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Mid-Course Review Report for the Washington, DC-MD-VA 1-Hour Ozone Nonattainment Area

Prepared by:

Air Quality Planning Section
Department of Environmental Programs
Metropolitan Washington Council of Governments
Washington, DC 20002

for:

District of Columbia Department of Health,
Maryland Department of the Environment,
and
Virginia Department of Environmental Quality

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1.0 Introduction

This document is the Mid-Course Review (MCR) for the Washington, DC-MD-VA nonattainment area. The states in the Washington, DC-MD-VA nonattainment area made a commitment in the State Implementation Plan ("Severe Area SIP") submitted in February 2004 to conduct a Mid-Course Review by the end of 2004. The MCR is intended to show the progress being made to improve air quality in the nonattainment area and the efforts underway to assure that all necessary steps are taken to reach the federal health standard for the one-hour ozone standard by 2005. This MCR is being prepared after completion of the 2004 ozone season. The administrative review considers all of the local, regional, and national controls implemented by 2004.

1.1 Background

In 1990 EPA designated the Washington, DC-MD-VA nonattainment area shortly after adoption of the 1990 Clean Air Act Amendments (CAAA). EPA defined the Washington, DC region's nonattainment area as the metropolitan Washington Metropolitan Statistical Area (MSA). The nonattainment area is comprised of 9 counties; 4 from Maryland, 5 from Virginia (including 5 cities), and the District of Columbia. Table 1 lists all the counties and cities that are included in the Washington, DC-MD-VA nonattainment area.

Table 1. Washington, DC-MD-VA 1-Hour Nonattainment Area

STATE	COUNTY/CITIES
District of Columbia	Washington
Maryland	Montgomery
	Charles
	Fredrick
	Prince George's
Virginia	Arlington
	Alexandria (City)
	Fairfax
	Fairfax (City)
	Falls Church (City)
	Loudoun
	Manassas (City)
	Manassas Park (City)
	Prince William
	Stafford

The plan to improve air quality in the Washington, DC region to meet the national air quality standard for ozone (one-hour ozone standard) is provided in "The Severe Area

Attainment Plan" for the nonattainment area.[1] The Plan consists of two Rate of Progress demonstrations, for the period 1999-2002 and for the 2002-2005; and an attainment demonstration for 2005. Additionally, the plan includes commitments by the states to meet requirements for severe nonattainment areas, commitments by the states to meet additional EPA requirements for the Washington, DC region including a contingency plan for 1999 rate of progress, contingency plans for the 2002 and 2005 rates of progress, and an analysis of Reasonably Available Control Measures. The plan also provides emissions inventories for 1990, 2002 and 2005.

Since designated as nonattainment, governments in the region have taken steps to reduce emissions of ozone precursors. Based on the 2002 Rate-of-Progress demonstration, occurring between 1990 and January 2004, approximately 180 tons per day VOC and 270 tons per day NOx have been reduced compared to the uncontrolled baseline. This has resulted in declines in measured ozone concentrations during episodes and a 20 percent reduction in the region's design value.

The metropolitan Washington, DC region's air quality is significantly affected by ozone and its precursors from other regions outside the Washington, DC area. According to studies by the University of Maryland, as much as seventy percent of the ozone levels during an exceedance originate from upwind sources outside of the region. The states in the Washington metropolitan region agreed as part an Ozone Transport Commission agreement, to limit emissions from sources of nitrogen oxides beginning in 2003. EPA's NOx SIP call requires 23 states, including states in the Midwest upwind from the Washington, DC region, to control NOx emissions from stationary sources beginning in 2004. The original implementation date of the NOx SIP Call was 2003, but the date was postponed to 2004 due to litigation. EPA's analysis predicts that the reductions in NOx emissions from this regulation will enable the Washington, DC-MD-VA nonattainment area to attain the 1-hour ozone standard in 2005.

1.2 Methodology for Conducting the Mid-Course Review

The MCR analysis follows the procedures outlined in EPA's March 28, 2002 memo "Mid-Course Review Guidance for the 1-Hour Ozone Nonattainment Areas that Rely on Weight-of-Evidence for Attainment Demonstration". The administrative review focuses on determining whether the area has met its obligation to reduce emissions by implementing control measures. Data required to complete the review are from the Severe Area SIP and the Periodic Emissions Inventory. Emissions for 2004 are interpolated using data from 2002 and projections for 2005. Trends in air quality are determined through review of several key indicators. Data on measured ozone concentrations are available from monitors located within the nonattainment area. Statistical analyses are conducted to ascertain trends. The statistical analyses chosen to determine air quality trends were based on EPA guidance. Transport of ozone is analyzed by evaluating measured concentrations at sites upwind of the region and

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[1] *State Implementation Plan ("Severe Area SIP") Demonstrating Rate of Progress for 2002 and 2005; Revision to 1990 Base Year Emissions; and Severe Area Attainment Demonstration for the Washington, DC-MD-VA Nonattainment Area,* February 19, 2004.

through consideration of scientific studies documenting ozone transport in the eastern United States.

1.3 Structure of Report

The remainder of this report is organized as follows:

Emission and Control Analysis
- Emission and Control Analysis
- Impact of Emission Reduction on Design Values

Air Quality Indicator Trends Analysis
- Washington Nonattainment Area Design Values
- Washington Nonattainment Area Monitor Exceedances
- Effect of Meteorology on Ozone Trends
- Spatial Extent of Exceedances

Ozone Transport Analysis
- Regional Transport
- Local Transport
- Transport via Low-Level Jets

Summary/Conclusions

2.0 Emissions and Control Measures

2.1 Emission and Control Analysis

This section presents historical and current emissions estimates for ozone precursors (VOCs and NOx) affecting air quality in the Washington, DC-MD-VA nonattainment area. An emission control analysis is presented to satisfy the Administrative Review requirements of the MCR.

The base year emissions inventory for the region is 1990. The most recent emissions inventory was prepared in 2002. Emissions projections for 2005 are provided in the most recent ROP, submitted to EPA in 2004.

The state and local governments in the nonattainment area have adopted polices and implemented programs to fulfill the requirements of the "The Severe Area SIP". The region has gone beyond the Clean Air Act control measures requirements for areas in severe nonattainment of the 1-hour ozone standard by implementing additional regulations and voluntary programs. These measures involved implementing the Ozone Transport Commission (OTC) model rules (AIMs, Solvent Cleaning Operations, and Portable Fuel Container Rules), and a bundle of voluntary programs including investment in renewable energy technology.

Through these actions, there have been significant reductions in ozone precursor emissions since adoption of the CAAA. Emission trends from the Washington, DC-MD-VA region are summarized in Table 1. Nitrogen oxide (NOx) emissions from the Washington, DC region decreased by approximately 40 percent between 1990 and 2004. During this time, Volatile Organic Compound (VOC) emissions in the Washington, DC region were reduced by more than 65 percent.

Table 2. Emissions of Ozone Precursors in the Nonattainment Area

VOC (tpd)				NOx (tpd)			
1990	**2002**	**2005**	**2004 (Interpolated)**	**1990**	**2002**	**2005**	**2004 (Interpolated)**
955.2	346.9	325.8	332.8	869.3	611.4	487.5	528.8
% Reduction (1990-04) - 65.2 %				**% Reduction (1990-04) - 39.2%**			

Sources: *2002 Periodic Emissions Inventory of Ozone Precursor Emissions for the Washington, DC-MD-VA Ozone Nonattainment Area,* May 2004; and *State Implementation Plan ("Severe Area SIP") for the Washington, DC-MD-VA Ozone Nonattainment Area*, February 19, 2004.

Further emission reductions are expected to occur in 2005. For example, the following programs being implemented and expanded between January 1, 2004 and November 15, 2005 will reduce emissions:

- 2004 Highway Diesel Standards
- Tier II Motor Vehicle Emission Standards
- Reformulated Consumer Products Rule
- Portable Fuel Containers Rule
- AIMs Rule
- Solvent Cleaning Rule
- Graphics arts controls
- Autobody refinishing controls
- Locomotive standards
- Non-road Gasoline Engines Rule
- Voluntary Bundle

Total emission reduction resulting from these measures is expected to exceed 35 tons per day of Volatile Organic Compounds (VOC) and 125 tons per day nitrogen oxides (NOx) compared to the uncontrolled emission levels in 2005.[2]

In addition to the measures listed above, the states in the Washington metropolitan region agreed as part an Ozone Transport Commission agreement, to limit emissions from stationary sources of nitrogen oxides beginning in 2003. In addition to this agreement, a settlement between EPA, the Department of Justice, the Commonwealth of Virginia and the State of Maryland with Mirant will lead to further significant reductions in emissions originating from stationary sources within the nonattainment area. Four power plants in the region will reduce NOx emissions annually through 2010. The agreement will achieve actual NOx reductions in the Washington, DC region, without the use of purchased credits or allowances.

Transport of ozone increases the challenge of meeting air quality requirements in the region. According to studies by the University of Maryland, as much as seventy percent of the ozone levels during an exceedance originate from upwind sources outside of the region.[3]

Emissions from stationary sources that contribute to regional ozone transport can be mitigated through combustion and post-combustion controls. Stationary sources in areas upwind of the region are being controlled through Federal mandates -- the Acid Rain Program and NOx SIP Call. Under the Acid Rain Program, stationary sources must meet emission limits for generating units. EPA's NOx SIP call requires 23 states, including states in the Midwest upwind from the Washington, DC region, to control NOx emissions

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[2] *State Implementation Plan ("Severe Area SIP") Demonstrating Rate of Progress for 2002 and 2005; Revision to 1990 Base Year Emissions; and Severe Area Attainment Demonstration for the Washington, DC-MD-VA Nonattainment Area,* February 19, 2004.

