6.0 STATE AND CLASS I AREA SUMMARIES

As described in Section 2.0, each state is required to submit progress reports at interim points between submittals of Regional Haze Rule (RHR) State Implementation Plans (SIPs), which assess progress towards visibility improvement goals in each state's mandatory Federal Class I areas (CIAs). Data summaries for each CIA in each Western Regional Air Partnership (WRAP) state, which address Regional Haze Rule (RHR) requirements for visibility measurements and emissions inventories are provided in this section. These summaries are intended to provide individual states with the technical information they need to determine if current RHR implementation plan elements and strategies are sufficient to meet all established reasonable progress goals, as defined in their respective initial RHR implementation plans.

6.2 ARIZONA

The goal of the Regional Haze Rule (RHR) is to ensure that visibility on the 20% most impaired, or worst, days continues to improve at each Federal Class I area (CIA), and that visibility on the 20% least impaired, or best, days does not get worse, as measured at representative Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring sites. Arizona has 12 mandatory Federal CIAs, which are depicted in Figure 6.2-1 and listed in Table 6.2-1, along with the associated IMPROVE monitor locations.

This section addresses differences between the 2000-2004 baseline and 2005-2009 period, for both monitored data and emission inventory estimates. Monitored data are presented for the 20% most impaired, or worst, days and for the 20% least impaired, or best, days, as per Regional Haze Rule (RHR) requirements. Annual average trend statistics for the 2000-2009 10-year period are also presented here to support assessments of changes in each monitored species that contributes to visibility impairment. Some of the highlights regarding these comparisons are listed below, and more detailed state specific information is provided in monitoring and emissions sub-sections that follow.

- The 5-year deciview metric for the best days decreased between the 2000-2004 baseline period and the 2005-2009 progress period at all Arizona sites.
- The 5-year deciview metric for the worst days decreased between the 2000-2004 baseline period and the 2005-2009 progress period at most sites, but increased slightly at the GRCA2 (+0.3 dv) and IKBA1 (+0.1 dv) sites.
- Increases in the 5-year averages of particulate organic mass, elemental carbon, and ammonium sulfate contributed to deciview increases at the GRCA2 site, and increases in particulate organic mass and ammonium sulfate contributed to increases at the IKBA1 sites. For these increases:
  - Increases in particulate organic mass were affected by large events, including high measurements in June 2009 at the GRCA2 site that were likely related to several large fires in the area at the time. Increases in average elemental carbon at the GRCA2 site were also associated with the high particulate organic mass measurements in June 2009. At the IKBA2 site, the increase in 5-year average particulate organic mass was due to higher than average measurements between June and December 2005, which were likely related to fire.
  - All sites except SAGU1 and SAWE1 showed an increase in 5-year average ammonium sulfate, but annual average trends for ammonium sulfate were either insignificant or decreasing. Many regional sites, including sites in Arizona, Colorado, and New Mexico were affected by anomalously higher than average ammonium sulfate measurements in 2005. Increases were also not consistent with emissions inventory comparisons, where state-wide emissions totals and annual tracking of electrical generating units (EGU) emissions showed decreases in sulfur dioxide (SO_2), due mostly to decreases in point and off-road mobile sources.

- For ammonium nitrate, all sites had lower 5-year averages of ammonium nitrate for the 2005-2009 progress period, and central and northern Arizona sites showed decreasing annual trends in ammonium nitrate. This was consistent with emission inventories that showed net decreases in oxides of nitrogen (NO_X) emissions, with decreases reported for all sources except area. Increases in area source inventories may to due increases in population estimates used for calculations.
- For fine soil and coarse mass, measured concentrations are highest in the southern Western Regional Air Partnership (WRAP) region. Emissions inventories indicate that windblown and fugitive dusts are the largest contributors these haze species, with some contribution to fine soil from area and fire sources. Annual average trends for these species were varied, with both increasing and decreasing trends throughout the state.
- For coarse mass, increasing trends were noted at some of the eastern Arizona sites, but increases were not associated with increased deciview averages. Comparisons between coarse mass inventories showed increases in fugitive dust (including road dust) and windblown dust, although increases in windblown dust are likely due to updated inventory development methodology rather than actual increases. Increases in fugitive dust inventories may be to due increases in population used for calculations, and increases road dust may be due to a combination of use of a different model for output, and increases in estimated vehicle miles travelled.

