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PAMS Monitoring in the Lake Michigan Area

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INTRODUCTION

To obtain more comprehensive and representative data on ozone air pollution, the Clean Air Act Amendments of 1990 required the United States Environmental Protection Agency (USEPA) to promulgate regulations requiring States with serious (and above) nonattainment areas to enhance their existing ambient monitoring networks. The regulations for these new monitoring stations (known as Photochemical Assessment Monitoring Stations [PAMS]) were finalized on February 12, 1993. The PAMS network will join the State and Local Air Monitoring Stations (SLAMS) and National Air Monitoring Stations (NAMS) networks as the principal source of routine air quality data.

The Lake Michigan States (Illinois, Indiana, Michigan, and Wisconsin) have determined that the most useful and practical approach to meet these requirements is to establish a regional PAMS network. The four states believe that a regional network design is appropriate for the following reasons:

* it provides for the most efficient use of available resources;
* it is consistent with the regional nature of the ozone problem in the Lake Michigan area[1];
* it is consistent with the regional database from the 1991 Lake Michigan Ozone Study field program, which provides the underlying basis for the forthcoming regional attainment demonstration; and
* it provides some of the essential elements of the database needed to support regional photochemical modeling of future episodes.

On January 4, 1994, the four States submitted a joint PAMS plan to USEPA.[2] Such joint plans are encouraged by USEPA in instances where PAMS monitoring locations are located in different states (40 CFR Part 58.40). On February 16, 1994, USEPA approved the regional plan. An overview of this plan is presented below, along with the results of the 1994 PAMS monitoring, and the plans for the 1995 PAMS monitoring.

OVERVIEW OF REGIONAL PAMS MONITORING PLAN

Network Design

As a result of the 1990 and 1991 Lake Michigan Ozone Study (LMOS) field programs[3], the four states gained valuable knowledge and insight into the formation and transport of ozone in the region. During the 1991 field program, there were more than 85 surface ozone

monitoring stations, 32 oxides of nitrogen (NOx) stations, and 17 volatile organic compound (VOC) and carbonyl stations. Additionally, measurements were made on Lake Michigan by boats and throughout the region by aircraft. In subsequent years, over 60 ozone and 16 NOx monitoring stations continued to operate in the region. The regional PAMS network design is based upon the experience acquired from the LMOS field programs and utilizes the extensive, existing air monitoring network.

Figure 1 depicts the PAMS network for the Lake Michigan region and the ozone NAMS/SLAMS sites operational in 1994. A total of 10 PAMS sites are specified with the site type description as follows:

Site	Purpose	Illinois	Wisconsin	Indiana	Michigan
Type 1	Background	Braidwood	Wind Point		
Type 2	Maximum Emissions	Chicago-NWU	Milwaukee-UWM	Gary-Gate City Steel	
Type 3	Max. Downwind Ozone	Evanston	Harrington Beach		Muskegon
Type 4	Far Downwind Ozone	Zion-Camp Logan	Manitowoc		

The designation of these site types is based upon the predominant local summertime morning and afternoon wind directions. Most ozone exceedances in this part of the United States, occur when the region is on the "back side" of a high pressure system, with south-southwesterly winds and very warm, humid air. Thus, the upwind sites are typically located to the south and southwest of the major urban areas of Chicago/Gary and Milwaukee, and the downwind sites to the north and northeast. Under other meteorological conditions, these site types could obviously change (e.g., under synoptic northwesterly winds, Gary could be considered a Type 3 and Zion a Type 1 site). A regional network offers the advantage that the PAMS monitoring objectives can be achieved under a variety of meteorological conditions.

USEPA's enhanced monitoring rules provide, under Appendix D, Table 2, minimum network requirements. The Lake Michigan region contains two coinciding severe ozone nonattainment areas: Chicago-Gary-Lake County (IL,IN,WI) - population greater than 2 million and Milwaukee-Racine (WI) - population greater than 1 million. Correspondingly, Table 2 specifies a total of nine PAMS sites for these two areas, with two Type 2 sites in

each area. The Lake Michigan States have identified a 10-site network with two Type 2 sites for Chicago and one Type 2 site for Milwaukee. The design opted for a site on the eastern side of Lake Michigan (Muskegon) to provide for improved spatial coverage; in lieu of a second Type 2 site in Milwaukee.