[3] *The 2003 North American electrical blackout: An accidental experiment in atmospheric chemistry*; Marufu, et. al.; Geophysical Research Letters, Vol. 31, 2004.

from stationary sources beginning in 2004. The original implementation date of the NOx SIP Call was 2003, but the date was postponed to 2004 due to litigation.

EPA's analysis predicts that the reductions in NOx emissions from this regulation will enable the Washington, DC-MD-VA nonattainment area to attain the 1-hour ozone standard in 2005.[4] Based on EPA estimates, there are nearly 2,600 units in the NOx SIP call region. Of these, more than 75 coal-fired units have installed selective catalytic reduction (SCR) controls and approximately 20 have installed selective non-catalytic reduction (SNCR) controls.[5] By 2005, more than 50 percent of the coal-fired capacity in Indiana, Kentucky, Ohio, Tennessee, and West Virginia will be controlled with SCR.[6] Power plants in regions upwind of the Washington, DC region will continue to install controls in 2005, leading to further reductions in emissions of nitrogen oxides and reduced ozone transport.

2.2 Impact of Emission Reduction on the Design Value

In response to the significant reductions in emissions of ozone precursors, the design value for the Washington nonattainment area declined by approximately 17 percent between 1990 and 2004. Additional emissions reduction occurring in 2005 should cause the design value to decline further. To reach attainment, the design value must be reduced by approximately 7 percent.

Table 3. Impact of Emission Reduction on the Design Value

Design Value	
1990	**2004**
165	137
% Reduction (1990-04) - 17%	

3.0 Air Quality Indicator Trend Analysis

Various trends will be analyzed to determine if the Washington, DC-MD-VA nonattainment area is likely to reach attainment by 2005. A number of analyses will be conducted including trends in the region's 1-hour ozone design values, monitor exceedances, meteorology, emissions, population, economic activity and individual monitors. Trends will be analyzed from 1985 through 2004. This is the extent of the

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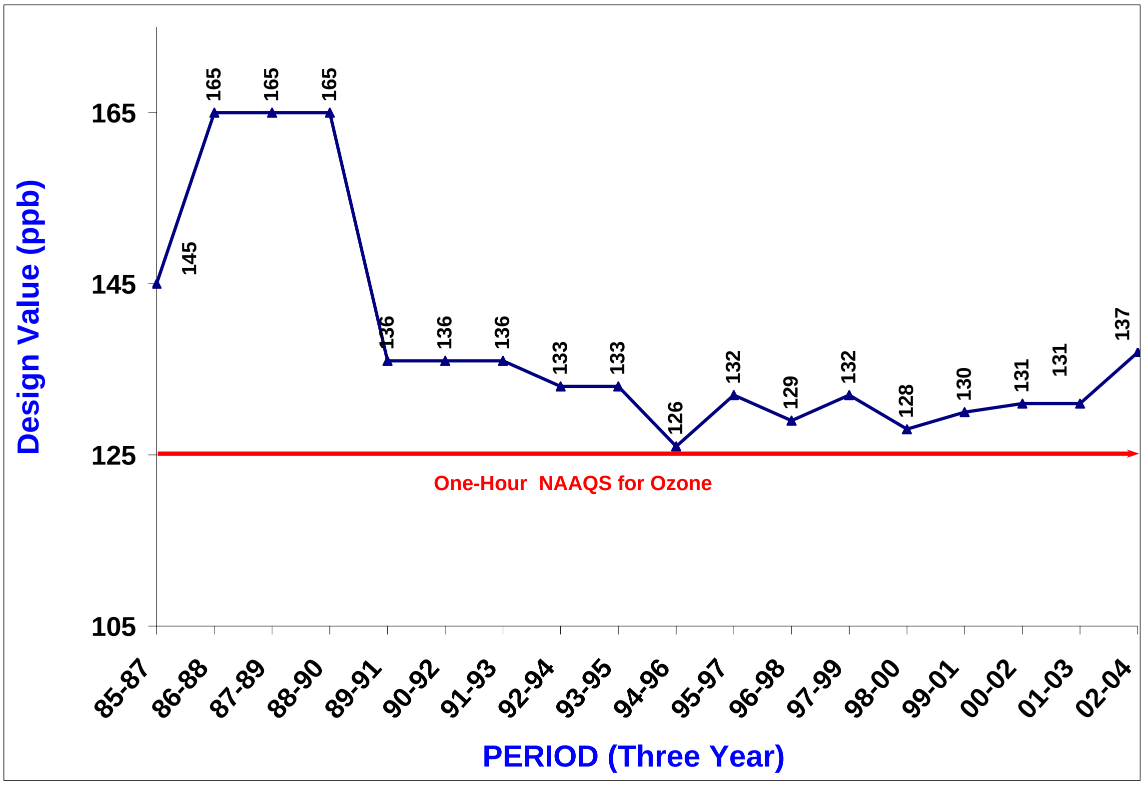
[4] *State Implementation Plan ("Severe Area SIP") Demonstrating Rate of Progress for 2002 and 2005; Revision to 1990 Base Year Emissions; and Severe Area Attainment Demonstration for the Washington, DC-MD-VA Nonattainment Area,* February 19, 2004.
[5] *NOx Budget Trading Program: 2003 Progress and Compliance Report.* United States Environmental Protection Agency, Clean Air Markets Program, Washington, D.C. August 2004.
[6] *The Role of Ozone Transport in the Washington, DC Area*. Presentation by Tad Aburn (Maryland Department of the Environment) and Jeff Stehr (University of Maryland), to the Metropolitan Washington Air Quality Committee. February 19, 2004.

information on EPA's online AIRS database and allows for a comparison of pre 1990 Clean Air Act conditions to post 1990 Clean Air Act conditions.

3.1 One-Hour Design Value Trends

Figure 1 displays the 1-hour ozone design value for the Washington nonattainment area. This is the maximum monitor design value for all monitors within the Washington, DC-MD-VA nonattainment area. Only monitors with 3-years of valid 1-hour ozone concentrations were used.

Figure 1. Washington Nonattainment Area 1-Hour Design Values

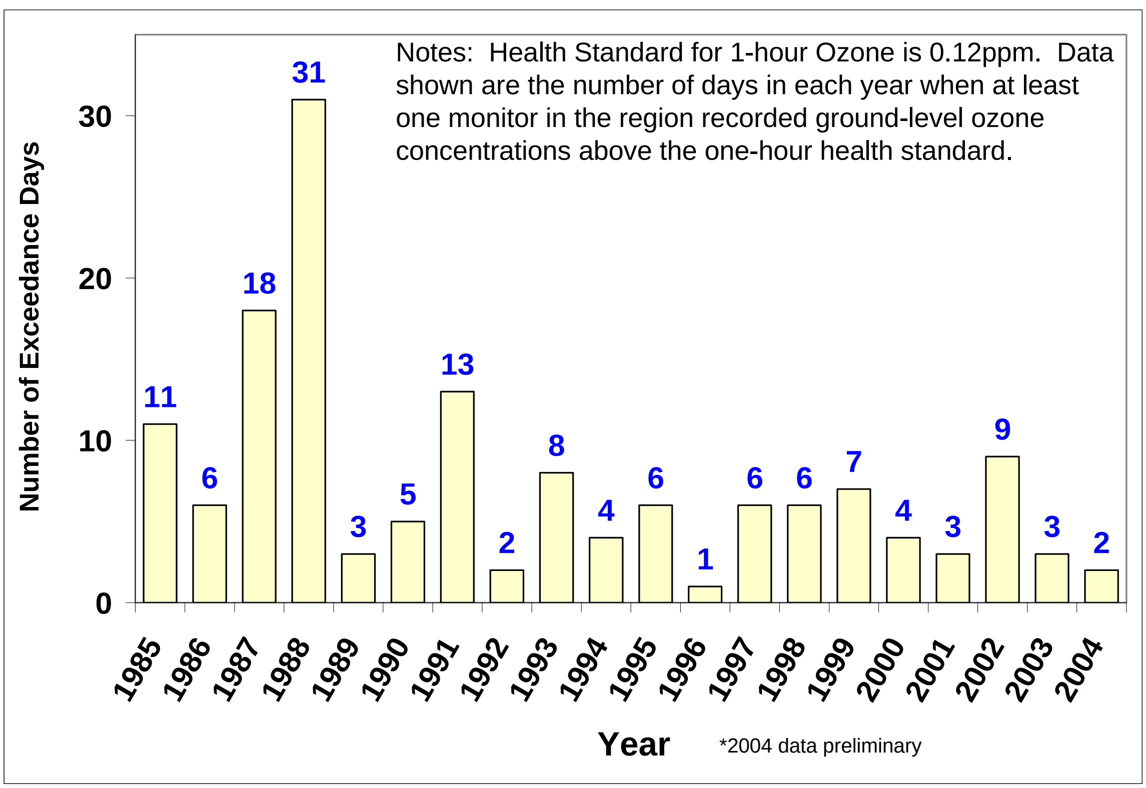


1-hour ozone design values in the Washington nonattainment area have declined since 1990. Average design values from 1991-2004 have declined 17 percent from average design values from 1985-1990 (pre-1990 Clean Air Act).