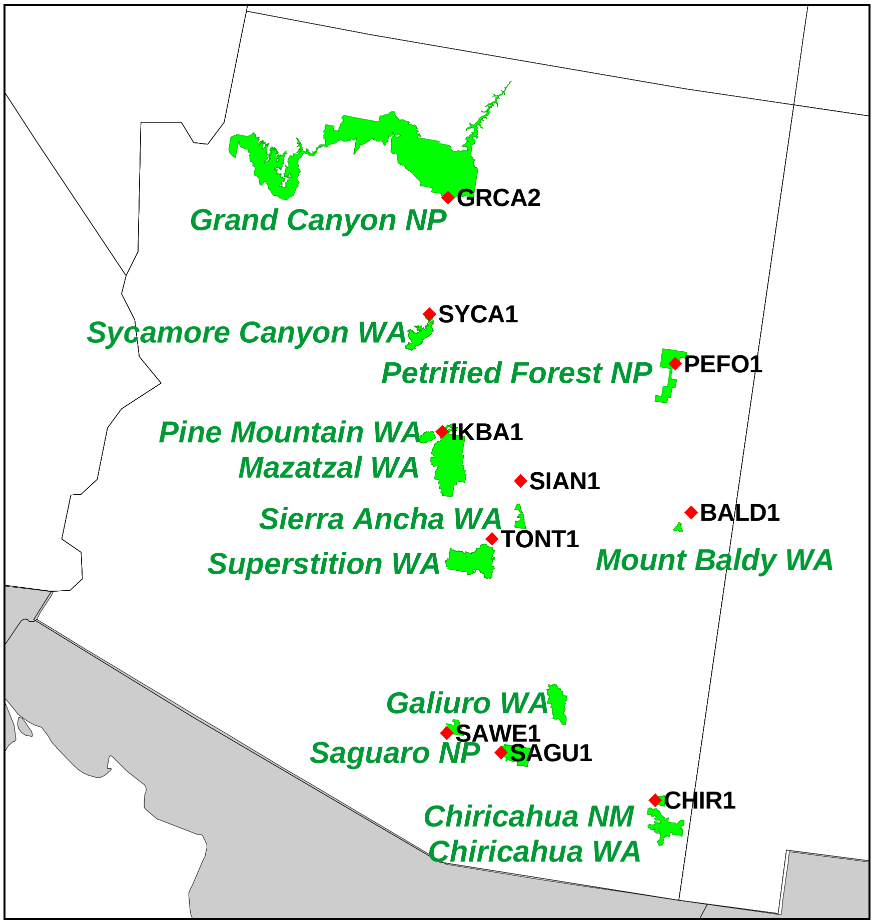


Figure 6.2-1. Map Depicting Federal CIAs and Representative IMPROVE Monitors in Arizona.

Table 6.2-1
Arizona CIAs and Representative IMPROVE Monitors

Class I Area	Representative IMPROVE Site	Latitude	Longitude	Elevation (m)
Mount Baldy WA	BALD1	34.06	-109.44	2508
Chiricahua NM Chiricahua WA Galiuro WA	CHIR1	32.01	-109.39	1554
Grand Canyon NP	GRCA2	35.97	-111.98	2267
Mazatzal WA Pine Mountain WA	IKBA1	34.34	-111.68	1297
Petrified Forest NP	PEFO1	35.08	-109.77	1766
Saguaro NP	SAGU1	32.17	-110.74	941
	SAWE1	32.25	-111.22	714
Sierra Ancha WA	SIAN1	34.09	-110.94	1600
Sycamore Canyon WA	SYCA1	35.14	-111.97	2046
Superstition WA	TONT1	33.65	-111.11	775

6.2.1 Monitoring Data

This section addresses RHR regulatory requirements for monitored data as measured by IMPROVE monitors representing Federal CIAs in Arizona. These summaries are supported by regional data presented in Section 4.0 and by more detailed site specific tables and charts in Appendix B.

As described in Section 3.1, regional haze progress in Federal CIAs is tracked using calculations based on speciated aerosol mass as collected by IMPROVE monitors. The RHR calls for tracking haze in units of deciviews (dv), where the deciview metric was designed to be linearly associated with human perception of visibility. In a pristine atmosphere, the deciview metric is near zero, and a one deciview change is approximately equivalent to a 10% change in cumulative species extinction. To better understand visibility conditions, summaries here include both the deciview metric, and the apportionment of haze into extinction due to the various measured species in units of inverse megameters (Mm^{-1}).

6.2.1.1 SIAN1 Data Substitutions

As described in Section 3.1.1, RHR guidance outlines data completeness requirements for the 2000-2004 baseline period, and each subsequent progress period. In WRAP states, only the SIAN1 site, representing the Sierra Ancha Wilderness Area in Arizona, did not meet data completeness criteria for the 2005-2009 progress period. RHR guidelines provide provisions to fill in, or patch, missing data under specific circumstances, and these methods are routinely applied to all IMPROVE data.[68] Additional data substitutions beyond the routine RHR patched values were required for the SIAN1 monitoring site to achieve data completeness for the progress period.

Data substitution methodology for the 2005-2009 progress period was consistent with methodology that was previously applied for similarly incomplete 2000-2004 baseline period for seven WRAP sites.[69] The data substitution methods include estimating missing species from other on-site measurements and appropriately scaling data collected at a nearby site which demonstrated favorable long-term comparisons. Only years deemed incomplete under RHR guidance were candidates for additional data substitutions, which included the years 2006, 2007, and 2008 at the SIAN1 site. Years deemed complete were not changed, although there may have been missing samples during those years.

