Trends

Trends

1999 Average Best and Average Worst Visibility Impairment in the Phoenix Area

Introduction

Whether air quality meets the standards is an important question, but a more frequently asked question is whether the air quality is improving or deteriorating. Because of the phasing out of leaded gasoline in the mid-1970s and the installation of effective controls on copper smelters in the 1980s, the concentrations of both lead and sulfur dioxide in Arizona decreased rapidly. Although improvements have also been made in the concentrations of carbon monoxide, ozone and particulates, the last two still exceed air quality standards at some sites. The eight-hour ozone standard is exceeded at several sites in greater Phoenix and the 24-hour and annual PM_{10} standards are exceeded at a few rural sites. Visibility – the aspect of the urban atmosphere that is most obvious to the population – is measured continuously in Tucson and Phoenix. This discussion examines the trends in these three common air pollutants and urban visibility trends in Arizona.

Carbon Monoxide

Since the mid to late 1970s, carbon monoxide concentrations have declined by as much as two-thirds. In Tucson, the maximum annual eight-hour concentration of carbon monoxide at 22nd Street and Alvernon declined from 12 to 4 parts per million (ppm). In Phoenix at 18th Street and Roosevelt (Central Phoenix), the decline was from 23.0 to 7.1 ppm (Figures 2 and 3). The number of exceedances of the eight-hour standard – 9 ppm – in Phoenix decreased from 75 to 0 at Central Phoenix. The entire Phoenix network of carbon monoxide monitors

recorded more than 100 exceedances each year from 1981 through 1986, with an average of 134 per year. No exceedances were recorded by this network in 1997 and 1998 and a single exceedance was recorded in 1999. Most of this improvement can be attributed to federal standards for new-vehicle emission, augmented by emission reductions from the Vehicle Emissions Inspection Program, which began in 1976, and the use of oxygenated fuels in the winter, which began in 1989.

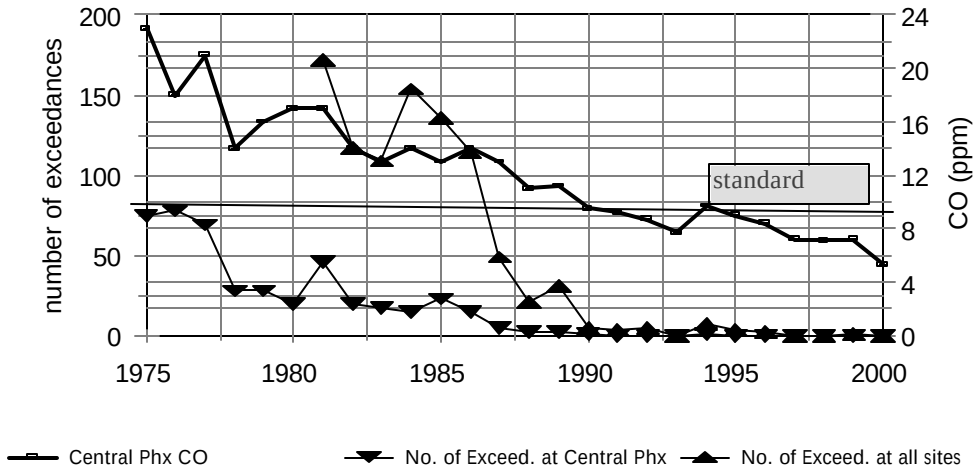

Figure 2. Eight-Hour Maximum Carbon Monoxide Concentrations at Central Phoenix (CPHX), with the Number of Exceedances of the Standard at CPHX and in the Entire Network

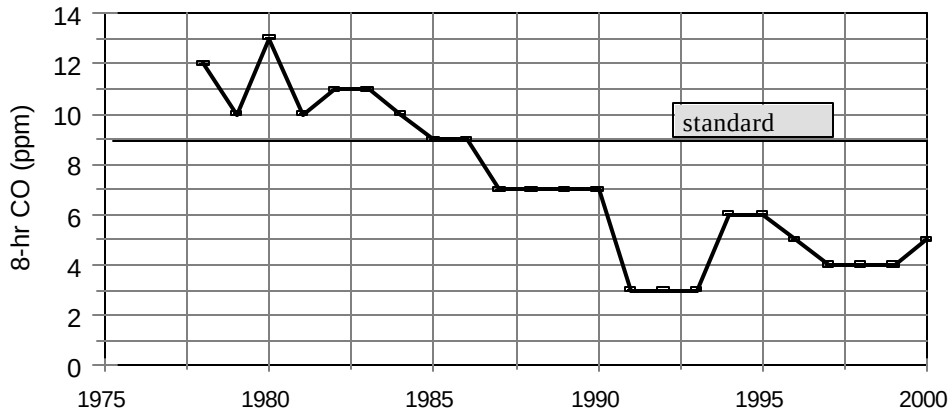

Figure 3. Eight-Hour Carbon Monoxide Maxima at 22nd Street and Alvernon Way in Tucson

Ozone

One-Hour Ozone Concentrations

Maximum one-hour average ozone concentrations have remained steady in Tucson and Yuma but have declined in Phoenix since 1980 (Figure 4). The Phoenix decrease in ozone concentrations has been nowhere near as pronounced as its declining carbon monoxide trend, but the net result has been similar with no exceedances of the ozone standard were recorded in 1997-2000. Because of ozone's relatively high background level and its photochemical formation from hydrocarbons and nitrogen oxides, changes in emissions would not be expected to translate into proportional changes in concentrations.