Sampling and Analysis Methods

The Lake Michigan PAMS sites will use only automated reference or equivalent methods (40 CFR Part 58, Section 50.1) for ozone and recommended for NO, NO2, and NOx (40 CFR Part 58, Appendix C Section 4.1 and 4.2). VOC and carbonyl monitoring will be performed using the methods described in the Technical Assistance Document (40 CFR Part 58, Appendix C Section 4.3) or USEPA-approved alternate methodologies.

Meteorological measurements will be conducted in accordance with the Technical Assistance Document referenced above and the "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Meteorological Measurements".

Monitoring Period

The Lake Michigan PAMS ozone monitors will operate in accordance with each States' USEPA-approved ozone season - i.e., April through October (40 CFR Part 58, Appendix D Section 2.5). The ozone precursor and meteorological PAMS monitors need only operate during the months of June, July, and August.

Sampling Frequencies

The Lake Michigan PAMS ozone, NO, NO2, and NOx monitoring will be continuous. For VOC and carbonyl, the States objected to the requirement for continuous sampling and proposed the following alternative sampling frequency:

* routine samples collected at Type 2 sites for four 3-hour intervals (0000-0300, 0600-0900, 1200-1500, and 1500-1800), and at Type 1, 3, and 4 sites for three 3-hour intervals (0600-0900, 1200-1500, and 1500-1800) on a once every third-day schedule;

* during episodic periods, samples collected at the same 3-hour intervals as noted above on the ramp-up day of the episode and each day of the episode, up to 15 episodic days per year determined on a forecast basis; and

* one 24-hour sample every sixth-day at all sites during the monitoring season, and year-round at the Type 2 sites.

In addition, the States committed to investigate the use of an automated gas chromatograph (GC) at the Chicago Type 2 site. Should this effort prove successful, consideration will be given to installing and operating automated GCs at the other Type 2 sites.

This approach focuses sampling on the expected highest ozone days and should provide sufficient data to meet all of the PAMS monitoring objectives. USEPA accepted this alternative sampling frequency as part of their approval of the Lake Michigan PAMS plan.

Meteorological Monitoring

Each PAMS monitoring station, or a location generally representative of the area, will be equipped with meteorological monitoring equipment, including wind measurements at 10 meters above the ground, consistent with 40 CFR Part 58 Appendix D Section 4.6.

Upper air meteorological monitoring is planned at several stations throughout the region. A doppler acoustic sounder will be operated along the lakeshore near the Illinois-Wisconsin stateline. National Weather Service (NWS) rawinsonde data will be acquired (two regular daily soundings, plus two additional soundings on forecasted high ozone days). Upper air measurements (with rawinsondes) in or near downtown Chicago may also be pursued, if sufficient funding is available.

Network Implementation Schedule

Four regional PAMS sites are already in operation, as discussed below. The tentative implementation schedule for the remaining sites is as follows:

1995	Type 1:	Braidwood (IL)
	Type 2:	Gary (IN)
	Type 4:	Manitowoc (WI)
1996	Type 1:	Wind Point (WI)
	Type 3:	Evanston (IL)
	Type 3:	Muskegon (MI)

The ability to meet this schedule is dependent on the availability of sufficient funding. If achieved, then the network will be operational well ahead of the implementation schedule in USEPA's enhanced monitoring regulations (i.e., operation of all sites by 1998).

Quality Assurance

The PAMS Quality Assurance program will be developed in accordance with the provisions of 40 CFR Part 58 Appendix A. The states will continue with their existing, approved quality assurance plans and will update those plans as guidance from USEPA is received. The four states will additionally coordinate quality assurance activities to ensure uniform data quality throughout the regional PAMS network.

RESULTS OF 1994 PAMS MONITORING

During the 1994 sampling season, a total of four PAMS stations were operated in the Lake Michigan area:

Type 2:	Chicago - NWU (IL) Milwaukee - UWM North (WI)
Type 3:	Harrington Beach (WI)
Type 4:	Zion - Camp Logan (IL)

The two Type 2 sites started-up in 1993, and the other sites in 1994. All four sites began operation one year prior to the date required by the regulations.

VOC and carbonyl sampling was performed at all four sites with canisters and cartridges in accordance with the approved alternative sampling schedule. Data capture generally exceeded 90% at all four sites. In addition to the regular every third-day sampling days, there were five episodic sampling days during 1994: June 6, June 17, June 18, June 20, and August 25. Forecasting for the selection of these episodic days worked well; no ozone exceedance days were missed.