The first substitution method applied uses organic hydrogen (org H), measured on the IMPROVE A Module filter, as a surrogate for organic carbon (OC) and elemental carbon (EC), which are collected on the C Module. Hydrogen is assumed to be primarily associated with organic carbon and inorganic compounds such as ammonium sulfate. Therefore, OC can be estimated using the historical comparison between estimated org H and OC. Org H is estimated

---

[68] Routine data substitutions are described in the *Guidance for Tracking Progress Under the Regional Haze Rule*, EPA-454/B-03-004, September 2003, www.epa.gov/ttnamti1/files/ambient/visible/tracking.pdf .
[69] A description of data substitution methodology applied for the baseline data for WRAP states is available at http://vista.cira.colostate.edu/docs/wrap/Monitoring/WRAP_Data_Substitution_Methods_April_2007.doc.

by subtracting the portion of H that is assumed to be associated with the inorganic compounds from the total H (Org_H = H – 0.25*S). Linear regression statistics were used to correlate all org H and OC mass collected at the SIAN1 site during the 2005-2009 period, and regression statistics were applied to organic H to estimate OC on days where org H was available, but OC was not. OC and EC correlations for the period were then used to estimate EC from OC. Regression statistics for these substitutions were calculated and applied quarterly to account for seasonal variations.

Because the carbon data substitution methods were not sufficient to complete the required years, a second method was applied that involved scaling data from the closest neighboring IMPROVE site, TONT1. This site had previously been determined to have favorable long-term comparisons and similar regional characteristics for substitutions performed on the 2000-2004 baseline period, when the SIAN1 site was selected, in consultation with the state of Arizona, as a donor site for TONT1. Species specific mass correlations between SIAN1 and TONT1 during the 2005-2009 period were calculated quarterly, and applied to adjust TONT1 data for substitution on incomplete days at SIAN1.

Figure 6.2-2 presents bar charts showing daily SIAN1 extinction data, including substituted data, for the 2005-2009 progress period years. Original RHR data are shown in blue and substituted data by species in the standard IMPROVE colors. Substituted days are also identified with a black bar underneath the day. The red line indicates the threshold above which days are counted in the 20% worst days for that year. Note that some of the substituted days had partial data available, and only individual species missing in a given sample were substituted. Figure 6.2-3 presents similar bar charts showing all species, with days in which all or part of the day was substituted indicated by a black bar underneath the day. Note that very few of the substituted days were counted among the 20% worst days for the substituted years. All summaries for the SIAN1 site in this progress report support document include these substituted data, and substituted data and detailed methodology information will also be made available on the WRAP TSS website.[70]

[70] Tools and information supporting WRAP state RHR SIPs and progress reports are available on the WRAP TSS website at http://vista.cira.colostate.edu/tss/.