3.2 Exceedance Count Across All Monitors

Trends in the total number of monitor exceedances between 1985 and 2004 are shown in Figure 2. Monitor exceedances occur whenever a monitor's 1-hour ozone concentration is greater than or equal to 0.12 ppm. There has been a significant decrease in the number of monitored exceedances since 1988. Beginning in 1999, the number of exceedances has been on decline, with the exception of 2002, an outlier year meteorologically. The decrease cannot be attributed to a decline in the number of monitors in the Washington, DC-MD-VA nonattainment area since the number of ozone monitors has actually increased slightly from 13 monitors in 1985 to 17 monitors in 2004.

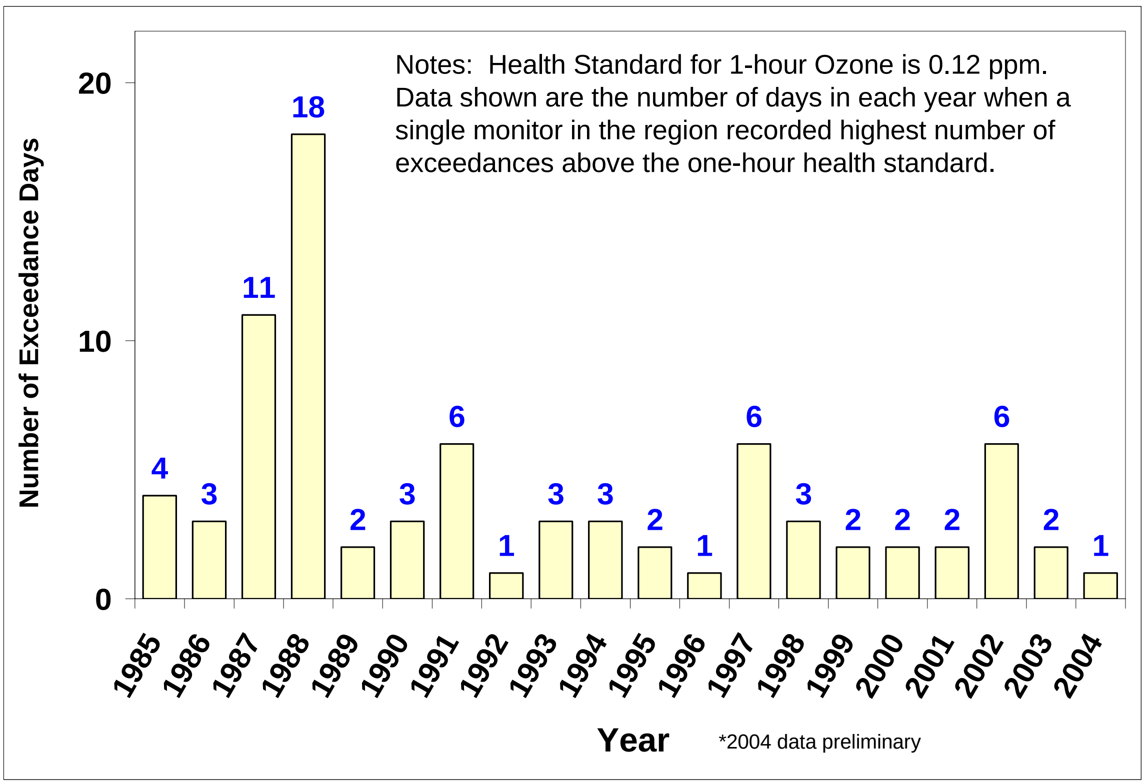
Figure 2. Monitored Exceedances Across All Monitors in Washington 1-Hour Nonattainment Area



3.3 Exceedance Count at the Monitor with Most Exceedances

Trends in the total number of exceedances at the monitor recording highest number of exceedances between 1985 and 2004 are shown in Figure 3. There has been a significant decrease in the number of monitored exceedances since 1988. Except for the year 2002, which was meteorologically an outlier year, number of exceedances has been steady at 2 during the period 1999 through 2003 and went down to 1 in 2004.

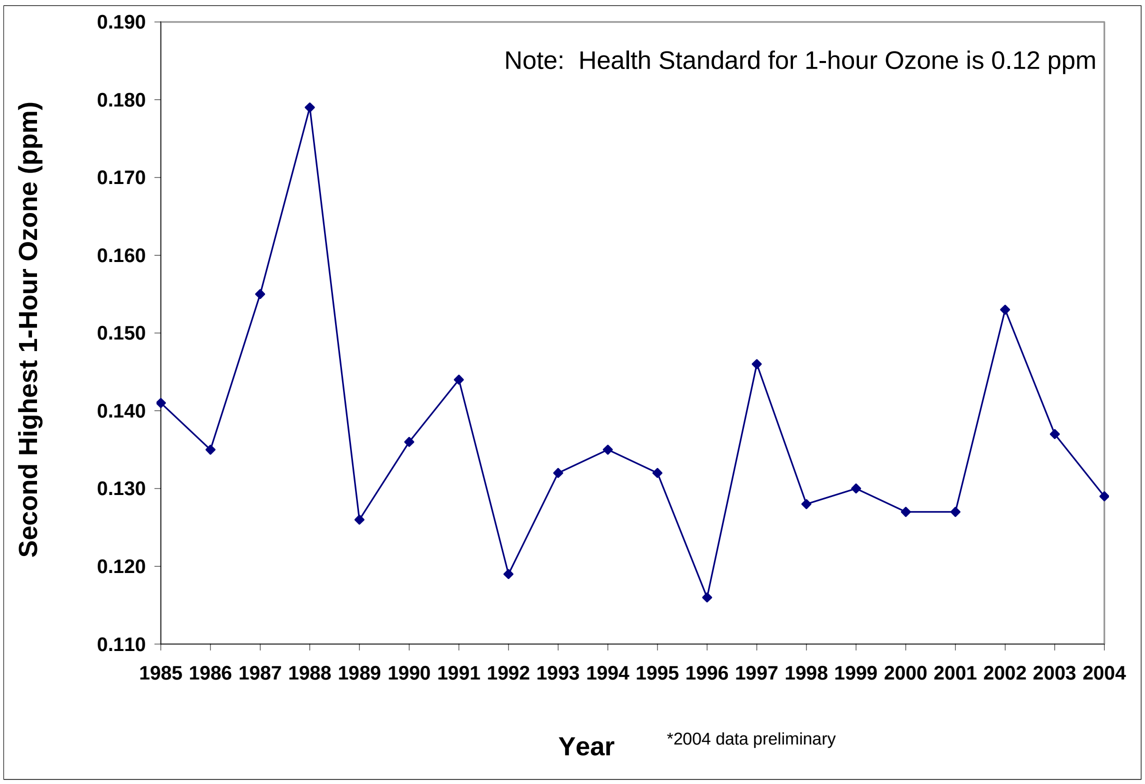
Figure 3. Monitored Exceedances at the Monitor with Most Exceedances in Washington 1-Hour Nonattainment Area



3.4 Highest 2nd High Daily Maximum Ozone Concentration

Trends in the highest 2nd high daily maximum ozone concentration between 1985 and 2004 are shown in Figure 4. There has been a significant decrease in the number of monitored exceedances since 1988. Beginning 1999, the highest 2nd high daily maximum ozone concentration has overall observed a declining trend except for 2002, which was meteorologically an outlier year.

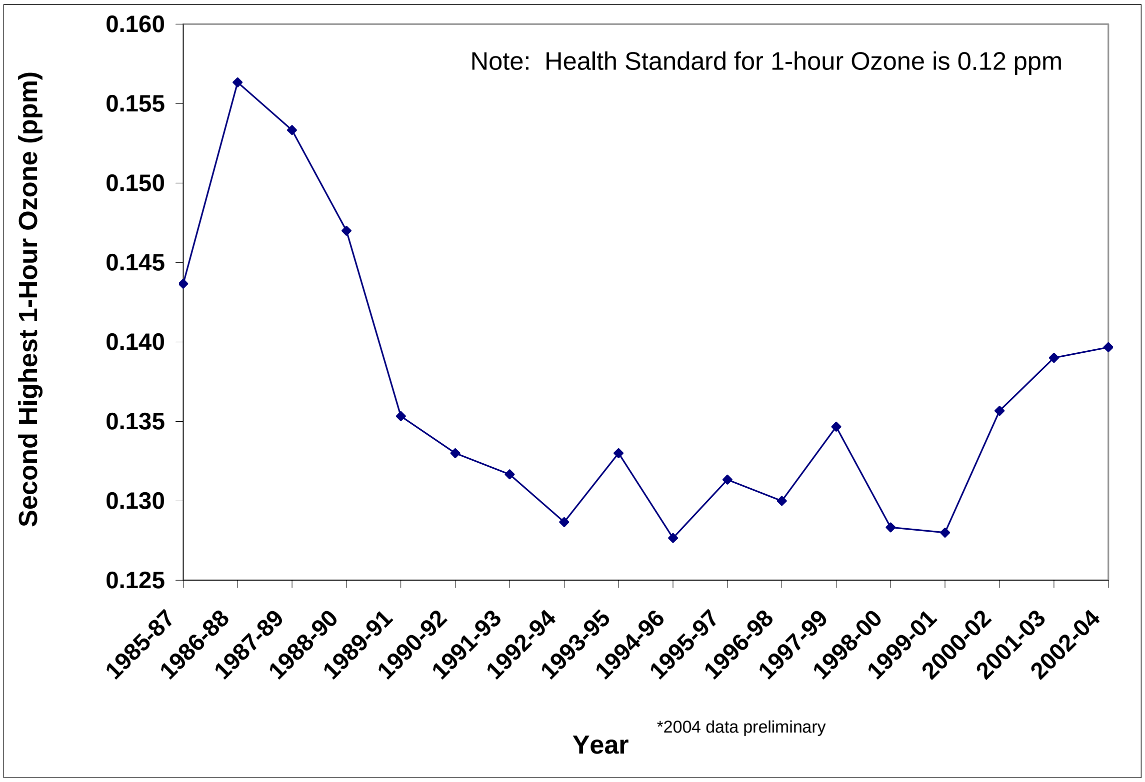
Figure 4. Highest 2nd High Daily Maximum Ozone Concentration in Washington 1-Hour Nonattainment Area



3.5 Highest Running Average 2nd High Daily Maximum Ozone Concentration

Trends in the highest running average 2nd high daily maximum ozone concentration between 1985 and 2004 are shown in Figure 5. There has been a significant decrease in the number of monitored exceedances since 1988. Beginning 1999, the highest 2nd high daily maximum ozone concentration has overall observed a declining trend except for 2002, which was meteorologically an outlier year.