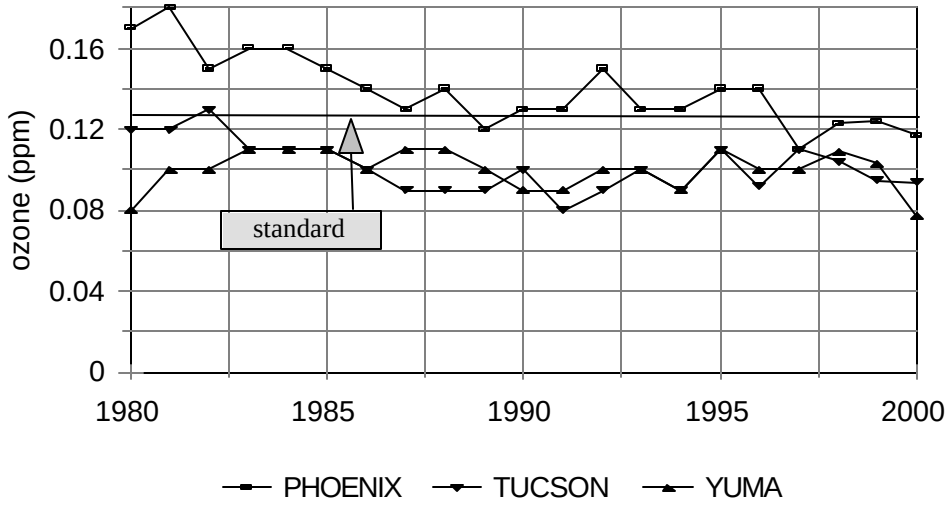

Figure 4. Maximum One-Hour Ozone Concentrations in Phoenix, Tucson and Yuma

Eight-Hour Ozone Concentrations

In 1997, EPA proposed a new eight-hour ozone standard, which is expressed as the three-year average of the annual fourth-highest concentration, not to exceed 0.08 parts per million. This proposed standard was the subject of a lawsuit. The U.S. Supreme Court upheld EPA's decision that an eight-hour standard is viable but remanded the case to EPA to further determine what the final standard should be. Analysis of ambient ozone concentrations nationwide showed that the eight-hour standard is likely to be exceeded in many areas across the United States where the one-hour standard is met. Phoenix falls into this category; Tucson and Yuma do not. Long-term trends of the fourth-highest ozone concentrations in Tucson are fluctuating, but steady overall, with the exception of Saguaro National Monument East, which shows a slight increase (Figures 5 and 6).

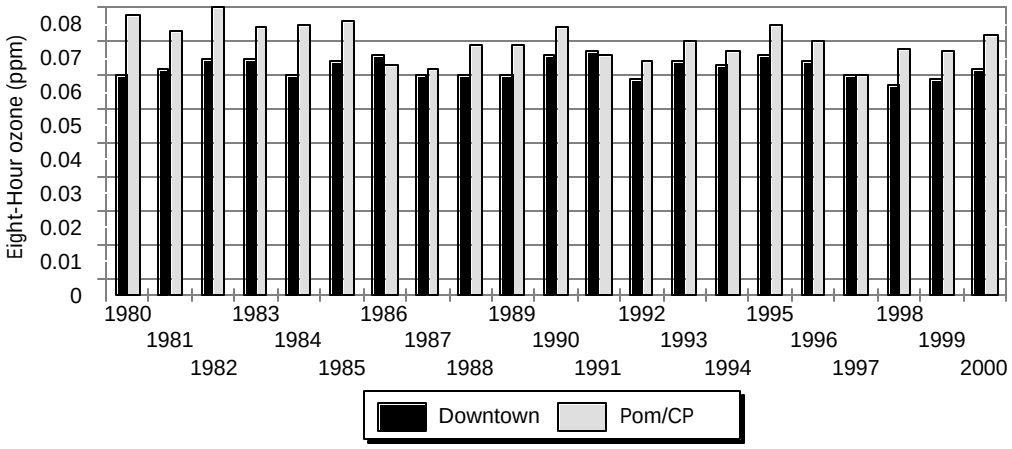

Figure 5. Tucson Long-Term Trends in the Fourth-Highest Eight-Hour Ozone Concentrations at Two Sites (Pom/CP is Pomona/Childrens Park)

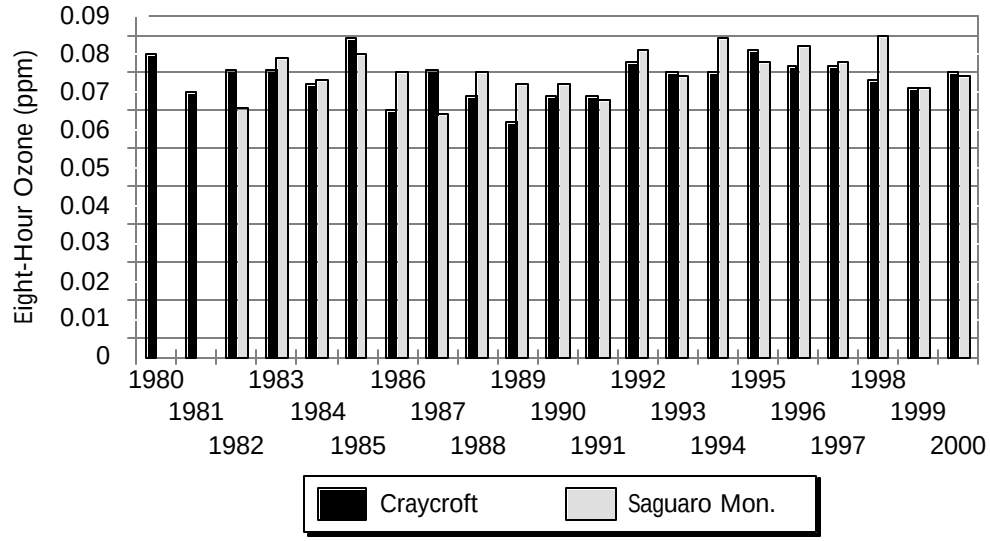

Figure 6. Tucson Long-Term Trends in the Fourth-Highest Eight-Hour Ozone Concentrations at Two Additional Sites

As the data presented in Table 26 show, 24 of the 28 sites in greater Phoenix have recorded annual fourth-highest ozone values in excess of the three-year average standard of 0.084 ppm in 1995-1999. The standard of 0.084 ppm is the *de facto*, or operational standard, in contrast to the statutory standard of 0.08 ppm. This operational standard takes into account the precision of the instrumental method and the rounding off to the nearest 0.01 ppm. Half the sites exceeded the three-year average standard in either 1995-1997, 1996-1998 or 1997-1999 (Figure 7 and Table 27). Achieving this standard in Phoenix will undoubtedly be difficult, especially considering the relatively high concentrations in such background sites as Hillside (80 miles northwest of Phoenix).