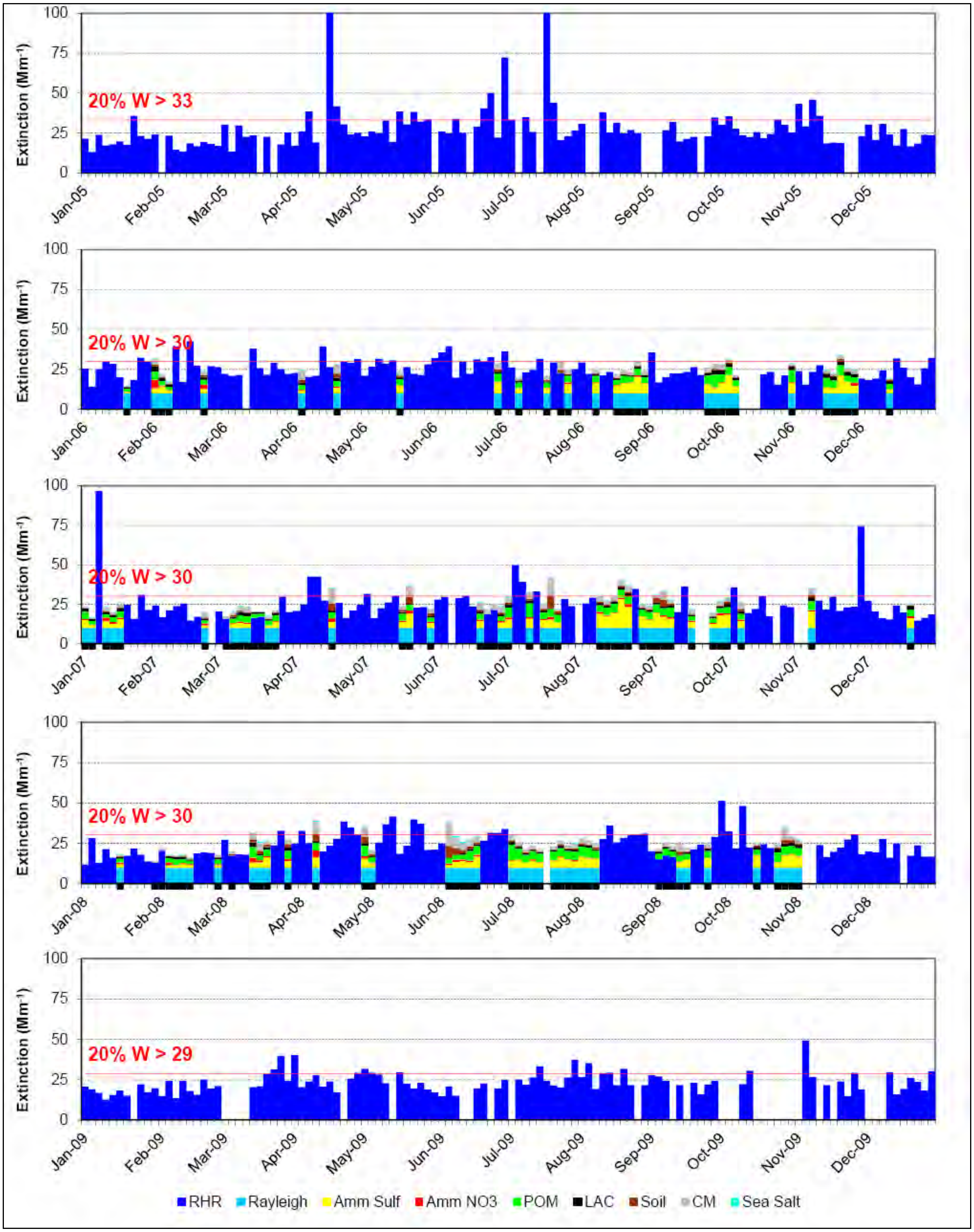


Figure 6.2-2. IMPROVE SIAN1 Data Collected During the 2005-2009 Progress Period, Where Original SIAN1 RHR Data Are Depicted in Dark Blue, and Substituted Data Are Depicted with Separate Colors by Species.