Illinois and Indiana also investigated the use of an automated GC at the Chicago and the Gary sites. Funding for the Chicago site was not received until August. Delivery of the equipment is expected by April 1995. Operation may begin by June 1, 1995. (Canisters will be collected also during 1995 at the Chicago Type 2 site.) Equipment for the Gary site has been received and installation began in late 1994. Full operation of this site is expected by June 1, 1995.

Regional Ozone Exceedances

Within the Lake Michigan region, the States operate about 70 ozone monitors as part of their NAMS, SLAMS, and PAMS networks. During 1994, the National Ambient Air Quality Standard (NAAQS) for ozone of 0.12 ppm ($\geq$ 124 ppb) was exceeded on only 5 days in the region, with no more than 3 exceedances at any one site (see Table 1). This exceedance frequency is below the average of 10 days per year over the last 5 years (1990-1994), and is well below the average of 22 days per year for the previous 5 years (1985-1989). Overall, 23 of the regional ozone sites recorded an exceedance.

All sites recorded at least one hour greater than 80 ppb. Nine sites recorded peak one-hour ozone concentrations greater than 150 ppb. The highest observed ozone concentration during 1994 was 175 ppb at the Harrington Beach PAMS site in northeast Wisconsin (June 16). This peak value is consistent with the average of the highest annual peak value over the last 5 years of about 170 ppb, and is significantly less than the highest annual peak value over the previous 5 years of about 200 ppb. The magnitude of peak concentration and the frequency of exceedances both indicate a significant improvement in ozone air quality levels in recent years.

All but two exceedances in 1994 occurred on several days in the middle of June: an exceedance at the Bayside monitor (in northern Milwaukee County) on May 30, and an exceedance at the Muskegon monitor on July 6. During the mid-June episode, elevated concentrations (>100 ppb) were measured on six consecutive days (June 15 - 20) over the entire 4-State region. Exceedances were measured on 3 consecutive days: at 17 sites in 2 States on June 16; 4 sites in 3 States on June 17; and 5 sites in 2 States on June 18. The time duration and spatial extent of this episode is typical of historical episodes (i.e., about 2/3 of exceedance days during the last 10 years occur as part of episodes lasting 2 days or more, and impact 2 or more monitoring stations).

Supplemental Measurements

Another sampling program was also initiated in 1994. Two aircraft were employed to collect aloft ozone and ozone precursor data along the upwind (southern and western) boundaries and over Lake Michigan downwind of Chicago and Milwaukee. Previously, aloft ozone and ozone precursor concentrations were collected on only a few days in the Lake Michigan area during the 1991 (and 1990) LMOS field programs. The aloft upwind measurements are necessary to better understand the horizontal and vertical structure of the incoming pollutant flux. (Note, surface measurements are inadequate for this purpose given that aloft ozone concentrations from the 1991 field program were about 60 ppb higher than corresponding surface measurements at night).

One plane, which was operated by the State of Wisconsin, made continuous measurements of ozone, NO, NO2, NOx, and temperature, and took grab samples of VOC and carbonyl compounds at preplanned locations and altitudes. The other aircraft, which was operated by a private contractor (R.B. Jacko & Associates), only made continuous measurements of ozone. The flight patterns for these two planes are shown in Figure 2.

The aircraft were available during July and August. Sampling was conducted on days forecast to have elevated ozone concentrations within the Lake Michigan region. As noted in Table 1, there was only one exceedance day during July and August (i.e., July 6). Aircraft sampling was performed on this day. In the interest of collecting general information on incoming ozone and ozone precursor concentrations, aircraft sampling was also performed on several days of moderate ozone concentrations in late August while the planes were still available.

There were a total of six aircraft sampling days. On most days, the incoming aloft ozone concentrations were on the order of 70 - 100 ppb, which confirm the high levels measured during the LMOS field programs. The ozone concentrations for a typical day are presented in Figure 3. These data show the influence of several nearby, large cities in the Midwest (i.e., impacts of 10 - 30 ppb), on top of an elevated regional background of 70 - 80 ppb. Concentrations of this magnitude are notable, especially given that there were no measured ozone exceedances in the Lake Michigan region during this late August period. Aircraft measurements should be made to quantify the magnitude of the incoming transport during future ozone episodes.