Table 26. Annual Fourth-Highest Eight-Hour Ozone Concentrations in Greater Phoenix (in ppm)						
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Blue Point	0.093	0.098	0.083	0.089	0.087	0.088
Central Phoenix	0.085	0.076	0.077	0.079	0.078	0.077
Humboldt Mountain	0.077	0.092	0.081	0.090	0.086	0.083
South Phoenix	0.084	0.091	0.075	0.080	0.075	0.084
Maryvale	0.088	0.087	0.078	0.086	0.077	0.081
Mount Ord	0.081	0.098	0.084	0.088	0.087	0.090
North Phoenix	0.092	0.095	0.091	0.089	0.084	0.087
South Scottsdale	0.089	0.087	0.076	0.078	0.072	0.080
Mesa	0.092	0.090	0.084	0.080	0.083	0.076
Emergency Management	0.108	0.095	0.085	0.081	0.086	0.070
Pinnacle Peak	0.091	0.091	0.082	0.086	0.083	0.086
Falcon Field	0.095	0.09	0.081	0.083	0.082	0.075
W. Chandler	0.084	0.086	0.077	0.074	0.069	0.078
Fountain Hills	ND	0.09	0.088	0.086	0.086	0.085
Arrowhead	ND	0.098	0.060	0.076	ND	ND
Glendale	0.088	0.085	0.076	0.070	0.081	0.081
W. Phoenix	0.084	0.081	0.078	0.086	0.091	0.081
Perryville	ND	0.086	ND	0.075	ND	ND
Phoenix Supersite	0.102	0.087	0.079	0.079	0.061	0.077
Phoenix V.E.I.	0.099	0.095	ND	ND	ND	ND
Salt River-Pima Indian Reservation	0.092	0.092	0.082	0.087	0.082	ND
Roosevelt	ND	ND	0.086	0.085	ND	ND
Rio Verde	ND	ND	0.085	0.079	0.086	0.086
CAP	ND	ND	ND	0.081	ND	ND
Lake Pleasant	ND	ND	ND	0.082	0.081	0.083
Hillside	ND	0.085	0.076	0.083	0.084	0.083
Palo Verde	ND	0.070	0.077	0.080	0.080	0.080
Apache Junction	0.095	0.093	0.082	0.083	0.080	0.082

ND – No data

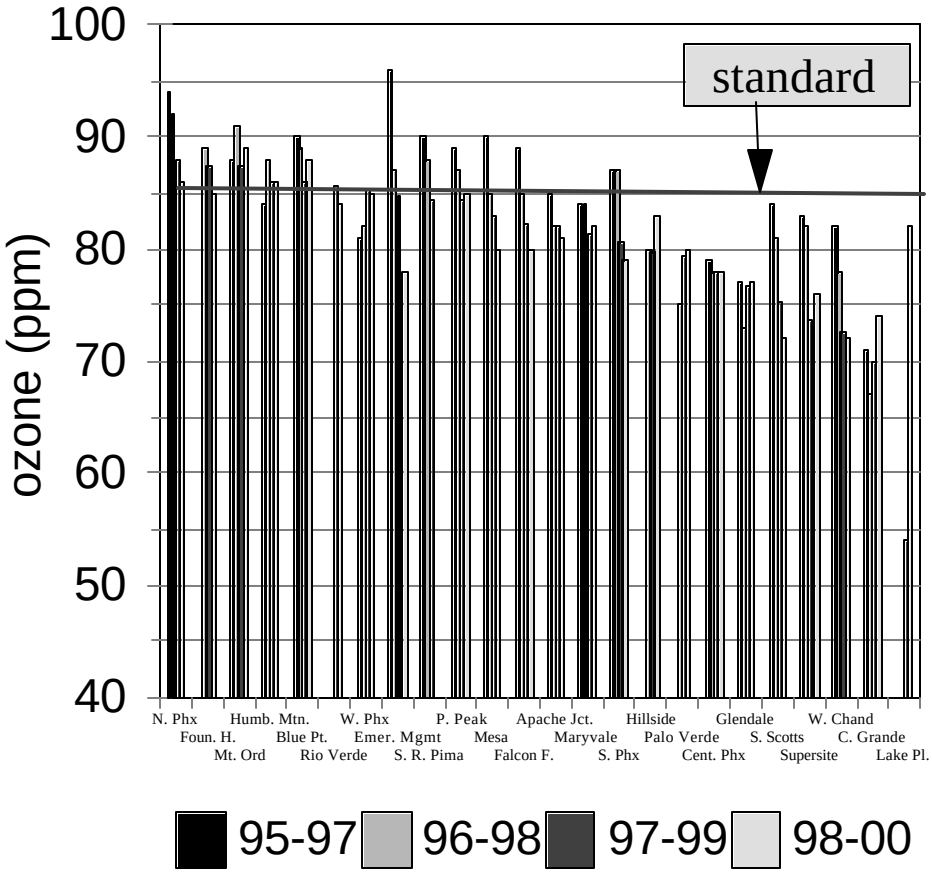

Figure 7. **Three-Year Averages of the Fourth-Highest Eight-Hour Ozone Concentrations in Phoenix and Environs**

Table 27. Three-Year Averages of the Annual Fourth-Highest Eight-Hour Ozone Concentrations in Phoenix and Environs
(Units are in parts per billion, bold values exceed the operational standard of 84 ppb)

Site	1995-1997	1996-1998	1997-1999	1998-2000
Hillside	N/A	80	80	83
Palo Verde	N/A	75	79	80
Lake Pleasant	N/A	N/A	54	82
Maryvale	84	84	81	82
Glendale	77	73	77	77
West Phoenix	81	82	**85**	**85**
Super Site	83	82	74	72
South Phoenix	**87**	**87**	81	79
North Phoenix	**94**	**92**	**88**	**86**
Central Phoenix	79	78	78	78
Emer. Mgmt	**96**	**87**	**85**	78
West Chandler	82	78	73	72
Casa Grande	71	67	70	74
S. Scottsdale	84	81	75	76
Mesa	**90**	**85**	83	80
Salt River Pima	**90**	**88**	84	N/A
Pinnacle Peak	**89**	**87**	84	85
Falcon Field	**89**	**85**	82	80
Fountain Hills	N/A	**89**	**87**	**85**
Blue Point	**90**	**89**	**86**	**88**
Humboldt Mountain	84	**88**	**86**	**86**
Rio Verde	N/A	N/A	**86**	84
Apache Junction	**85**	82	82	81
Mt. Ord	**88**	**91**	**87**	**89**