Figure 5. Highest Running Average 2nd High Daily Maximum Ozone Concentration in Washington 1-Hour Nonattainment Area



3.6 Effect of Meteorology on Ozone Trends

Ozone concentrations are quite dependent on meteorological conditions. Ozone is formed by a chemical reaction between Volatile Organic Compounds (VOCs) and Oxides of Nitrogen (NOx). Clear skies and warm temperatures are generally needed to drive ozone production. Correlations can be made between ozone concentrations and metrological variables such the number of 90ºF days, average temperature, and average winds during crucial hours. Hot dry summers can produce long periods of elevated ozone concentrations while ozone production can be limited during cool and wet summers.

Meteorological data from the Reagan National Airport was reviewed to determine any trends between 1-hour ozone values and summertime weather conditions. There were strong correlations found between number of 1-hour exceedance days and warm days (> 90º F), average max. 1-hour ozone and average max temperature, and 1-hour exceedance days and average max temperature.

There have been two unusually warm summers in 1988 and 2002. Table 3 lists meteorological data for all years from 1987 through 2003 along with the average 1-hour maximum ozone concentration and the number of exceedance days within the Washington, DC-MD-VA nonattainment area.

Table 4. Comparison of Warm Summers
Reagan National Airport 1987-2003

Year	Avg 1-Hour Max Ozone	1-Hour Exceedance Days	Avg Max Temperature	Avg Wind (2 pm)	90ºF Days
1987	142	20	89	4.3	13
1988	146	28	94.5	5.11	25
1989	134	3	90	5.33	2
1990	135	5	88.4	4.2	2
1991	137	9	92.8	6.11	7
1992	128	2	86.5	6.5	0
1993	134.5	10	94.4	4.7	9
1994	133.6	8	91.5	4.75	6
1995	137.9	7	91.7	4.33	7
1996	125	1	90	0	1
1997	139.7	7	93.5	5.5	5
1998	130.7	7	89.6	5.59	23
1999	132.5	7	91.2	6.05	23
2000	135.5	2	89.5	4.91	7
2001	130.3	3	88.4	3.95	8
2002	137.6	10	91.1	5.73	27
2003	135	3	89.4	6.57	3

Since a very good relationship was found between meteorological variables and the 1-hour maximum ozone trend, two different types of statistical techniques were used to remove the effect of meteorology from the 1-hour maximum ozone trend. The first technique used is the simple trend line drawn across the 1-hour maximum ozone trend line which is basically a power-type regression line. Figure 6 shows the trend in 1-hour ozone levels when adjusted for meteorology using this simple technique. The best-fit curve shows that there has been a steady decline in meteorologically adjusted 1-hour ozone levels during 1995-2004. Figure 7 shows trend in meteorologically adjusted 1-hour ozone design value using power-type regression trend line. The best-fit curve shows that there has been a steady decline in 1-hour ozone design value from 1995 to 2004.

The second statistical technique used here to adjust the 1-hour maximum ozone trend for meteorology is an advanced statistical technique called KZ filter. Figure 8 shows the 1-hour maximum ozone trend free from the effect of temperature. This technique has been described fully by Zurbenko, I.G.[7]

Daily maximum temperature and 1-hour maximum ozone concentration data used in this analysis were acquired from the National Weather Service station at the Reagan National Airport and EPA, respectively.

The temporal variations of ozone measurements were analyzed using moving average filters and a linear least squared regression model to reduce the influence of both short-term variation and meteorological fluctuation in the ozone trends. The moving average filters, also called KZ filters were used to remove the high-frequency (short-term) variations from the ozone and temperature time series. The KZ filters are based on the premise that ozone and temperature time series can be expressed as:

$$X(t) = W(t) + S(t) + e(t)$$

where $X(t)$ is the original time series, $W(t)$ is the short-term variation, $S(t)$ is the seasonal variation, $e(t)$ is the long-term trend, and t is time.

Two specific filters were used in this study. One was the KZ (15,5) filter, with a window length of 15 days and 5 iterations, used to remove the components with periods less than about 33 days. The other was the KZ (183,3) filter, with a window length of one "ozone year" (from April 1 to September 30), which is capable of removing all components with periods less than about 500 days (or two "ozone years"). Using these two filters, the time series of ozone concentrations were separated into (1) a short-term component representing the influence of fluctuating synoptic meteorological conditions and random processes, (2) a seasonal component representing the influence of earth's rotation around the sun, and (3) a long-term component representing the influence of changes in emissions and climate.

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[7] *Spectral Analysis of Non-Stationary Time Series,* Zurbenko, I. G.; Int. Stat. Rev., 1991, Vol. 59, pp. 163.

After the short variations in daily maximum ozone were removed by filter KZ (15,5), the ozone baseline had both seasonal and meteorological effects. A linear least-squared regression model then was used to remove the meteorological effect from the ozone baseline. In this study, the influence of meteorology on ambient ozone was moderated using surface temperature as a surrogate for all meteorological conditions that affect ozone.[8] The filtered ozone baseline can be expressed as

$$\mathrm{KZ}(15,5)\ \mathrm{ozone}(t) = \alpha + \beta \mathrm{KZ}(15,5) T(t+\Delta t) + \varepsilon(t)$$

where KZ(15,5) ozone(t) are filtered ozone concentrations, KZ(15,5)$T(t+\Delta t)$ are filtered corresponding surface temperatures, α and β are regression coefficients, Δt is the lag time between the ozone and temperature annual cycles that maximize the regression determination R^2, $\alpha + \beta$KZ(15,5)$T(t+\Delta t)$ represents the seasonal and long-term variation explained by the temperature, and $\varepsilon(t)$ is the residuals of the regression, consisting of the seasonal and long-term variations unexplained by the temperature. Finally, by applying the filter KZ (183,3) on the residuals, $\varepsilon(t)$, to remove the seasonal component, the long-term trend in remaining residuals can be attributed to changes in emissions caused by regulatory actions.

The regression analysis was performed using data from the Arlington, VA monitor for the period of 1994–2004 to evaluate the 1-hour maximum ozone trend during this period. Figure 8 shows the ozone trend after the effect of temperature has been removed. The residual trend can be regarded as the ozone trend caused by changes in emissions. The magnitude of both the increase and the decrease is about 0.2 in log scale, which is about 1.6 ppbv in ozone concentration. This is in agreement with studies performed by other researchers for the mid-Atlantic region such as Yang & Miller.[9] The trend increased between 1996 and 1998 and again slightly between 2001 and 2002, and decreased during 1998–2001 and 2002-2004. Overall it appears that after 1998 ozone levels have been declining.

However, there are other factors such as short and long-distance transport that have not been accounted for in this trends analysis. Since it is not possible to quantify and remove the effect of transport from the ozone trend analysis, transport may be affecting the long-term ozone trend.

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[9] Trends and Variability of Ground-Level ozone in Connecticut over the Period 1981–1997; Yang & Miller; Vol. 52, Dec. 2002, pp. 1354.

Figure 6. Meteorology Adjusted 1-Hour Maximum Ozone Concentration in theWashington, DC-MD-VA Nonattainment Area

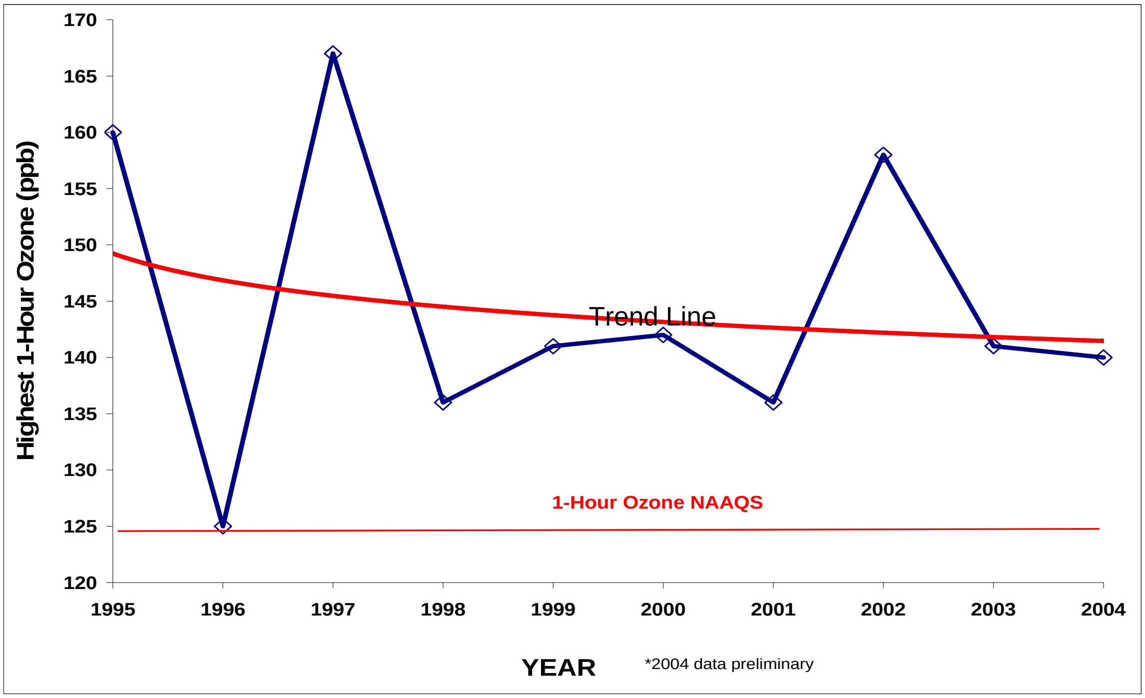


Figure 7. Meteorology Adjusted 1-Hour Design Value in the Washington, DC-MD-VA Nonattainment Area