PLANS FOR 1995 PAMS MONITORING

During the 1995 sampling season, a total of seven PAMS stations are expected to be in operation in the Lake Michigan area:

Type 1:	Braidwood (IL)
Type 2:	Chicago (IL) (Due to construction, the NWU site will be moved to a nearby location for the 1995 sampling season.) Milwaukee - UWM North (WI) Gary - Gate City Steel (IN)
Type 3:	Harrington Beach (WI)
Type 4:	Camp Logan/Zion (IL) Manitowoc (WI)

A serious effort will be made to begin site selection and, possibly, site preparation for the remaining three PAMS sites (i.e., Type 1: Wind Point (WI); and Type 3: Evanston (IL) and Holland (MI)). If sufficient Federal funds are available, then the full 10-station PAMS network may be on-line by 1996.

VOC and carbonyl sampling will be performed according to the approved alternative sampling schedule. In addition, as noted above, continuous GCs will be operated at the Chicago and Gary Type 2 sites.

Forecasting support will be provided by Illinois and Wisconsin. The forecasting team will hold regular conference calls to determine the need to initiate special sampling (e.g., VOC and carbonyl measurements, and aircraft sampling).

Upper air meteorological monitoring will begin in 1995. As noted above, the first-year plans for this monitoring are rather minimal given the lack of available funding. At a minimum, it is expected that the doppler acoustic sounder data, and NWS data will be obtained.

Several supplemental measurements are also planned:

(1) Aircraft sampling along the southern and western upwind boundaries and over Lake Michigan similar to the 1994 effort (i.e., two planes and same flight patterns).

(2) Tall building measurements (Sears Tower) by Illinois.

(3) Operation of an ozone monitor over Lake Michigan on the ferry which operates between Manitowoc, WI and Ludington, MI.

CONCLUSIONS

Two enhancements of the monitoring programs in the Lake Michigan region have been implemented in recent years: the regional PAMS network and boundary aircraft flights. The PAMS network was initiated in 1993 pursuant to the requirements of the Clean Air Act Amendments of 1990 and subsequent regulations promulgated by USEPA. Data from the PAMS network will allow the States to better characterize the nature and extent of the regional ozone problem; aid in tracking ozone precursor emissions; assess air quality trends; and make more informed attainment/nonattainment decisions. Only limited analyses of these data can be performed at this time given the recent start-up of the PAMS network.

Boundary aircraft flights were made in 1994 to provide more complete information on ozone boundary conditions. Elevated boundary conditions, as a result of super-regional transport

of ozone across the eastern United States, has emerged as a major issue to states trying to prepare local attainment demonstrations. The aircraft data are needed to determine current incoming concentration levels, to assess the representativeness of the previous measurements, and to determine if the adoption of controls upwind have been effective in lowering the incoming concentration levels.

REFERENCES

[1] Koerber, M., "An Overview of the Lake Michigan Ozone Study", The Journal of Environmental Engineering and Management, Winter 1991.

[2] Lake Michigan Air Directors Consortium, "Lake Michigan Regional PAMS Network", January 4, 1994.

[3] Bowne, N.E. and D.L. Shearer, "Summary of 1991 LMOS Field Measurements Program", ENSR Consulting and Engineering, Glastonbury, CT.

Table 1. High Ozone Concentrations in the Lake Michigan in 1994

SITE	MAY		JUNE			JULY		AUG	
	22	30	16	17	18	5	6	17	25
DAY OF WEEK	SUN	MON	THURS	FRI	SAT	TUES	WED	WED	THURS
WISCONSIN									
Chiwaukee	---	(123)	166	---	---	---	---	(124)	---
Kenosha	---	---	149	---	---	---	---	---	---
Racine	---	---	153	---	---	---	---	---	---
S.Milw(Blakewood	---	---	140	---	---	(120)	---	---	---
UWM-N	---	---	148	---	132	---	---	---	---
Alverno Coll	---	---	132	---	---	---	---	---	---
Appleton Ave	---	---	---	---	---	---	---	---	---
Bayside	---	128	162	---	134	---	---	---	---
Waukesha	---	---	---	---	---	---	---	---	---
Grafton	---	(121)	160	---	---	---	---	---	(122)
Harrington Beach	---	---	175	---	---	(122)	---	---	---
Sheboygan	---	---	156	---	---	---	---	---	---
Manitowoc	---	---	163	138	---	---	---	---	---
Kewaunee	---	---	140	---	---	---	---	---	---
Newport	---	---	130	125	---	---	---	---	---
ILLINOIS									
Camp Logan	---	---	132	---	---	---	---	---	---
Waukegan	---	---	126	---	---	---	---	---	---
Libertyville	---	---	128	---	---	---	---	---	---
Deerfield	---	---	126	---	---	---	---	---	---
Elgin	---	---	---	---	127	---	---	---	---
Lemont	---	---	---	---	169	---	---	---	---
S.Lockport	---	---	---	---	130	---	---	---	---
INDIANA									
Michigan Cty	---	---	---	125	---	---	---	---	---
South Bend	(124)	---	---	---	---	---	---	---	---
MICHIGAN									
Muskegon	---	---	---	---	---	---	146	---	---
Grand Rapids	---	---	---	149	---	---	---	---	---