N/A – Not available

Particulates

PM_{10}

The concentrations of PM_{10} have decreased considerably throughout the state in both urban and rural settings. For example, annual PM_{10} concentrations in South Phoenix averaged 63 µg/m^3 from 1985 through 1989, but only 49 µg/m^3 in 1995-97, a decrease of 22 percent. Similar percentage decreases occurred from the 1980s at Central Phoenix and West Phoenix (Figures 8 and 9). In 1999, the concentrations increased, presumably because of the unusually dry weather from mid September through the end of the year.

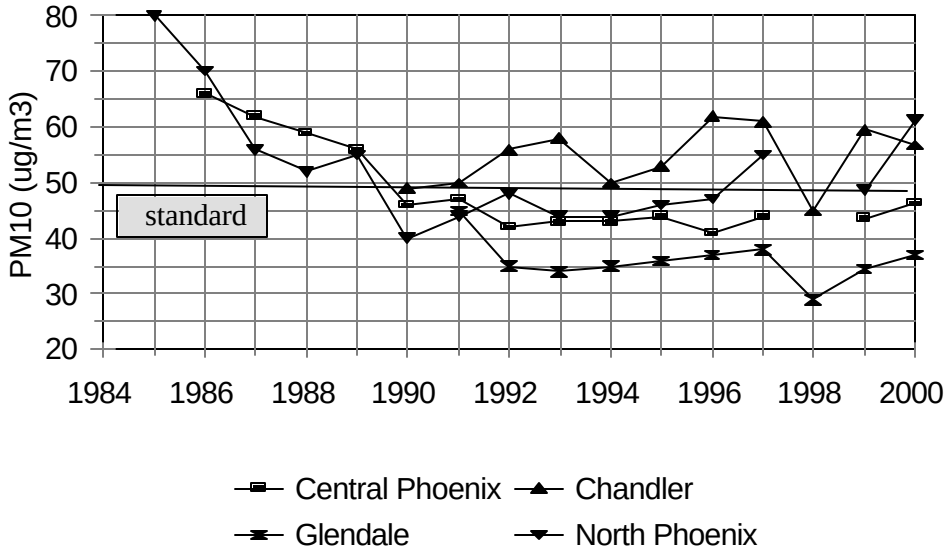

Figure 8. Annual PM_{10} Concentrations at Four Sites in Greater Phoenix

In Tucson, the background site of Corona de Tucson and the rural site of Green Valley have had steady, even trends of PM_{10}, but the four long-term urban sites all show substantial decreases. Orange Grove averaged 45.5 µg/m^3 in 1985-86, but steadily decreased in the next 15 years to an average concentration in 1997-98 of 27.5 µg/m^3 – a decrease of 40 percent. South Tucson, Prince Road and Broadway/Swan showed smaller, but substantial, decreases (Figure 10). Similar to the Phoenix monitoring sites, the 1999 concentrations in Tucson increased substantially over their 1998 levels, again due to the drier weather.

These PM_{10} reductions in the urban settings can probably be attributed to a reduction of coarse particulate emissions caused by paving roads, alleys and road shoulders, and better controls of construction dust emissions.

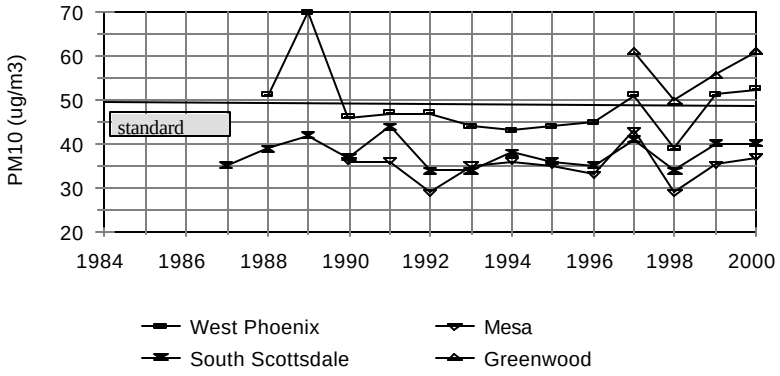

Figure 9. Annual PM_{10} Concentrations at Four Additional Sites in Greater Phoenix

Throughout the state, PM_{10} concentrations have declined since 1985 at many sites. Consider a group of high concentration sites: Douglas, Hayden and Nogales concentrations have been cut in half, Payson and Paul Spur have been reduced threefold, and Rillito and Yuma have decreased 40 percent. In each of these localities, road paving and better industrial dust controls can be given credit for most of the improvement (Figure 11).

