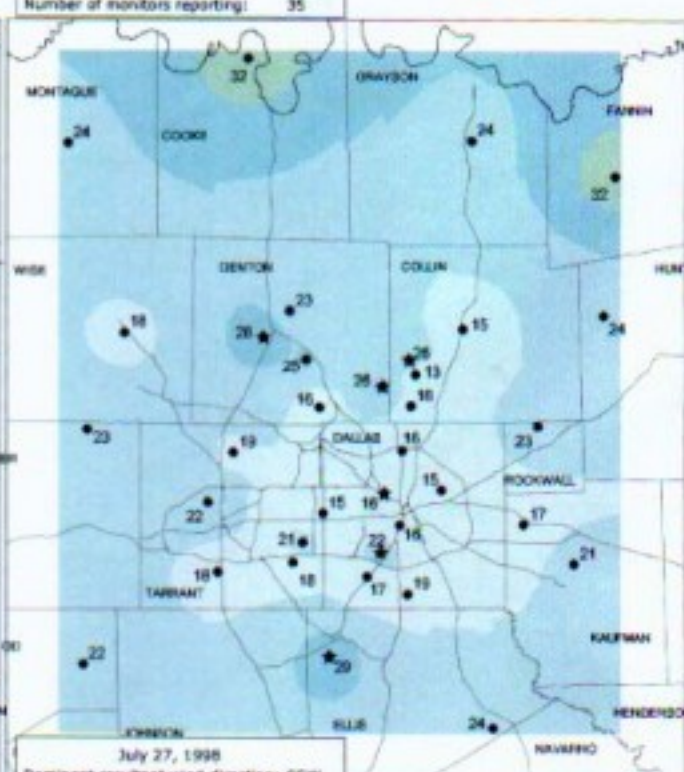
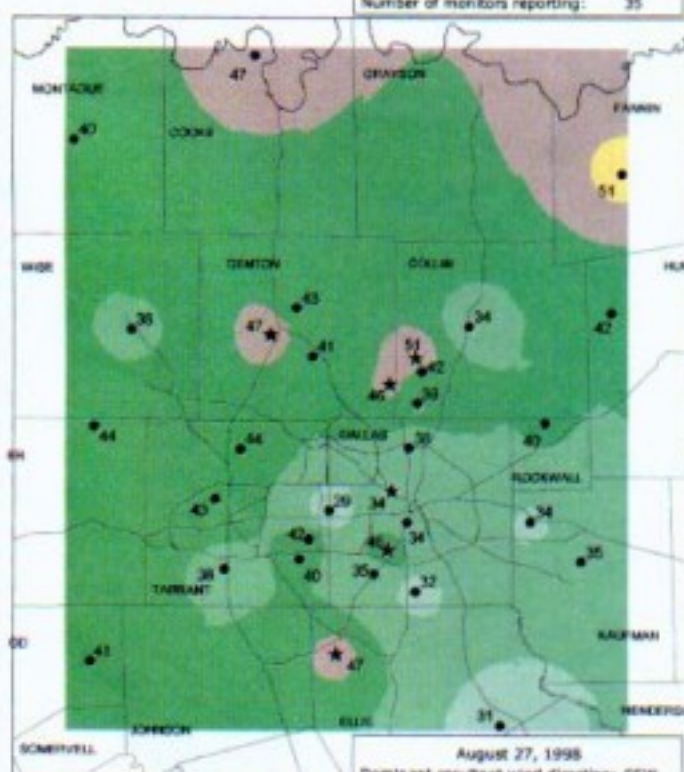


Figure 5j



**Value Ranges**  
 Less than 20 ppb  
 20 - 24 ppb  
 25 - 29 ppb  
 30 - 34 ppb  
 35 - 39 ppb  
 40 - 44 ppb  
 45 - 49 ppb  
 50 - 54 ppb  
 55 - 59 ppb  
 60 - 64 ppb  
 65 - 69 ppb  
 70 ppb or Greater

★ 40 Continuous Ozone Monitor  
 24-Hour Value (ppb)  
 ★ 40 Passive Ozone Monitor  
 24-Hour Value (ppb)  
 Interstate/Major Highway



**Sources**  
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 1992 Census Bureau TIGER/Line Files



Daily values rounded to the nearest integer.  
 Contours are shaded in ranges of 5 ppb.