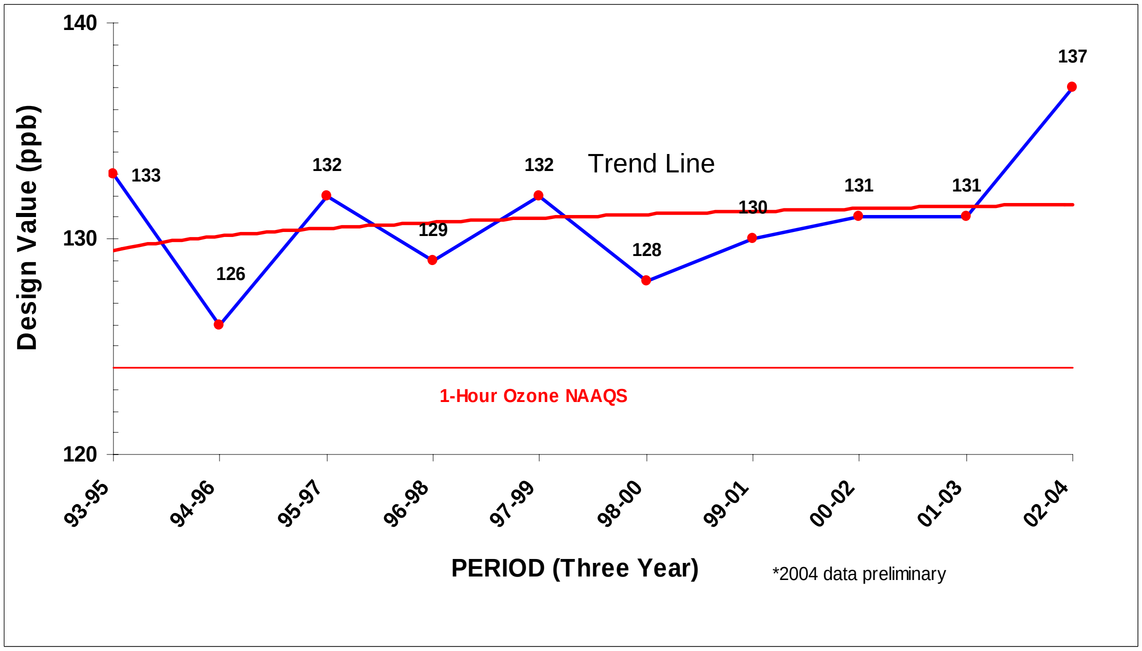
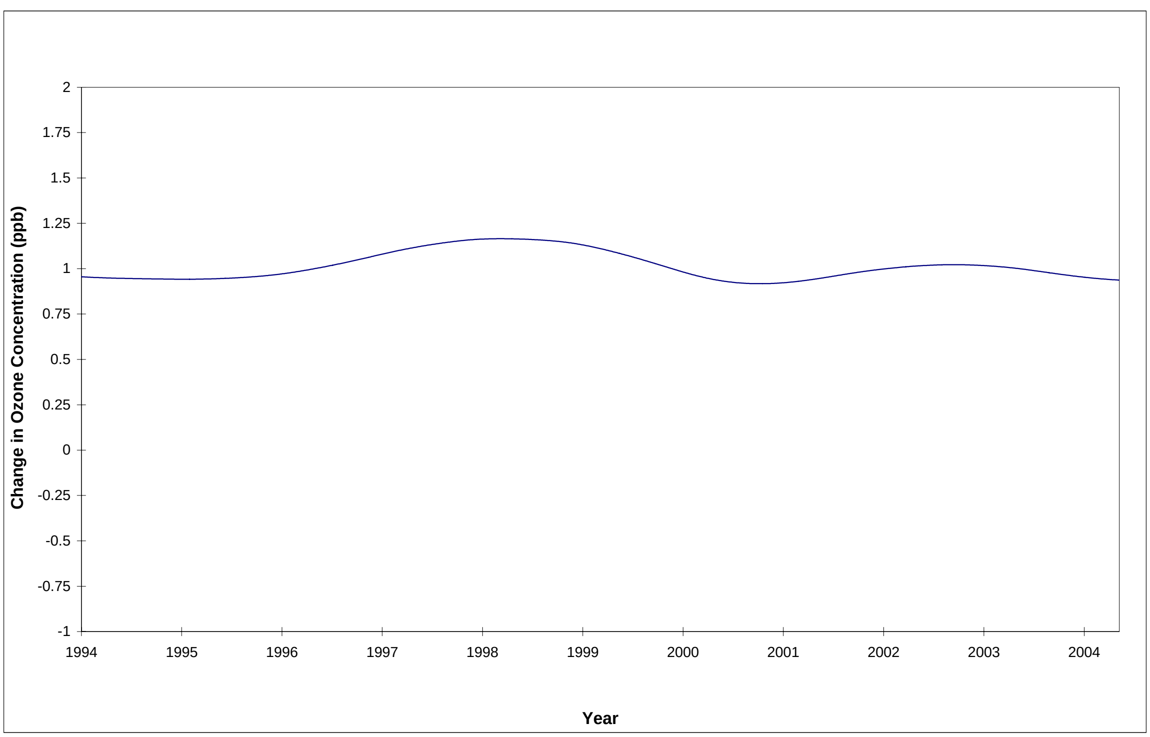


Figure 8. Meteorology Adjusted 1-Hour Maximum Ozone Trend at the Arlington Monitor



3.7 Spatial Extent of Exceedances

Washington, DC-MD-VA nonattainment geographical area has been decreasing since 1987. Figure 9 through Figure 11 show a decrease in the spatial extent of the nonattainment zone within the Washington, DC-MD-VA nonattainment region. The actual nonattainment geographical area exceeding 1-hour ozone design value of 124 ppbv has been shown in red color in these figures. Figure 9 shows the nonattainment geographical area during 1985-1987. It is clear that more than half of the Washington metropolitan region was in nonattainment during this period. The extent of the area involved in nonattainment decreased substantially during 1991-93 (Figure 10). The 2002-2004 data (Figure 11) show the area has reduced further in size to small parts in the District of Columbia, Arlington, VA, and Prince George's counties.

Figure 9. Washington 1-Hour Ozone Nonattainment Zone
1-Hour Design Value (1985-1987)