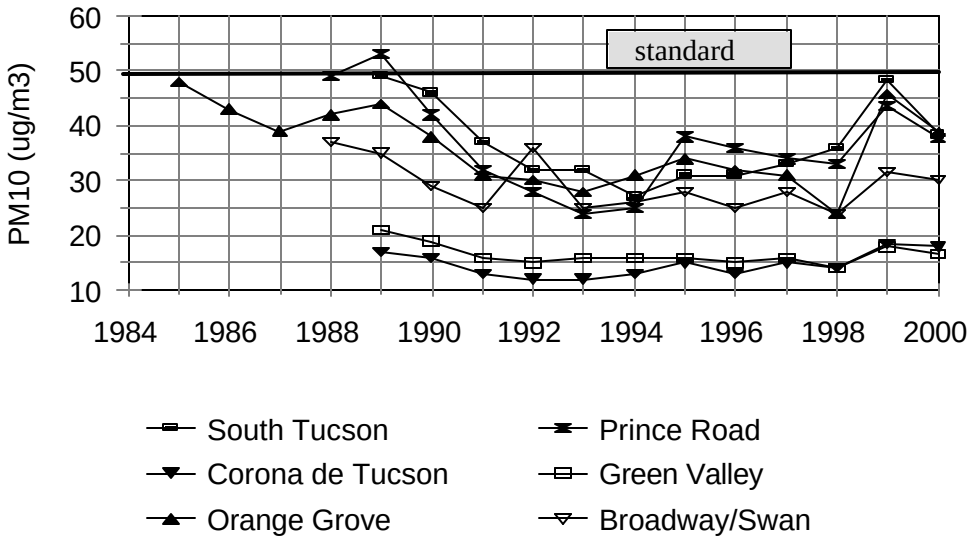

Figure 10. Annual PM10 Concentrations in Tucson

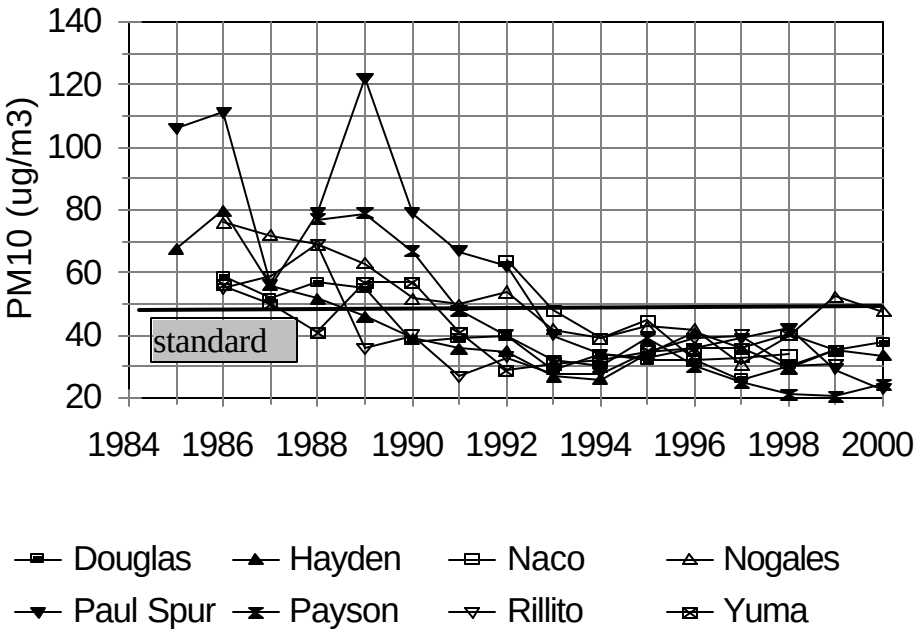

Figure 11. Annual PM_{10} Concentrations at the Higher Concentration Sites in Arizona

PM_{10} concentrations at the sites with lower concentrations have decreased, also, with Ajo concentrations reduced by 50 percent, Bullhead City by 66 percent, and Safford by 15 percent. Other lower concentration sites in the lower elevations were steady or slightly decreasing (Figure 12).

With the exception of Montezuma's Castle, a background site that has had an even trend, all of the higher-elevation, low-concentration sites showed decreasing trends for PM_{10}. The decreases were 38 percent in Clarkdale, 69 percent in Flagstaff, 45 percent in Joseph City, 45 percent in Nelson and 56 percent in Show Low. Part of these decreases may be attributed to cleaner-burning wood stoves and fireplaces (Figure 13). None of these sites, whether urban, industrial, agricultural or rural, show an upward trend, which is an encouraging sign.

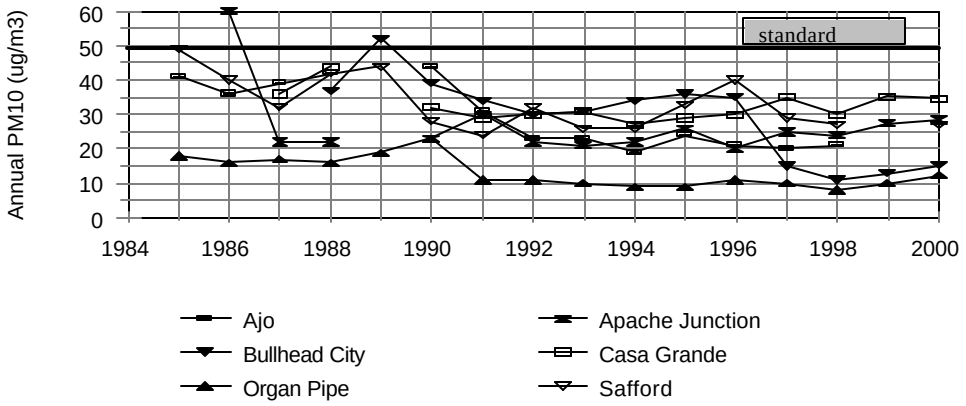

Figure 12. Annual PM_{10} Concentrations at Lower Concentration Sites at Lower Elevations

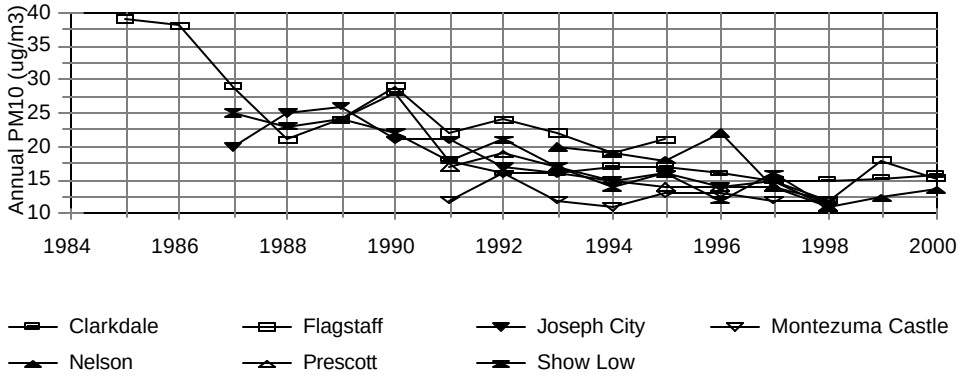

Figure 13. Annual PM_{10} Concentrations at Low Concentration Sites at Higher Elevations

$PM_{2.5}$

$PM_{2.5}$ has not been monitored as long as PM_{10}. The earliest measurements began in 1991 in the smaller cities and towns, in 1994 in Tucson and in 1995 in Phoenix. Slight downward trends at the urban sites are apparent. Nogales, Yuma and Flagstaff have shown consistent trends, while Payson's is down by 39 percent. Exceedances of the annual $PM_{2.5}$ standard occurred for four years in Payson and for one year in Higley. Payson, Nogales and the central area of Phoenix have the highest concentrations of fine particulates. Flagstaff and the urban fringe of Tucson (the Tangerine and Fairgrounds sites) have the lowest concentrations. These data are presented in Table 28 and Figures 14, 15 and 16.