All meteorological data analyzed from  
 6am to 8pm local daylight time from site #6  
 in Arlington. (AIRS# 48-439-0057)



EPA Region 6  
 GIS Support Team  
 March 20, 2000 20000320ML04



Figure 5k

Figure 5l



# POND 24-Hour Contours

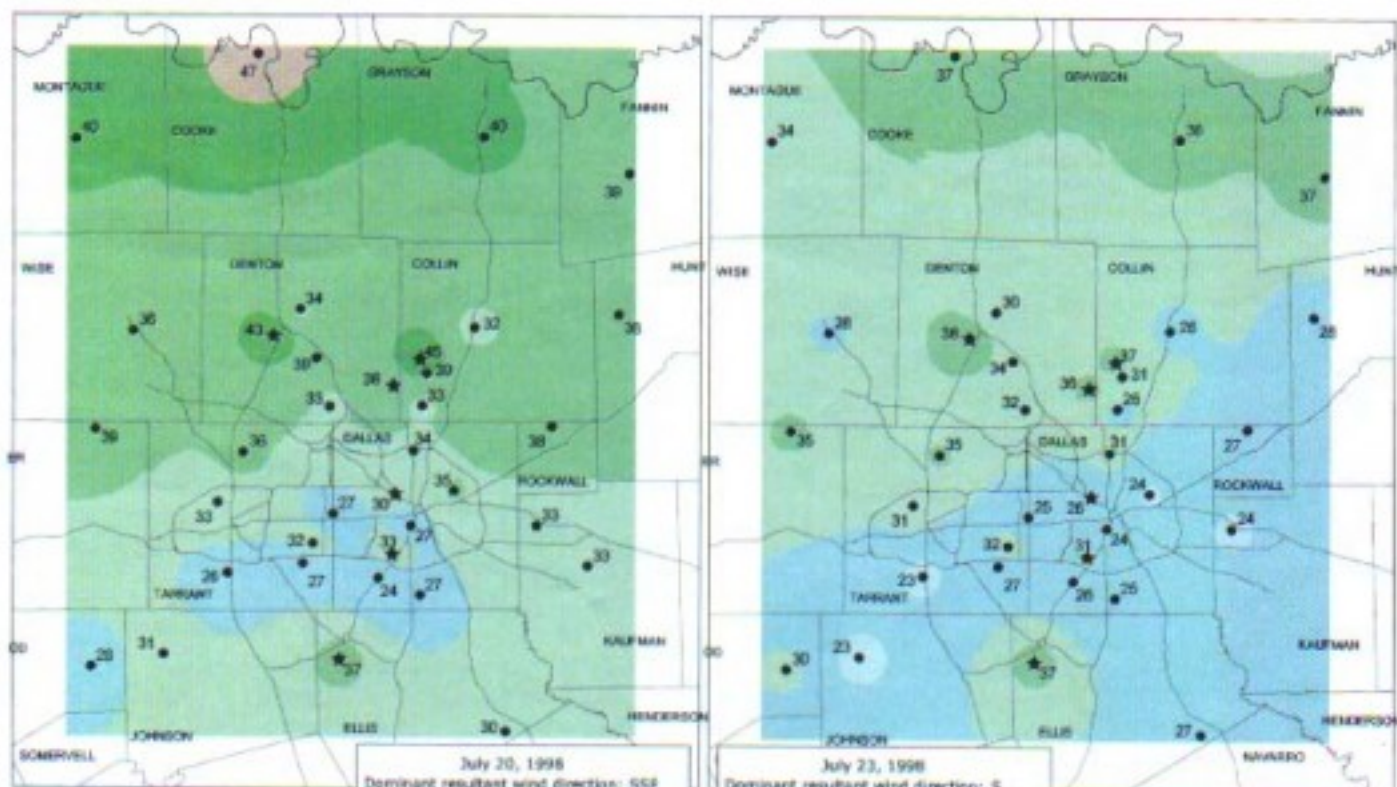


Figure 5m

Figure 5n

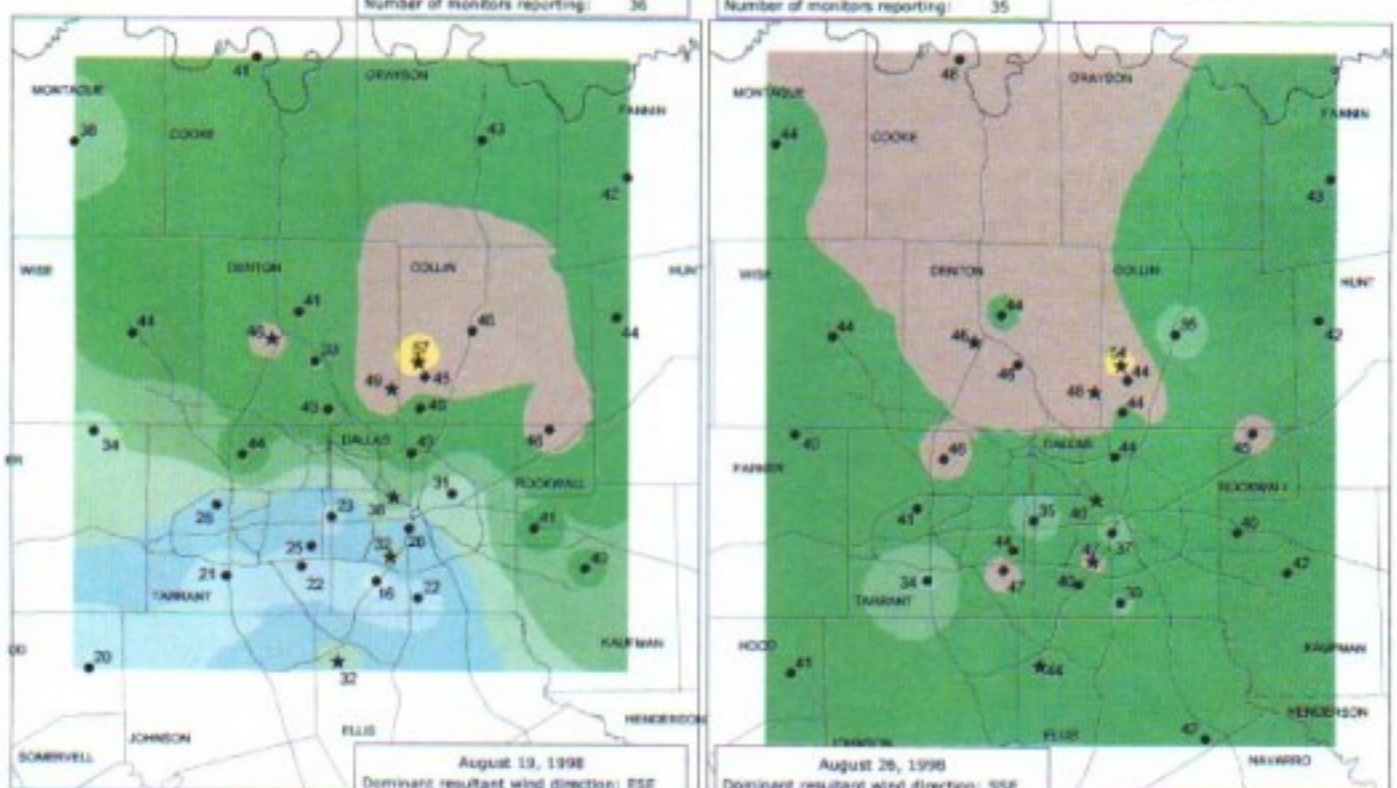


Figure 5o

Figure 5p

FIGURE 5. (a-p) Selected ozone contour maps generated from the 30-site passive ozone network.

**Value Ranges**

- Less than 20 ppb
- 20 - 24 ppb
- 25 - 29 ppb
- 30 - 34 ppb
- 35 - 39 ppb
- 40 - 44 ppb
- 45 - 49 ppb
- 50 - 54 ppb
- 55 - 59 ppb
- 60 - 64 ppb
- 65 - 69 ppb
- 70 ppb or Greater

- ★ 43 Continuous Ozone Monitor 24-Hour Value (ppb)
- ★ 40 Passive Ozone Monitor 24-Hour Value (ppb)
- Interstate/Major Highway



Sources:  
AIRS Database  
EPA Region 6 M2P2 and ORD  
1992 Census Bureau TIGER/Line Files



Daily values rounded to the nearest integer. Contours are shaded in ranges of 5 ppb.