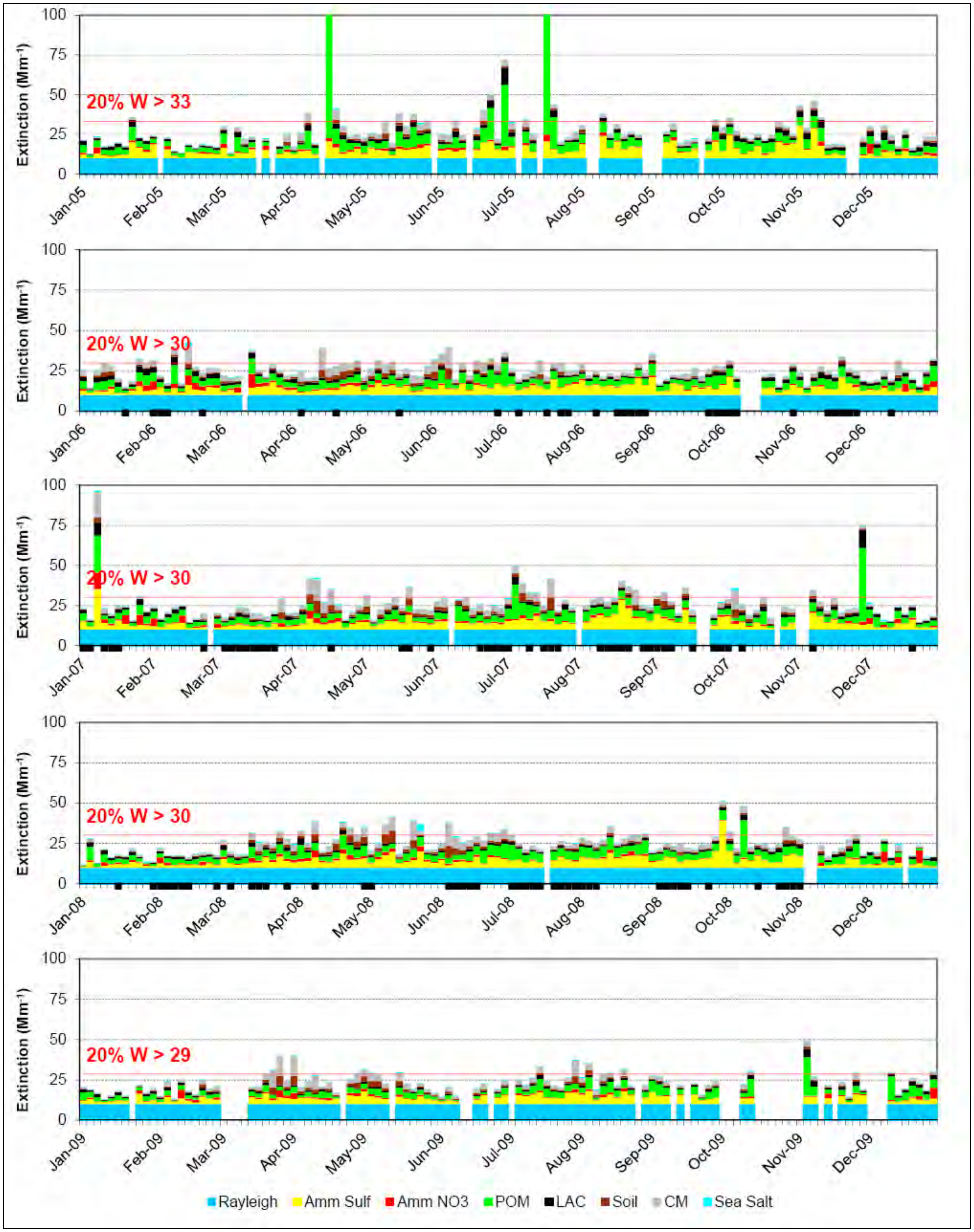


Figure 6.2-3. IMPROVE SIAN1 Data Collected During the 2005-2009 Progress Period, Where Substituted Days Are Depicted with a Black Bar Beneath the Data.

6.2.1.2 Current Conditions

This section addresses the regulatory question, ***what are the current visibility conditions for the most impaired and least impaired days (40 CFR 51.308 (g)(3)(i))?*** RHR guidance specifies that 5-year averages be calculated over successive 5-year periods, i.e. 2000-2004, 2005-2009, 2010-2014, etc.[71] Current visibility conditions are represented here as the most recent successive 5-year average period available, or the 2005-2009 period average, although the most recent IMPROVE monitoring data currently available includes 2010 data.

Tables 6.2-4 and 6.2-5 present the calculated deciview values for current conditions at each site, along with the percent contribution to extinction from each aerosol species for the 20% most impaired, or worst, and 20% least impaired, or best, days, respectively, for each of the Federal CIA IMPROVE monitors in Arizona. Figure 6.2-4 presents 5-year average extinction for the current progress period for both the 20% most impaired and 20% least impaired days. Note that the percentages in the tables consider only the aerosol species which contribute to extinction, while the charts also show Rayleigh, or scattering due to background gases in the atmosphere.

Specific observations for the current visibility conditions on the 20% most impaired days are as follows:

- The largest contributors to aerosol extinction at Arizona sites were particulate organic mass, ammonium sulfate, and coarse mass.
- The highest aerosol extinction (15.2 dv) was measured at the SYCA1 site, where particulate organic mass was the largest contributor to aerosol extinction, followed by coarse mass. The lowest aerosol extinction (11.8 dv) was measured at the BALD1 site.

Specific observations for the current visibility conditions on the 20% least impaired days are as follows:

- The aerosol contribution to total extinction on the best days was less than Rayleigh, or the background scattering that would occur in clear air. Average extinction (including Rayleigh) ranged from 2.2 deciview (GRCA2) to 8.0 deciview (SAWE1).
- For all sites except SIAN1 and SAWE1, ammonium sulfate was the largest contributor to aerosol extinction.
- At the SIAN1 site, particulate organic mass was the largest contributor to aerosol extinction, followed by ammonium sulfate. At the SAWE1 site, coarse mass was the largest contributor, followed by ammonium sulfate.

[71] EPA's September 2003 *Guidance for Tracking Progress Under the Regional Haze Rule* specifies that progress is tracked against the 2000-2004 baseline period using corresponding averages over successive 5-year periods, i.e. 2005-2009, 2010-2014, etc. (See page 4-2 in the Guidance document.)

Table 6.2-2
Arizona Class I Area IMPROVE Sites
Current Visibility Conditions
2005-2009 Progress Period, 20% Most Impaired Days

Site	Deciviews (dv)	Percent Contribution to Aerosol Extinction by Species (Excludes Rayleigh) (% of Mm^{-1}) and Rank*						
		Ammonium Sulfate	**Ammonium Nitrate**	**Particulate Organic Mass**	**Elemental Carbon**	**Soil**	**Coarse Mass**	**Sea Salt**
BALD1	11.8	25% (2)	4% (6)	**42% (1)**	8% (4)	6% (5)	16% (3)	0% (7)
CHIR1	12.2	**36% (1)**	5% (5)	16% (3)	5% (6)	10% (4)	27% (2)	1% (7)
GRCA2	12.0	22% (2)	7% (5)	**41% (1)**	11% (4)	6% (6)	12% (3)	0% (7)
IKBA1	13.4	26% (2)	8% (5)	**29% (1)**	8% (6)	8% (4)	21% (3)	1% (7)
PEFO1	13.0	23% (2)	5% (6)	**31% (1)**	11% (4)	8% (5)	21% (3)	1% (7)
SAGU1	13.6	25% (2)	9% (5)	18% (3)	8% (6)	11% (4)	**28% (1)**	1% (7)
SAWE1	14.9	21% (2)	11% (5)	16% (3)	8% (6)	13% (4)	**31% (1)**	1% (7)
SIAN1	13.0	25% (2)	6% (6)	**33% (1)**	9% (4)	8% (5)	19% (3)	1% (7)
SYCA1	15.2	15% (4)	4% (6)	**29% (1)**	9% (5)	15% (3)	28% (2)	0% (7)
TONT1	13.8	**28% (1)**	8% (5)	21% (3)	7% (6)	9% (4)	26% (2)	1% (7)

*Highest aerosol species contribution per site is highlighted in bold.