Table 28. Annual $PM_{2.5}$ Concentrations Throughout Arizona (in µg/m^3)

Statewide				
	Yuma	**Flagstaff**	**Payson**	**Nogales**
1991	7.6	N/A	**17.9**	12.3
1992	5.7	N/A	**17.2**	12.6
1993	6.1	5.4	13.0	9.7
1994	8.3	4.9	**15.8**	10.4
1995	7.2	5.8	**15.7**	14.3
1996	8.7	11.2	14.4	13.3
1997	6.0	5.0	12.2	11.3
1998	8.3	4.7	10.9	12.5
1999	7.9	4.9	9.8	16.0 [a]
2000	8.7	4.8	10.0	12.8

Phoenix					
	Higley	**Tempe**	**Super**	**ASU West**	**Estrella**
1995	**15.4**	10.0	12.6	11.1	11.7
1996	11.1	10.0	13.4	10.5	11.1
1997	10.4	9.8	12.1	9.1	7.9
1998	9.4	9.4	10.9	8.3	7.1
1999	11.1	10.1	10.8	9.1	8.9
2000	10.0	10.0	10.4	8.5	7.7

Tucson					
	Orange	**22 Cray**	**Tangerine**	**Fairgrounds**	**Central**
1994	9.4	7.9	5.3	5.8	8.9
1995	8.9	8.6	5.3	5.1	8.9
1996	8.2	6.4	4.9	4.7	7.7
1997	8.7	7.3	5.1	5.5	8.4
1998	7.3	6.3	5.0	5.0	7.5
1999	9.6	7.5	N/A	N/A	7.2
2000	7.6	N/A	N/A	N/A	7.8

Bold values exceed the standard of 15 µg/m^3
N/A – Not Available
[a] – Less than 75 percent data recovery

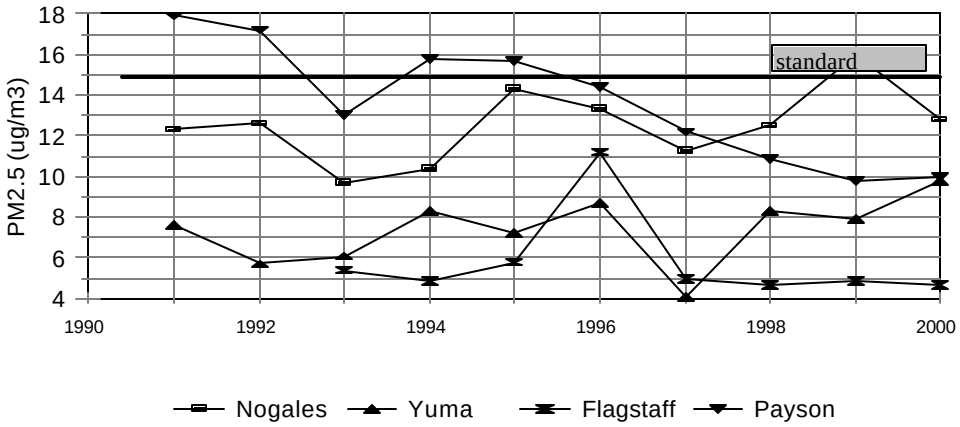

Figure 14. Statewide Annual $PM_{2.5}$ Concentrations

Visibility

Optical measurements of visibility have been made continuously since 1993 in Tucson and since 1994 in Phoenix. Transmissometers measure light extinction, the degree to which sunlight is reduced by its interaction with fine particles and gases in the atmosphere, continuously. These measurements are divided into the mean of the dirtiest 20 percent of all hours, the mean of all hours and the mean of the cleanest 20 percent of all hours for the entire day and the 5-11 a.m. period. Table 29 Figures 17 and 18 present these data.

Table 29. Light Extinction in Phoenix and Tucson (in Mm^{-1})		
Phoenix		
Year	**All Hours**	**5-11 a.m.**