All meteorological data analyzed from 6am to 8pm local daylight time from site #6 in Arlington. (AIRSH 48-439-0057)



EPA Region 6  
GIS Support Team  
March 20, 2000





**TABLE 1. Evaluation of Passive Ozone Measurements in 12 Peri-urban Counties during 8-h NAAQS Exceedances in the DFW Urban Core**

county & POND site no.	frequency of 24-h PSDs > 50 ppb O <sub>3</sub> during 11 urban 8-h exceedances	av of county PSD values > 50 ppb O <sub>3</sub> during exceedances	min/max 24-h PSD <sup>d</sup>	wind direction at PSD max <sup>e</sup>	date of max PSD
Rockwall-19	5 (11) <sup>a</sup>	57 <sup>b</sup>	40/69	WNW	09/03/98
Parker-20	5 (11)	56	37/57 <sup>f</sup>	ENE	07/14/98
				ESE	08/31/98
Kaufman-16	4 (11)	58	35/72	WNW	09/03/98
Hood-30	4 (11)	55	40/58	ENE	09/01/98
Kaufman-13	3 (11)	59	34/65	WNW	09/03/98
Grayson-4	3 (8)	53 <sup>c</sup>	34/57	ESE	07/15/98
Hunt-29	2 (11)	55	34/55 <sup>f</sup>	WSW	08/03/98
				WNW	09/03/98
Wise-28	2 (11)	58	34/59	ESE	07/15/98
Cooke-27	2 (11)	56	36/56	NNW	07/16/98
Fannin-26	2 (9)	51	32/51	SSW	08/27/98
Montague-25	1 (11)	55	24/55	NNW	07/16/98
Ellis-5	1 (8)	50	31/50	ENE	07/14/98
Johnson-10	0 (5)		42/47 <sup>f</sup>	NNE	07/13/98
				ESE	07/15/98

<sup>a</sup> Parentheses ( ) indicate the number of days PSD data are available in the respective county for the 11 urban exceedance days (see Figure 5a-k). <sup>b</sup> For example, Rockwall County recorded 5 PSD values > 50 ppb (50, 52, 55, 58, 69) averaging 57 ppb for all 11 urban exceedance days. <sup>c</sup> For example, Grayson County recorded 3 PSD values > 50 ppb (51, 51, and 57) averaging 53 ppb for 8 of the 11 urban exceedance days. <sup>d</sup> Recorded at each county site on two of the 11 urban 8-h exceedance days. <sup>e</sup> Wind directions for the 11 urban 8-h exceedance days: ENE 3, ESE 2, NNW 2, NNE 1, WSW 1, WNW 1, and SSW 1. <sup>f</sup> Identical maximum PSD measurement on multiple urban 8-h exceedance days.

**TABLE 2. Counties of DFW Metroplex Ranked by Average Percentage of Land Area Estimated to Have an 8-h Maximum above 85 ppb during the 1998 POND Study<sup>a</sup>**

county	av land area (%) above estd 85 ppb O <sub>3</sub>	corresponding land area (km <sup>2</sup> )
Rockwall	29	114
Hood	28	272
Kaufman	27	578
Somervell <sup>b</sup>	24	110
Hunt	22	345
Wise	21	517
Tarrant <sup>c</sup>	21	496
Parker	20	397
Ellis	19	446
Cooke	18	426
Montague	17	406
Johnson	14	264
Grayson	14	365
Denton <sup>c</sup>	14	353
Dallas <sup>c</sup>	13	306
Collin <sup>c</sup>	10	232
Fannin	5	85

<sup>a</sup> These percentages were averaged for the 11 days when at least one continuous monitor within the four regulated urban counties exceeded the 8-h NAAQS. <sup>b</sup> A small county sharing borders with Hood and Johnson Counties; mapping techniques permitted this county also to be included. <sup>c</sup> Indicates one of the four urban counties regulated by continuous O<sub>3</sub> monitoring.

urban counties exceed those for the four core (footnote c) counties.