Table 6.2-3
Arizona Class I Area IMPROVE Sites
Current Visibility Conditions
2005-2009 Progress Period, 20% Least Impaired Days

Site	Deciviews (dv)	Percent Contribution to Aerosol Extinction by Species (Excludes Rayleigh) (% of Mm^{-1}) and Rank*						
		Ammonium Sulfate	**Ammonium Nitrate**	**Particulate Organic Mass**	**Elemental Carbon**	**Soil**	**Coarse Mass**	**Sea Salt**
BALD1	2.9	**36% (1)**	7% (5)	26% (2)	13% (4)	4% (6)	13% (3)	1% (7)
CHIR1	4.4	**38% (1)**	7% (5)	17% (3)	10% (4)	6% (6)	21% (2)	1% (7)
GRCA2	2.2	**45% (1)**	13% (4)	15% (2)	9% (5)	4% (6)	14% (3)	1% (7)
IKBA1	5.1	**29% (1)**	10% (5)	28% (2)	12% (4)	5% (6)	14% (3)	1% (7)
PEFO1	4.6	**31% (1)**	9% (5)	21% (2)	19% (3)	6% (6)	14% (4)	0% (7)
SAGU1	6.7	**28% (1)**	8% (6)	20% (3)	12% (4)	8% (5)	21% (2)	2% (7)
SAWE1	8.0	24% (2)	8% (6)	18% (3)	11% (4)	10% (5)	**26% (1)**	2% (7)
SIAN1	5.3	27% (2)	7% (5)	**32% (1)**	17% (3)	5% (6)	13% (4)	1% (7)
SYCA1	5.1	**27% (1)**	10% (5)	23% (2)	17% (3)	7% (6)	15% (4)	1% (7)
TONT1	5.7	**33% (1)**	9% (5)	23% (2)	12% (4)	6% (6)	16% (3)	1% (7)

*Highest aerosol species contribution per site is highlighted in bold.

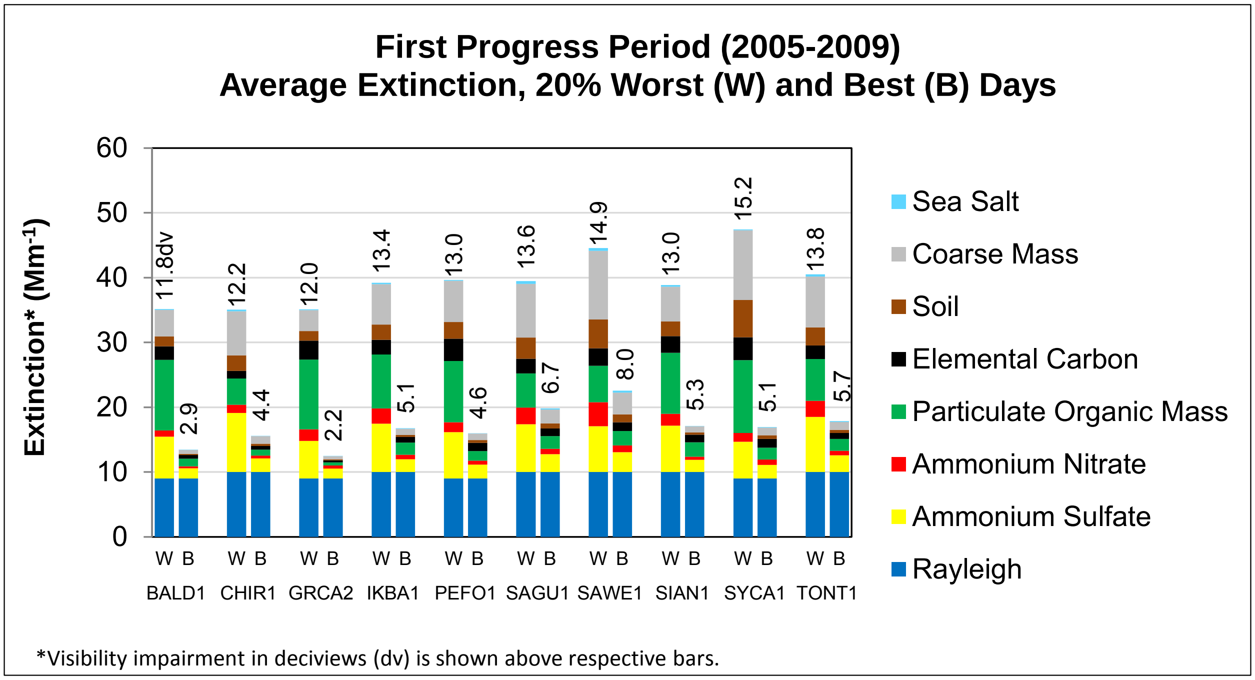


Figure 6.2-4. Average Extinction for Current Progress Period (2005-2009) for the Worst (Most Impaired) and Best (Least Impaired) Days Measured at Arizona Class I Area IMPROVE Sites.