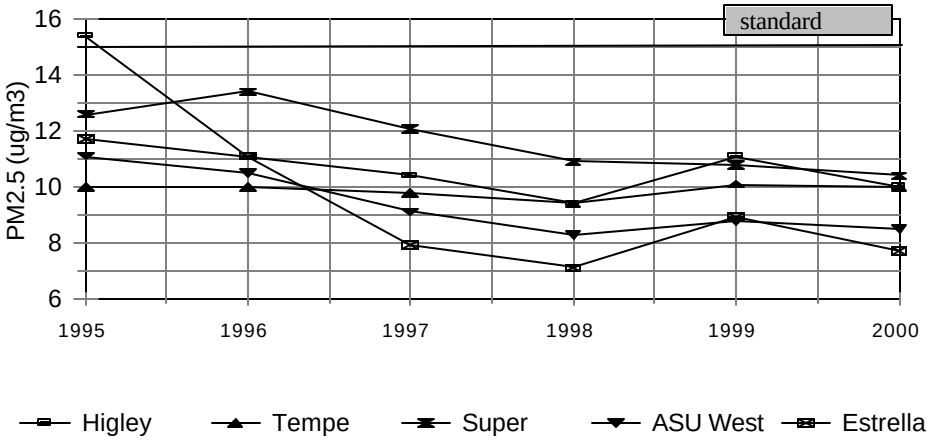

Figure 15. Annual $PM_{2.5}$ concentrations in Phoenix

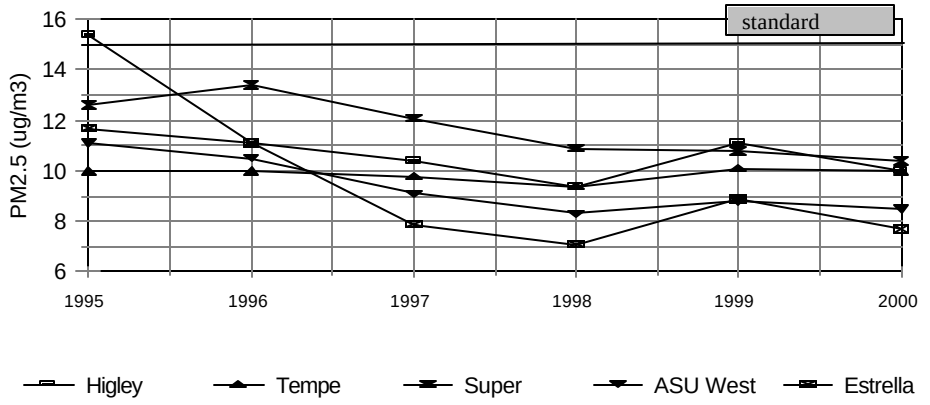

Figure 16. Annual $PM_{2.5}$ Concentrations in Phoenix

	Dirtiest 20 %	Mean	Cleanest 20 %	Dirtiest 20 %	Mean	Cleanest 20 %
1994	123	63	28	129	70	33
1995	138	75	38	134	78	42
1996	133	78	44	129	80	45
1997	137	83	50	136	87	54
1998	135	79	46	138	85	51
1999	125	71	38	124	75	42
2000	131	73	38	135	80	42
% Dif '94-'00	+6.50	+15.87	+35.71	+4.65	+14.29	+27.27
Annual %	+9.29	+2.27	+5.10	+0.66	+2.04	+3.90

Tucson						
Year	**All Hours**			**5-11 a.m.**		
	Dirtiest 20 %	**Mean**	**Cleanest 20 %**	**Dirtiest 20 %**	**Mean**	**Cleanest 20%**
1993	108	64	35	129	74	39
1994	92	58	35	110	68	40
1995	102	61	35	116	68	38
1996	104	65	39	116	73	43
1997	91	59	36	105	66	38
1998	N/A	N/A	N/A	N/A	N/A	N/A
1999	97	60	36	111	67	39
2000	101	57	27	115	66	31
% Dif '93-'00	-6.48	-10.94	-22.86	-10.85	-10.81	-20.51
Annual %	-0.93	-1.56	-3.27	-1.55	-1.54	-2.93

The percentage difference between either 1993 or 1994 and 2000 is divided by the number of years to give the average annual percentage change.

Tucson visibility shows improving trends in all six categories, although these trends are not strong and are somewhat obscured by considerable year-to-year variability. Phoenix has much stronger trends, but in the opposite direction. In Phoenix, all six categories of light extinction have increased from 1994 to 2000 with an apparent peak in 1997. Because the cleanest 20 percent of the hours has increased about five times faster than the dirtiest 20 percent, the increasing mean values have resulted because of a migration from the cleanest 20 percent to the mean. If these trends continue, the mean value in just five years will equal the dirtiest 20 percent value of 1998. This increase can be attributed to increases in nitrogen oxides and carbonaceous fine particulate emissions from motor vehicles. Vehicle miles traveled in metropolitan Phoenix vehicle increases about 3 percent a year and has now reached 64 million miles on an average weekday.

Seasonal patterns also vary between the two cites, with the mean and dirtiest 20 percent of all hourly light extinction values in Phoenix showing more pronounced winter and fall maxima than the Tucson counterparts (Figure 19). Both cities show almost no seasonal variation in the cleanest 20 percent of all hours. The seasonal light extinction values in Phoenix are considerably higher than Tucson's: for the dirtiest 20 percent of all hours, 52 percent higher in winter, 19 percent higher in spring, 13 percent higher in summer, and 49 percent higher in fall. These measurements of the decreased visibility in Phoenix will come as no surprise to those Arizonans familiar with both airsheds.