(Note: All values greater than 120 ppb are identified above. According to USEPA guidance, only values greater than 124 ppb are considered an exceedance.)

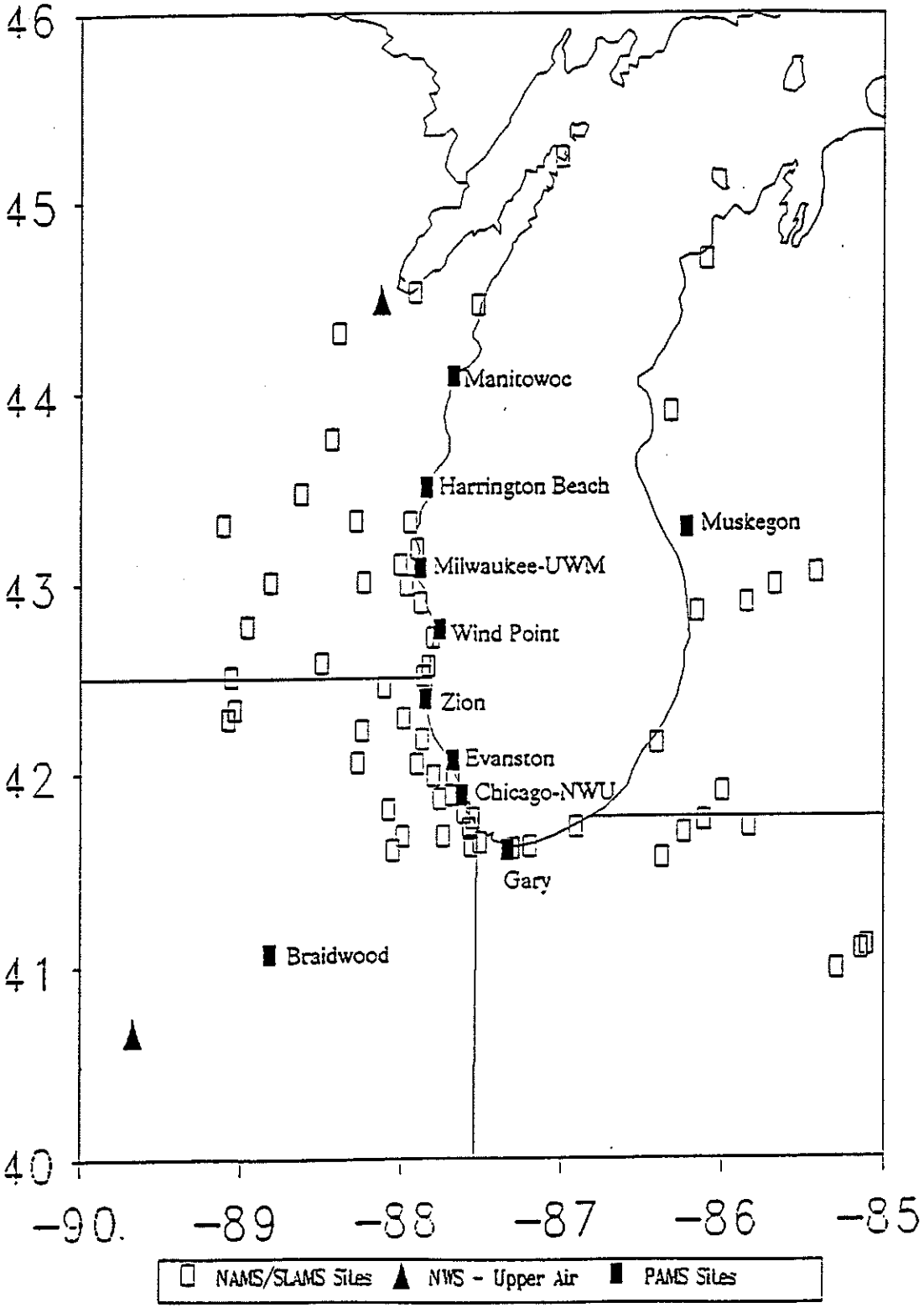

Figure 1. Ozone Monitoring Stations in the Lake Michigan Region

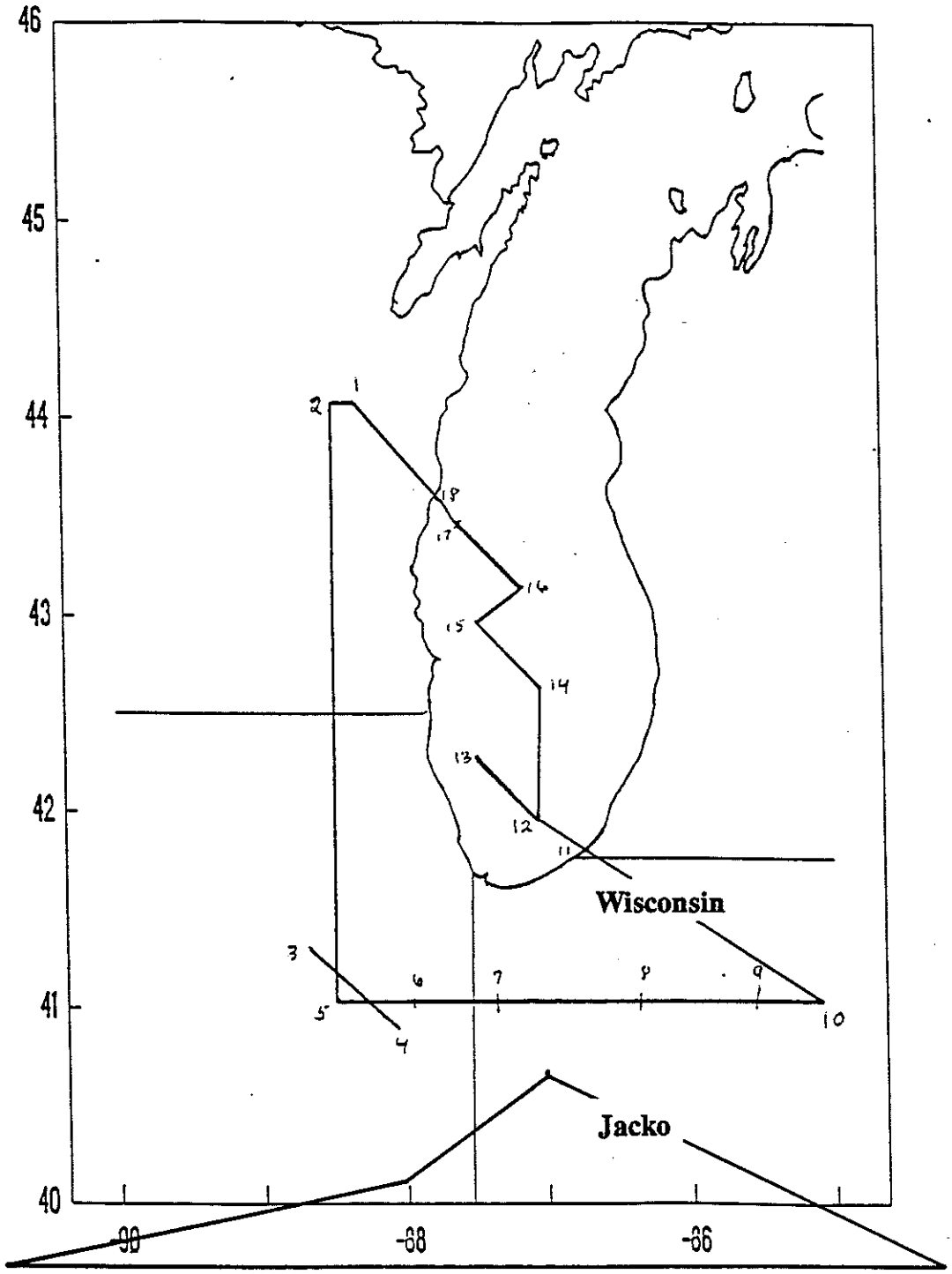