6.2.1.3 Differences between Current and Baseline Conditions

This section addresses the regulatory question, ***what is the difference between current visibility conditions for the most impaired and least impaired days and baseline visibility conditions (40 CFR 51.308 (g)(3)(ii))?*** Included here are comparisons between the 5-year average baseline conditions (2000-2004) and current progress period extinction (2005-2009).

Tables 6.2-4 and 6.2-5 present the differences between the 2000-2004 baseline period average extinction and the 2005-2009 progress period average for each site in Arizona for the 20% most impaired and 20% least impaired days, respectively. Averages that increased are depicted in red text and averages that decreased in blue.

Figure 6.2-5 presents the 5-year average extinction for the baseline and current progress period averages for the worst days and Figure 6.2-6 presents the differences in averages by aerosol species, with increases represented above the zero line and decreases below the zero line. Figures 6.2-7 and 6.2-8 present similar plots for the best days.

For the 20% most impaired days, the 5-year average RHR deciview metric increased between the 2000-2004 and 2005-2009 periods at the GRCA2 and IKBA1 sites and decreased at all other Arizona sites. Notable differences for individual species averages were as follows:

- All sites except GRCA2 and IKBA1 measured decreases in particulate organic mass.

- Increases in deciview at the GRCA2 site were mostly due to increases in ammonium sulfate and elemental carbon. These increases were partially offset by decreases in ammonium nitrate and coarse mass.
- Increases in deciview at the IKBA1 site were mostly due to increased ammonium sulfate and particulate organic mass measurements. These increases were partially offset by decreases in ammonium nitrate and soil.
- All sites except SAGU1 and SAWE1 measured increases in ammonium sulfate. The largest increases in ammonium sulfate were measured at the CHIR1, IKBA1, and TONT1 sites.
- All sites measured decreases in ammonium nitrate. The largest decreases in ammonium nitrate were measured at the IKBA1, SAGU1, and SAWE1 sites.

For the 20% least impaired days, the 5-year average deciview metric decreased at all sites except GRCA2, where the measured deciview average remained relatively unchanged. Notable differences for individual species averages on the 20% least impaired days were as follows:

- The largest decreases were due to particulate organic mass, which decreased at all sites except IKBA1.
- Ammonium sulfate decreased at most sites, but increased slightly at the GRCA2, SAGU1, and SYCA1 sites.
- Ammonium nitrate decreased at all but the GRCA2 site.

Table 6.2-4
Arizona Class I Area IMPROVE Sites
Difference in Aerosol Extinction by Species
2000-2004 Baseline Period to 2005-2009 Progress Period
20% Most Impaired Days

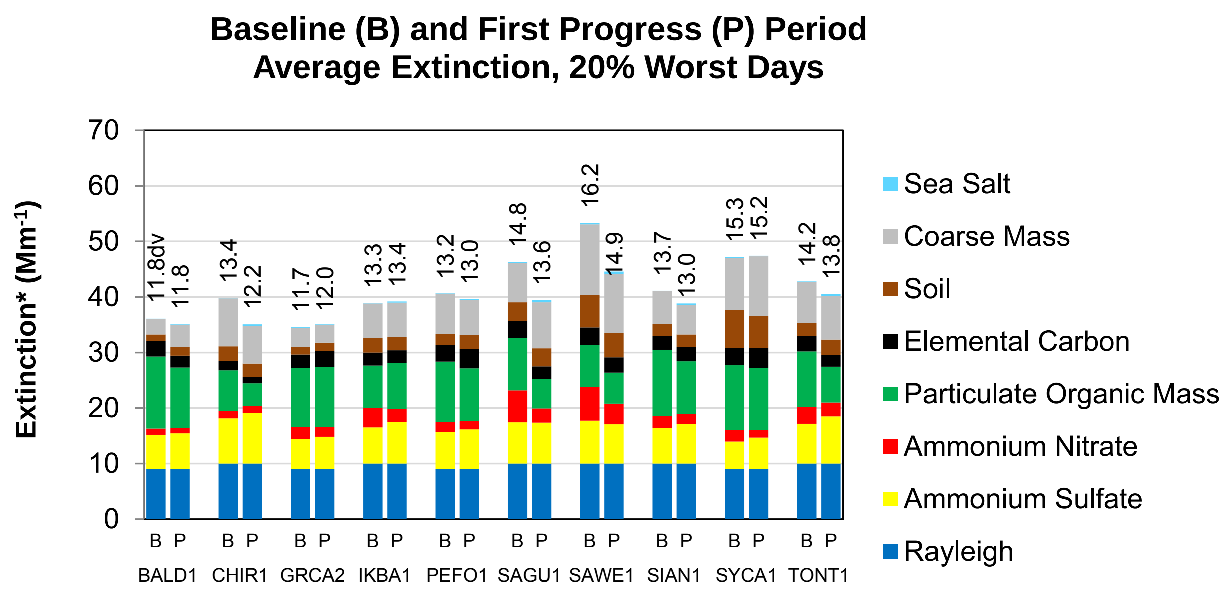
Site	Deciview (dv)			Change in Extinction by Species (Mm^{-1})*						
	2000-2004 Baseline Period	2005-2009 Progress Period	Change in dv*	Amm. Sulfate	Amm. Nitrate	POM	EC	Soil	CM	Sea Salt
BALD1	11.8	11.8	0.0	+0.3	-0.1	-2.1	-0.7	+0.4	+1.3	+0.1
CHIR1	13.4	12.2	-1.2	+1.0	-0.1	-3.2	-0.5	-0.3	-1.9	+0.2
GRCA2	11.7	12.0	+0.3	+0.5	-0.4	+0.1	+0.5	+0.1	-0.3	0.0
IKBA1	13.3	13.4	+0.1	+1.0	-1.2	+0.7	0.0	-0.3	0.0	+0.1
PEFO1	13.2	13.0	-0.2	+0.5	-0.3	-1.4	+0.5	+0.6	-1.0	+0.1
SAGU1	14.8	13.6	-1.2	-0.1	-3.2	-4.1	-0.9	-0.1	+1.2	+0.2
SAWE1	16.2	14.9	-1.3	-0.7	-2.3	-1.9	-0.5	-1.4	-2.2	+0.2
SIAN1	13.7	13.0	-0.7	+0.7	-0.3	-2.5	+0.1	+0.1	-0.6	+0.2
SYCA1	15.3	15.2	-0.1	+0.7	-0.7	-0.5	+0.4	-1.0	+1.4	0.0
TONT1	14.2	13.8	-0.4	+1.3	-0.5	-3.5	-0.6	+0.4	+0.5	+0.2