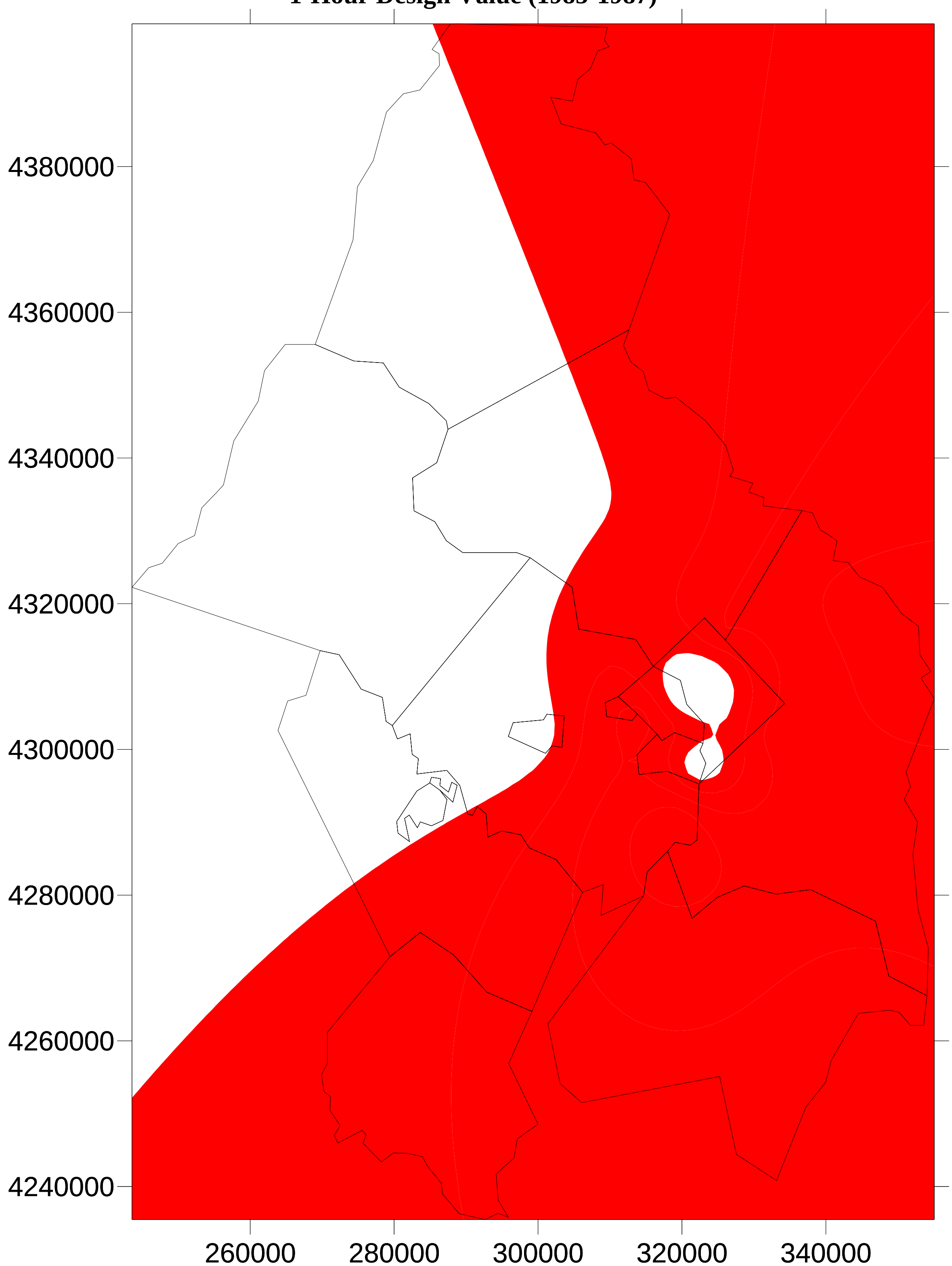


Figure 10. Washington 1-Hour Ozone Nonattainment Zone
1-Hour Design Value (1991-1993)

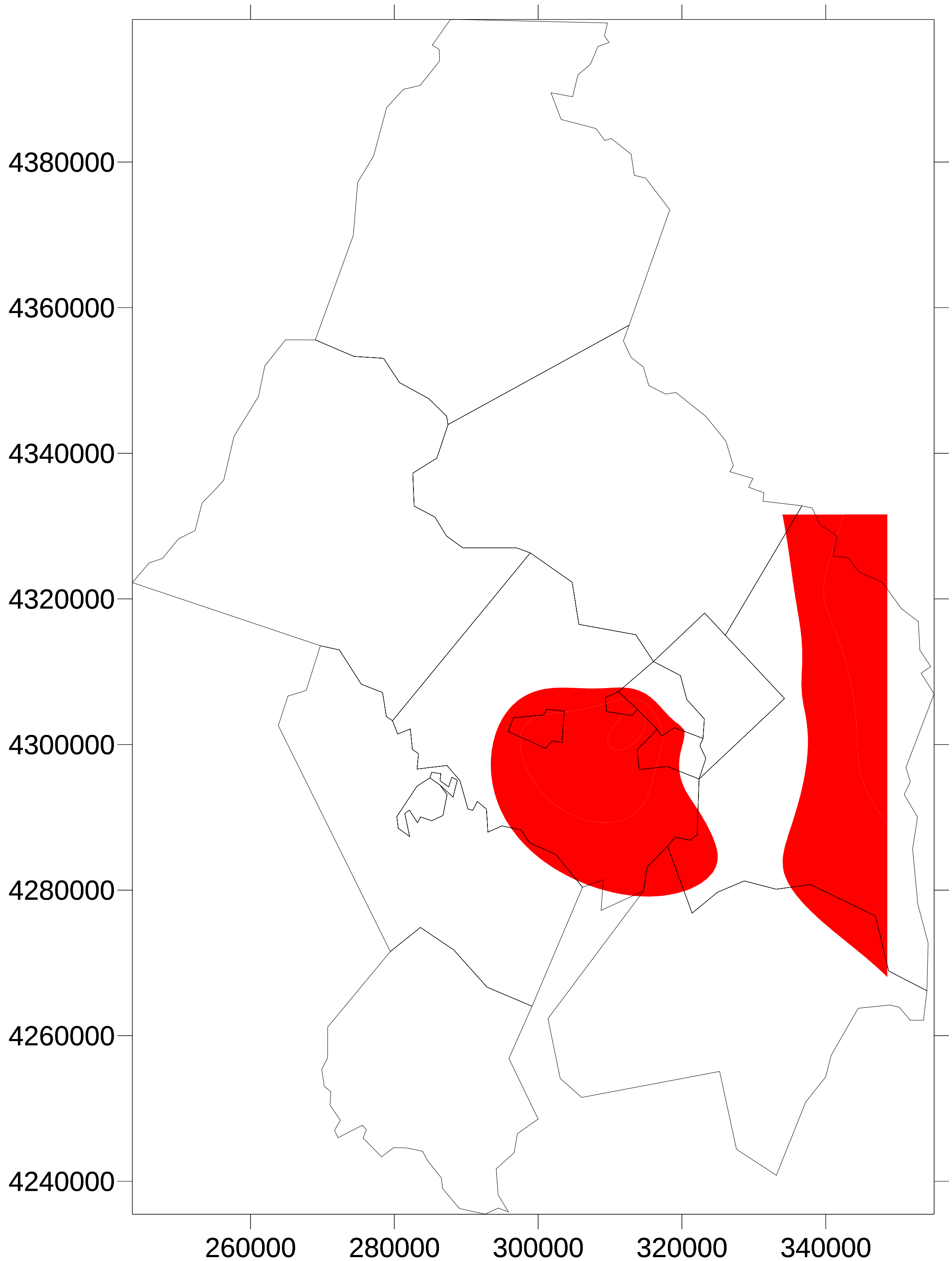
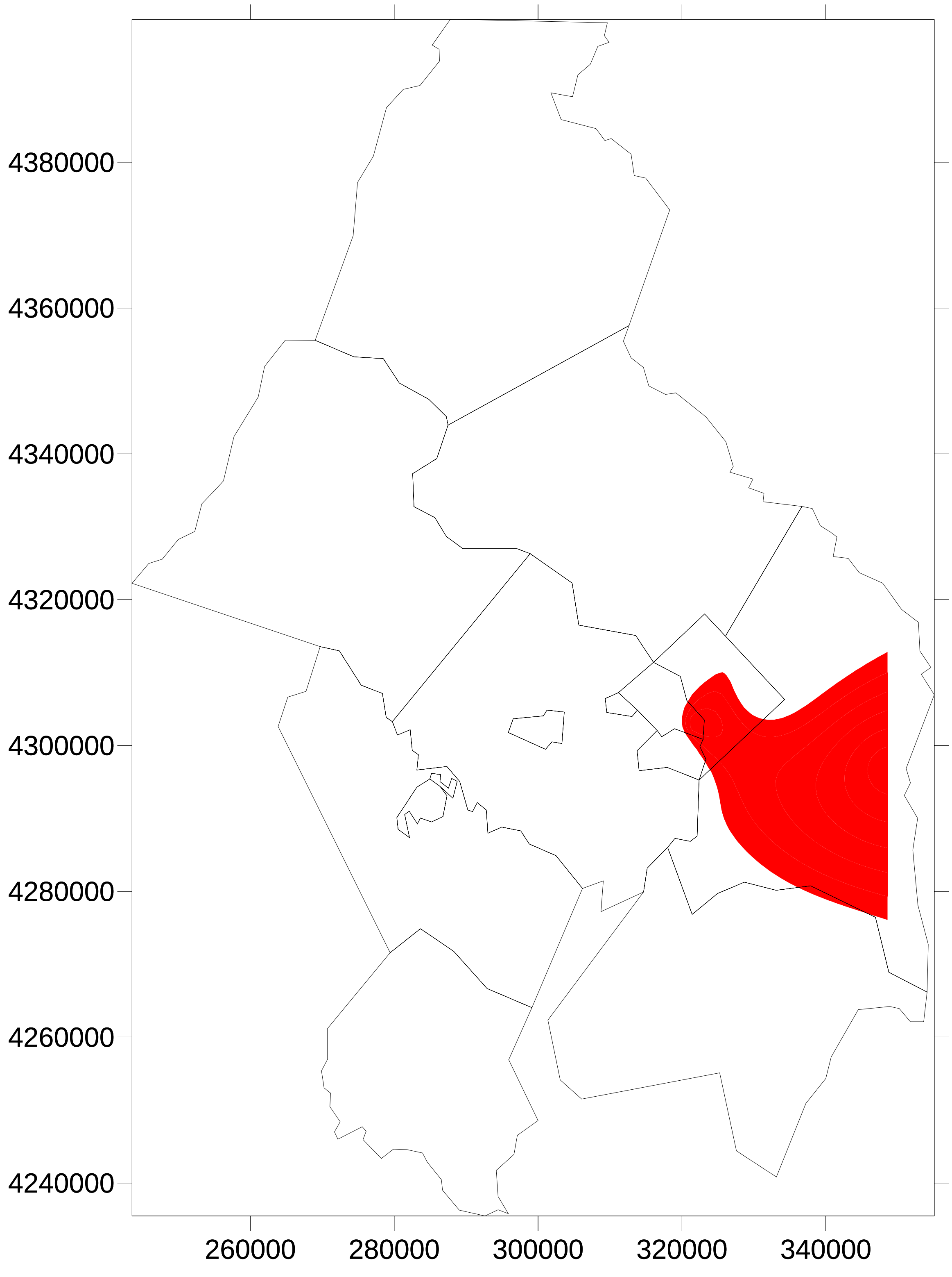