Figure 2. Boundary Aircraft Flight Patterns

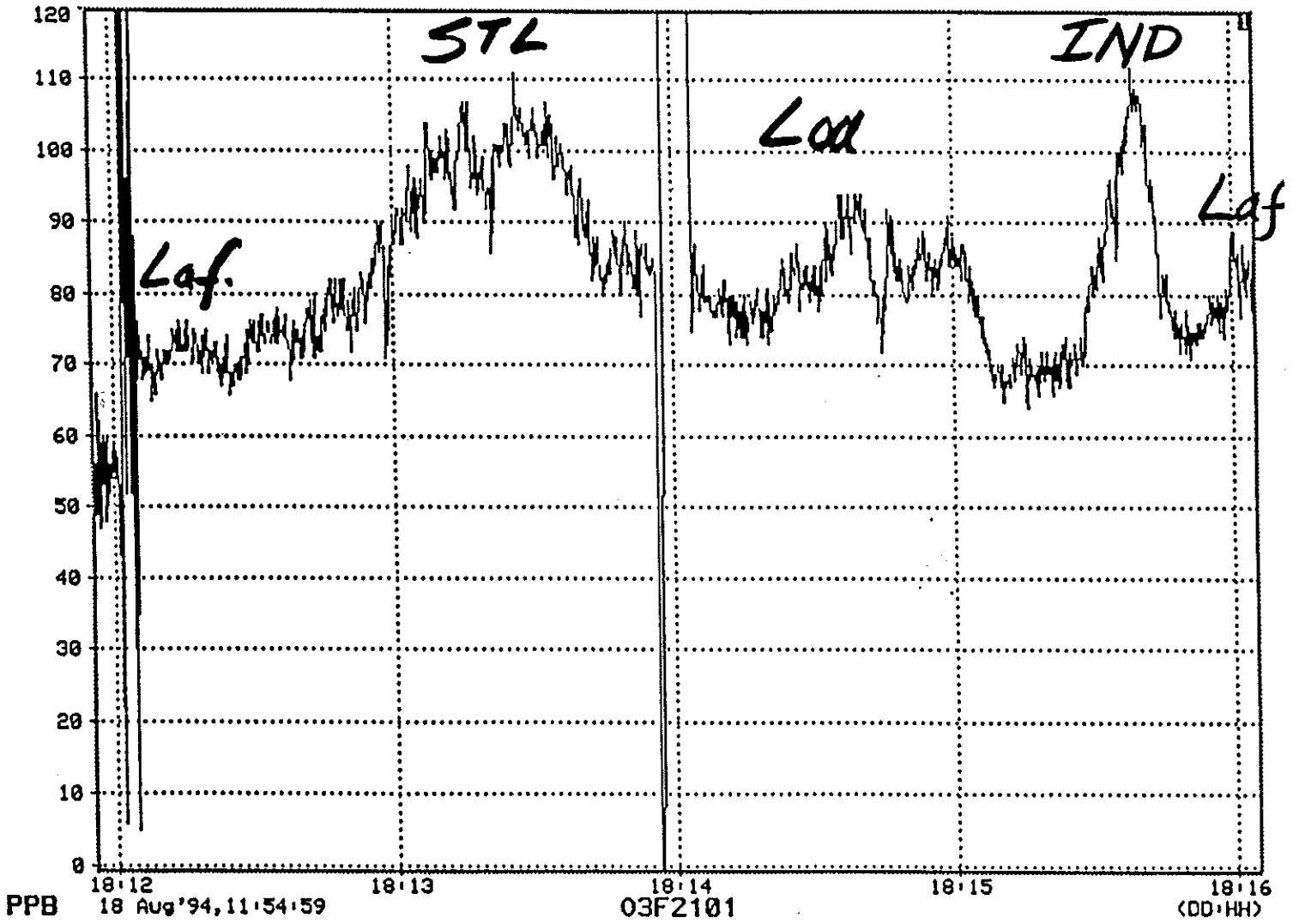

Figure 3. Ozone Concentrations Measured by Boundary Aircraft (August 18, 1994)