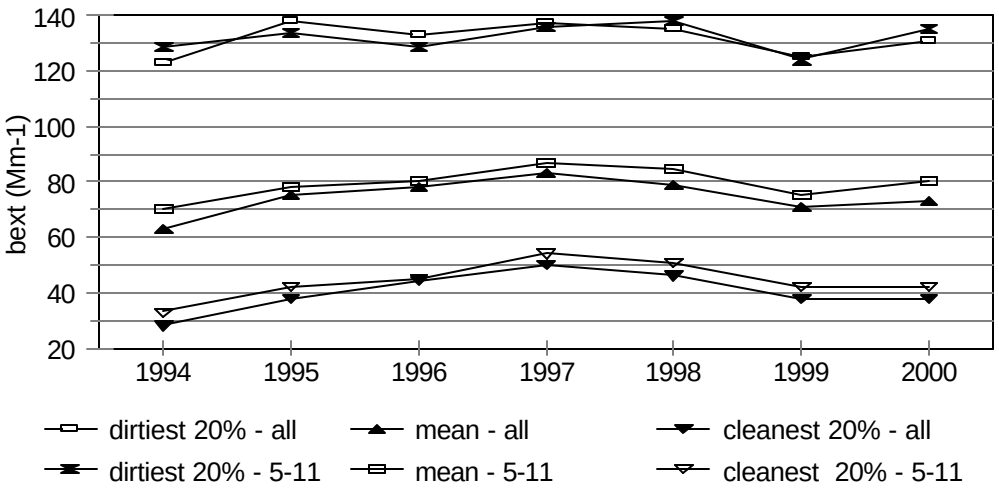

Figure 17. Light Extinction Trends in Phoenix

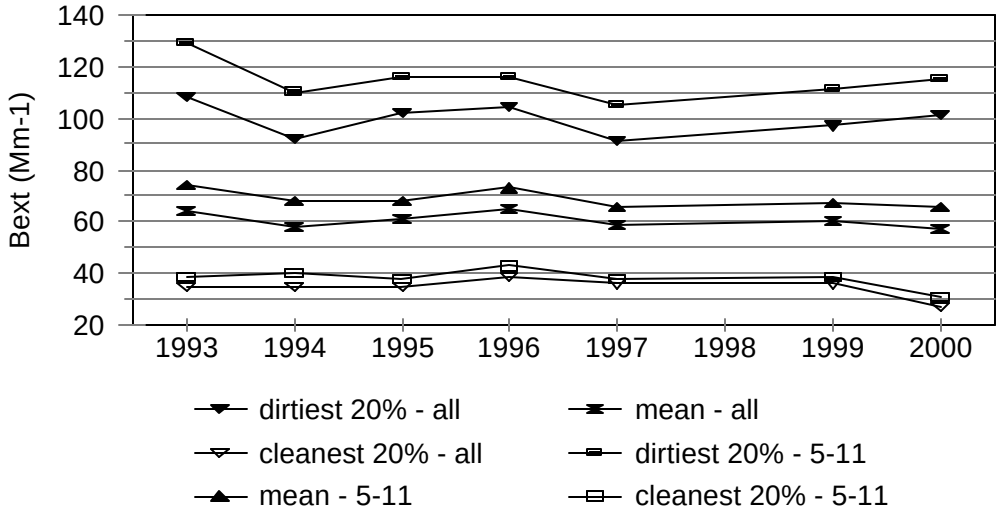

Figure 18. Light Extinction Trends in Tucson

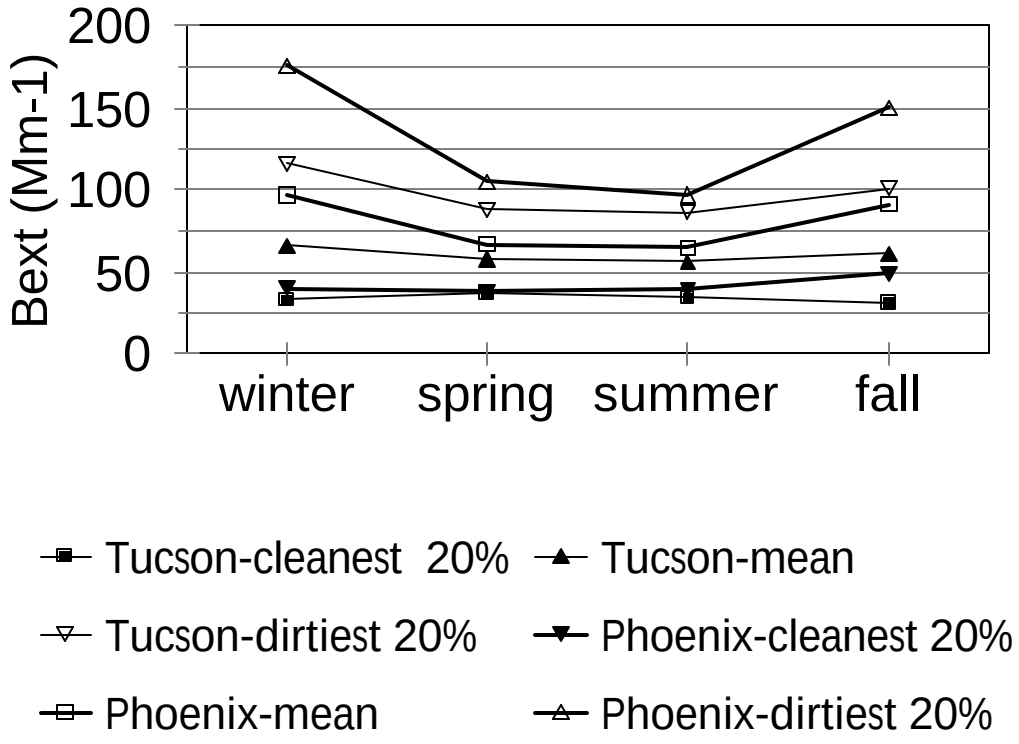

Figure 19. Seasonal Patterns of Hourly Light Extinction in Tucson and Phoenix: 1993-1998

Conclusions

Since the monitoring of air pollutants in Arizona began in the late 1960s, considerable progress has been made in reducing concentrations of lead, sulfur dioxide and carbon monoxide. Lead has been reduced to near background levels, sulfur dioxide concentrations near copper smelters, which chronically exceeded the standards until the mid-1980s, are now well within these standards and carbon monoxide concentrations, which regularly exceeded standards in neighborhoods and near busy intersections in Phoenix (and to a far lesser extent in Tucson), now meet the standards. One-hour ozone concentrations in Phoenix met the standard in 1997-2000, the first years since monitoring began. Phoenix ozone concentrations in the 1980s and early 1990s used to range as high as 0.15 to 0.18 parts per million (the standard is 0.12 ppm), in contrast to the highest, most recent reading of 0.14 ppm in 1996. Of the 26

monitoring sites in greater Phoenix, 12 still exceed the new eight-hour ozone standard.

Elevated concentrations of PM_{10} have been reduced substantially since the mid-1980s, with decreases of 20 to 70 percent in the urban areas and in most smaller cities and towns. In Payson and at some industrial sites, PM_{10} concentrations have been reduced by as much as two-thirds. By 2000, monitored violations of the PM_{10} standard – a once common occurrence at many sites only 10 years ago – were limited to a few sites. Fine particulates concentrations ($PM_{2.5}$) have decreased in Phoenix and Tucson since the mid-1990s. At the centrally located Phoenix Supersite, for example, the decrease has been 21 percent and at 22nd and Craycroft, in east central Tucson, the decrease has been 24 percent. The Phoenix decreases are inconsistent with the increasing trends in light extinction, which are primarily caused by small particles.

Despite the continued growth in Arizona, with the exception of Phoenix visibility in the last five years, not a single air pollutant at any site shows a consistent upward trend. Most standards are met most of the time, with the exceptions being the eight-hour ozone standard during Phoenix summers and the PM_{10} standards on both an episodic and annual basis at those sites affected by localized dense emissions. These improving air quality trends, resulting from control programs at the federal, state and local levels, have improved the respiratory health of the citizenry and can be considered a testament to the public support for a cleaner environment.