**Figure 11. Washington 1-Hour Ozone Nonattainment Zone
1-Hour Design Value (2002-2004)**



4.0 Ozone Transport Analysis

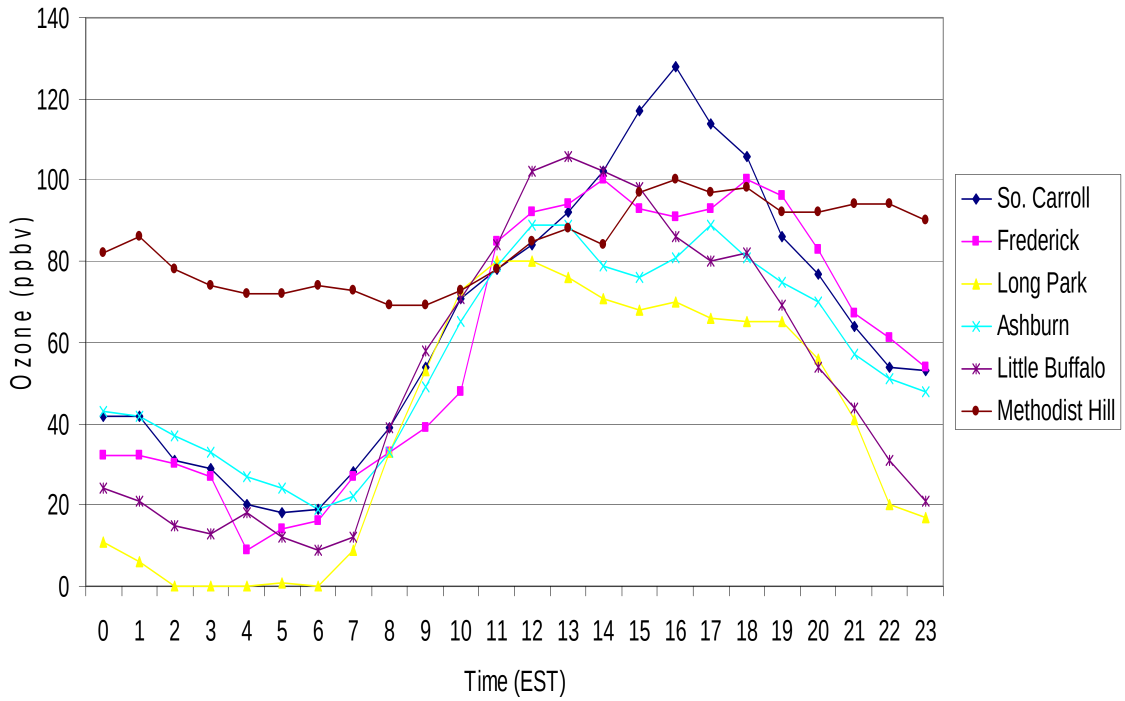
Ozone transport has a significant effect on ozone concentrations within the Washington, DC-MD-VA nonattainment area. Ozone transport is highly variable and gauging the effects on design values, exceedances and peak concentrations is quite difficult because it would necessitate an analysis of large amounts of data, some of which may no longer be easily accessible. A qualitative assessment will be made on large-scale regional transport, short-term local transport, and transport via low-level jets into the Washington, DC-MD-VA nonattainment area.

4.1 Regional Ozone Transport Assessment

Large-scale regional transport occurs when ozone concentrates within the lower boundary layer over a wide area, several hundred square miles. These regional-scale ozone plumes become embedded within the large-scale atmospheric flow affecting areas well away from their source regions. These regional plumes are often observed at ozone monitors located in elevated terrain. Ozone from these regional plumes can drift over regions then mix down to the surface affecting monitors over a large area.

Pennsylvania has operated an elevated ozone monitor at Methodist Hill on South Mountain (~1900 ft) since the mid 1990s. The effects of these regional ozone plumes on regional ozone concentrations have been observed on several occasions. Figure 12 demonstrates what happens when these regional plumes enter southcentral Pennsylvania. Ozone concentrations at the elevated monitor, Methodist Hill, remain high during the overnight hours. Ozone concentrations at the low-level monitors remain low until the morning temperature inversion is "burned" off. Atmospheric mixing taps the regional pool of ozone and ozone concentrations rise rapidly to match those of the elevated monitor.

Figure 12. Effect of Urban Ozone Plumes (July 1999 Episode)



Source: *The Role of Ozone Transport in the Washington, DC Area*. Presentation by Tad Aburn (Maryland Department of the Environment) and Jeff Stehr (University of Maryland), to the Metropolitan Washington Air Quality Committee. February 19, 2004.

The Washington, DC region has a number of monitoring sites with historical data to gauge the effects of long-range ozone transport. Ozone data from Shenandoah National Park monitor was used to gauge regional ozone transport. This particular monitor has a continuous ozone record between 1987 and 2004. The monitor is isolated in a National Park surrounded by rural areas between West Virginia and Virginia.

Changes in design values, peak values and 4th-high values were examined over the 1987 and 2004 time period. Again the analysis was divided into periods before and after the 1990 Clean Air Act. The results of this analysis as well as the average values for the Washington, DC region are posted in Table 4.

Table 5. Regional Transport Analysis using Shenandoah National Park

1-Hour Design Values
Shenandoah National Park vs. Washington 1-Hour Nonattainment Area

Monitor	2004 Design Value (ppm)	Average 1989-1990 DV (ppm)	Average 1991-2004 DV (ppm)	% Change
Shenandoah National Park	0.102	0.107	0.103	**-3.7%**
Washington	0.137	0.165	0.132	**-20%**

Peak & 4th High One-Hour Ozone Concentrations
Shenandoah National Park vs. Washington Area

	Peak Value (ppm)			**4th High (ppm)**		
Monitor	**Yearly AVG 1987-1990**	**Yearly AVG 1991-2004**	**% Change**	**Yearly AVG 1987-1990**	**Yearly AVG 1991-2004**	**% Change**
Shenandoah National Park	0.112	0.105	-6.25%	0.095	0.093	**-2.1%**
Washington	0.164	0.147	-10.4%	0.130	0.118	**-9.2%**

The data from Shenandoah National Park suggests a small reduction in regional ozone concentrations transported into the Washington, DC-MD-VA nonattainment area. This suggests the Clean Air Act reductions in regions upwind of Washington have done little to reduce large-scale regional ozone transport.

A recent study by Marufu et. al. provides a evidence of regional ozone transport into Washington, DC region.[10] This paper discusses the August 2003 North American electrical blackout, which provided a unique opportunity to quantify directly the contribution of power plants located in northeast US and southeastern Canada to ozone levels in Pennsylvania and Washington, DC regions. Ozone level decreased by ~38 ppbv in response to about 34 percent & 20 percent reductions in SO_2 and NO_X emissions from power plants during that period. While ozone levels were forecasted to be 125 ppbv on that day, they actually reached only 90 ppbv. Since the forecast error was only 10 ppbv, the bulk of this overestimation was attributed to reduced emissions from power plants.

[10] *The 2003 North American electrical blackout: An accidental experiment in atmospheric chemistry*, Marufu, et. al.; Geophysical Research Letters, Vol. 31, 2004.

The improvement in air quality provides evidence that transported emissions from power plants hundreds of kilometers upwind play an important role in ozone production.

4.2 Short Term Local Ozone Transport Assessment

Ozone transport within the lower boundary layer into the Washington, DC-MD-VA nonattainment area is another important process. Unlike regional transport, local transport occurs over shorter distances and affects a smaller area. This process includes the low-level ozone plumes that emanate from the large metropolitan areas in the northeast. Ozone plumes from Central Virginia have been observed migrating downwind towards Washington, DC region and further to Baltimore.[11] These plumes typically "dissipate" shortly after sunset as fresh NOx emissions react with ozone within these plumes. The "dissipated" ozone plume will reform downwind the next day when the solar-driven photochemistry resumes.

Ozone plumes can affect design values immediately downwind of the large metropolitan areas in the northeast. This explains why design values in Prince George's and Anne Arundel counties are at times higher than other monitors inside the Washington, DC-MD-VA nonattainment area.

4.3 Ozone Transport via Low-Level Jets

Ozone transport via low-level jets is a relatively recent discovery. Low-level jets are nocturnal phenomena that have the potential for moving large pools of ozone in the lower boundary layer. Low-level jets are similar to large-scale regional transport with ozone moving above the surface then mixing down to the surface shortly after sunrise. The vertical wind profiler at Fort Meade has observed low-level jets during the summer (see Figures 13&14).[12] Low-level jets form shortly after sunset when large-scale synoptic features are weak. Winds within these jets typically come from the south and may shift to the southwest towards daybreak. Wind speeds in the core of these jets can reach up to 15 m/s or nearly 35 mph. These jets have the potential of moving ozone laden air several hundred miles during the overnight hours. The nature of low-level jets makes it difficult to quantify their contribution to ozone transport into the Washington, DC-MD-VA nonattainment area. However, according to an estimate these jets can routinely carry about 80 to 90 ppbv ozone.

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[11] *The Role of Ozone Transport in the Washington, DC Area*. Presentation by Tad Aburn and Jeff Stehr, Maryland Department of the Environment, to the Metropolitan Washington Air Quality Committee. February 18, 2004.

[12] Ibid.