**O<sub>3</sub> Contour Mapping (Step 3).** Although steps 1 and 2 provided a ranking of O<sub>3</sub> concern among 12 PSD-monitored counties surrounding the DFW urban core, a third step, i.e., the visualization of the O<sub>3</sub> movements for 8 weeks in the 24 000 km<sup>2</sup> region, even at 24-h intervals, furnished additional critical information about the region's patterns of O<sub>3</sub> "hot

spots", O<sub>3</sub> transport, and diversity of O<sub>3</sub> patterns under reportedly similar meteorological conditions. It is beyond the scope of this paper to discuss the POND O<sub>3</sub> maps in detail, but the total POND database will be made publicly available. Figure 5a-p represent one-half of the daily software-generated O<sub>3</sub> contour maps from data collected by 30 POND and 6 continuous sites. The numbers within the colored area represent daily O<sub>3</sub> measurements at the respective site location. The first 11 contour maps (Figure 5a-k) represent each of the 11 urban core days that averaged over 85 ppb O<sub>3</sub> for 8 h. For the purpose of comparison, these maps represent the identical days used to prepare the 12 county rankings and related information listed in Table 1. It should be noted that the continuous monitoring site operated by the Texas Natural Resource Conservation Commission (TNRCC), the Midlothian Tower C94 located in Ellis County (designated \*), is shown on all the O<sub>3</sub> contour maps; however, Ellis County was outside the four-county core being regulated by NAAQS. The continuous monitoring site in Ellis County recorded two 1-h exceedances (e.g., 143 on September 2; Figure 5g) and four 8-h exceedances (e.g., 109 on July 16; Figure 5d) during the POND operation. The POND site in Ellis County recorded its maximum measurement of 50 ppb during the four-county core exceedance on July 14.

Two periods of four consecutive days of 8-h NAAQS exceedances occurred in the urban core during the first and eighth week of POND monitoring. For the first period, July 13-16 (Figure 5a-d), moderate to low surface level winds moved from out of the north/northeast (13th) to out of the east/northeast (14th) to out of the east/southeast (15th). A flow reversal occurred on the 16th with winds out of the north/northwest, causing very high ozone concentrations to be recorded in the southern part of the DFW area. For the second period, August 31-September 3 (Figure 5e-h), the winds gradually moved from out of the east/southeast (31st) to out of the west/northwest, with low average resultant wind speeds ranging between 3 and 5 mph. One-hour ozone NAAQS exceedances were also recorded on September 1st and 2nd. Of special note were the high POND ozone concentrations recorded in Parker, Hood, Rockwall, and Kaufman Counties and the very high ozone concentrations recorded at the Midlothian site (Ellis County), especially on September 2nd and 3rd with the northerly winds. It is suggested that the information from both Table 1 and the O<sub>3</sub> contour maps become synergistic when the task is the selection of additional sites for continuous monitors.

For maximum contrast, Figure 5l represents the lowest daily urban O<sub>3</sub> pattern measured by the POND. This map, while indicating favorable urban air quality, shows a discernible transport to the most northern rural counties, a situation more strongly depicted in Figure 5k, representing an O<sub>3</sub> exceedance day experiencing similar SSW wind conditions. Such general patterns should be useful to any region involved in long-term crop and ecological damage assessment.

Figure 5m-p represents days for wind directions not as yet mapped, i.e., S, SSE, and ESE. Figure 5m,p shows a strikingly different pattern in northern O<sub>3</sub> movement for the same SSE wind direction, suggesting a closer look at the respective meteorological conditions is needed for an explanation. On the other hand, Figure 5m,n is well behaved. The O<sub>3</sub> band in the most northern counties subtly and correctly shifts when the wind direction moves from SSE to S. These last contour maps illustrate that (i) an observer should expect regional O<sub>3</sub> patterns to emerge from daily mapping using data generated by a network similar to POND and (ii) deviations from expected O<sub>3</sub> patterns can be supported when underlying meteorological details are scrutinized.