Figure 13. Low Level Jet Recorded above Fort Meade, Maryland

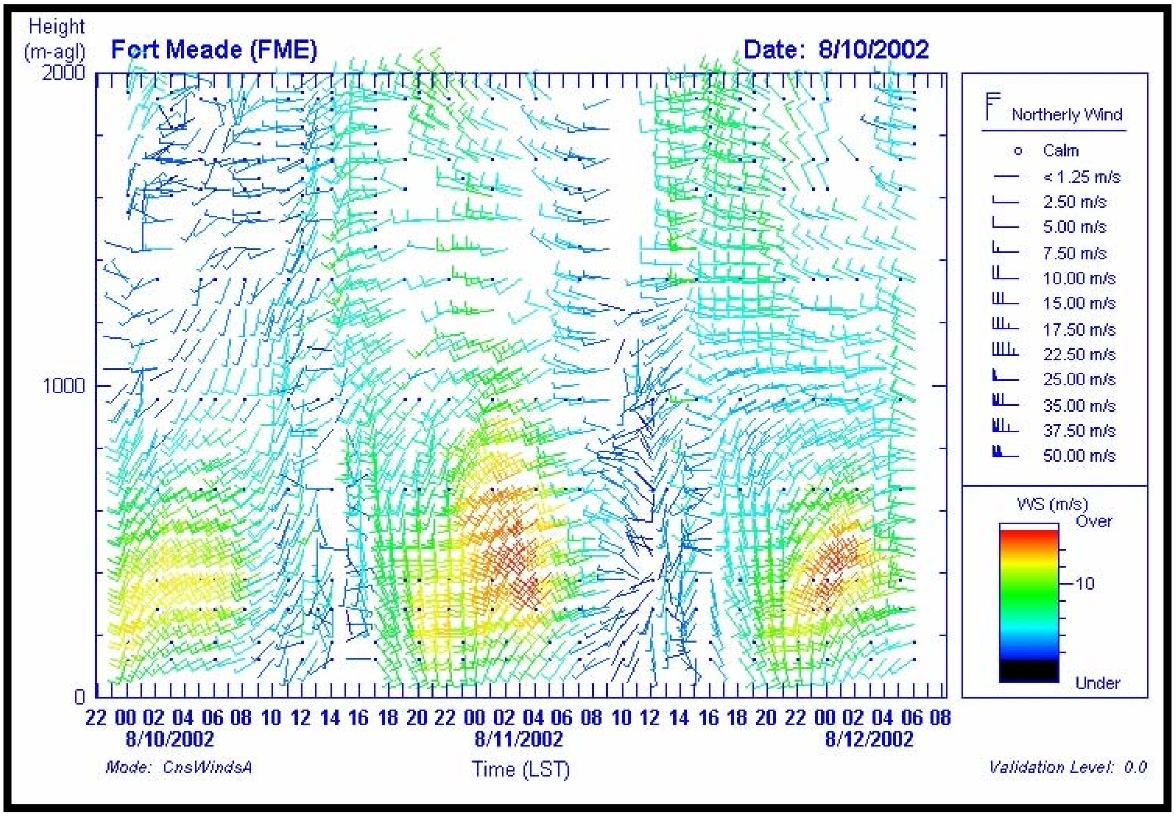
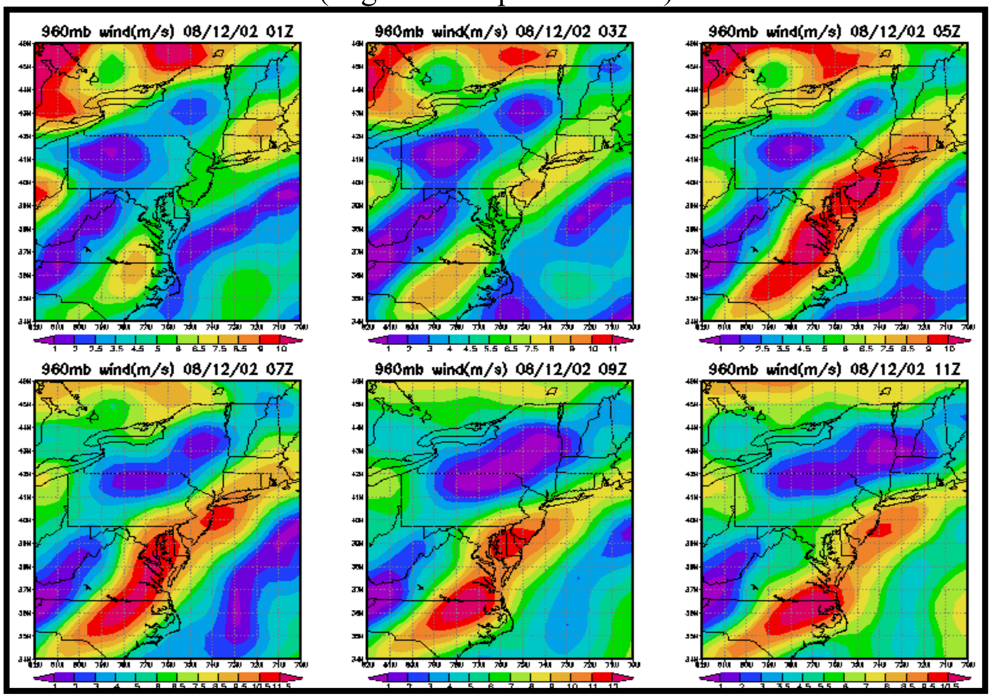


Figure 14. Model Depiction of the Low Level Jet

(High Wind Speeds in Red)



5.0 Summary and Conclusion

5.1 Emissions and Controls

There have been significant reductions in ozone precursor emissions in the Washington, DC-MD-VA nonattainment area since adoption of the Clean Air Act. Nitrogen oxide emissions from the Washington, DC region decreased by approximately 40 percent between 1990 and 2004. During this time, Volatile Organic Compound (VOC) emissions in the Washington, DC region have been reduced by more than 65 percent (see Table 2). Further emission reductions occurring in 2005 are expected to exceed 35 tons per day of Volatile Organic Compounds (VOC) and 125 tons per day nitrogen oxides (NOx) compared to the uncontrolled emission levels in 2005.[13] These emission reductions result from implementation of the region's "Severe Area SIP".

The Metropolitan Washington, DC-MD-VA region's air quality is significantly affected by ozone and its precursors from other regions outside the Washington, DC area. States upwind of the Washington, DC region began to increase control of NOx emissions from stationary sources in 2004 as a result of EPA's NOx SIP call. Additional controls are being installed in 2005. EPA's analysis predicts that the reductions in NOx emissions from this regulation will enable the Washington, DC-MD-VA nonattainment area to attain the 1-hour ozone standard in 2005. [14]

5.2 Air Quality Trend

Actions taken by governments in the Washington, DC-MD-VA nonattainment area to reduce emissions of NOx and VOCs have resulted in improvements in air quality in the region.

Design values and monitor exceedances are decreasing over time even when weather conditions are favorable for ozone formation (hot and dry summers). The current 1-hour design value for the region is 137 ppb at the Arlington, VA monitor. This represents a 17 percent decrease in the design value since implementation of programs mandated by the Clean Air Act in 1990.

For comparison purposes, the design value for the area during 1988-1990 was as high as 165 ppb compared to 137 ppb during 2002-2004. There were more than 30 total exceedance days in 1988 compared to only 9 in 2002, a year with meteorological conditions similar to 1988. In 2004, there were only 2 exceedances. The monitor with the most exceedances in 1988 registered 18 exceedance days as compared to 6 and only 1 in 2002 and 2004 respectively. During 1988-1990, 12 out of total 13 (92%) monitors in

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[13] *State Implementation Plan ("Severe Area SIP") Demonstrating Rate of Progress for 2002 and 2005; Revision to 1990 Base Year Emissions; and Severe Area Attainment Demonstration for the Washington, DC-MD-VA Nonattainment Area,* February 19, 2004.
[14] Ibid.

Washington nonattainment area exceeded the 1-hour ozone standard, while only 5 out of 17 (30%) total monitors exceeded this standard in 2004.

Improvements in air quality in this region becomes even more visible when the effect of meteorology, especially temperature is removed from the 1-hour ozone trend. Using both power type regression analysis and the advanced KZ filter techniques, it is clear that 1-hour ozone level is on decline in this region. This declining trend will be even more visible if the ozone transport factors (regional, local, and low level jets) are removed.

Another evidence of improvement in air quality is seen by looking at the decrease in the actual 1-hour ozone nonattainment geographical area over the years. It is clearly visible that there is a steady decline in the actual geographical area not in attainment within the larger Washington nonattainment area.

5.3 Conclusion

Progress toward meeting the 1-hour ozone NAAQS can be seen by looking at the 1-hour ozone trend with and without normalized for meteorology.

Decrease in the actual 1-hour ozone nonattainment geographical area over the years also is a good indicator of this progress.

There has been a significant decline in the design value since 1988-90. The Washington, DC-MD-VA 1-hour ozone nonattainment area is expected to be compliant with the 1-hour ozone standard by the 2005 attainment date. This was proven by calculating the design value for the attainment year (2005). This value was found to be 115 ppb, which is below 125 ppb (1-hour NAAQS). Methodology for this calculation has been described in detail in the Section 11.13.1 in pages 11-43 through 11-47 in the "Severe Area SIP, February 19, 2004" submitted to EPA.

While programs to reduce emissions have resulted in significant improvement in the region's air quality since 1988-90, transport has continued to significantly limit progress towards attainment of the 1-hour ozone standard. This has been demonstrated by a number of scientific studies evaluating the impact of transported ozone on local ozone concentrations. EPA modeling efforts have concluded that implementation of regional control programs to address transported ozone will help the region reach attainment of the 1-hour ozone standard in 2005.

Appendix 1: Washington Nonattainment Area Ozone Monitors