*Change is calculated as progress period average minus baseline period average. Values in red indicate increases in extinction and values in blue indicate decreases.

Table 6.2-5
Arizona Class I Area IMPROVE Sites
Difference in Aerosol Extinction by Species
2000-2004 Baseline Period to 2005-2009 Progress Period
20% Least Impaired Days

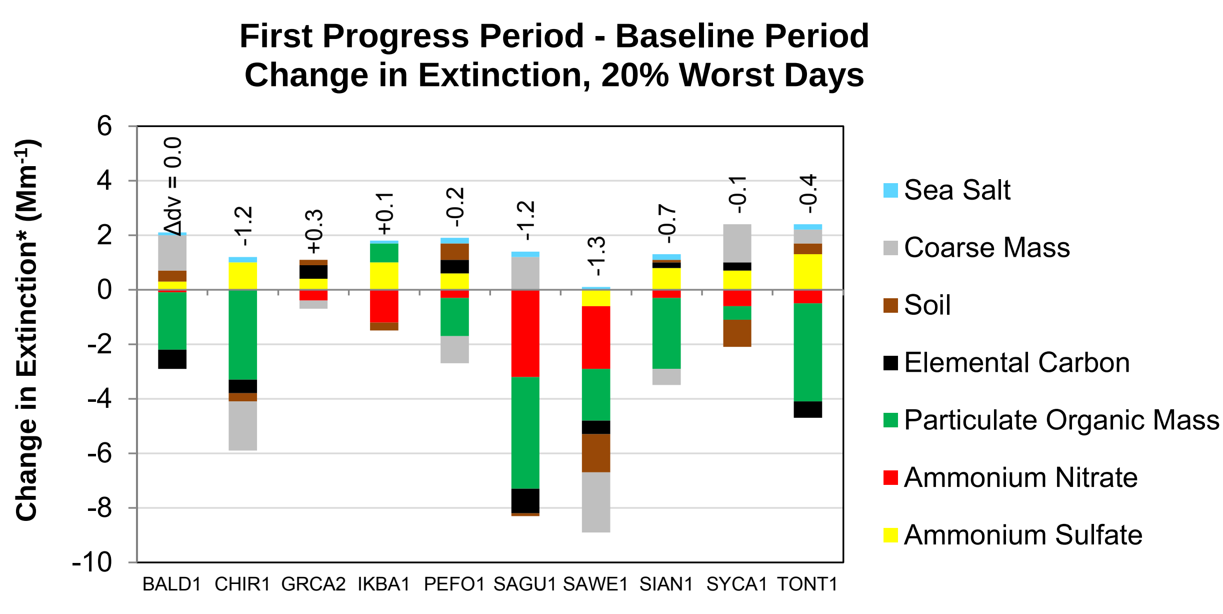
Site	Deciview (dv)			Change in Extinction by Species (Mm^{-1})*						
	2000-2004 Baseline Period	2005-2009 Progress Period	Change in dv*	Amm. Sulfate	Amm. Nitrate	POM	EC	Soil	CM	Sea Salt
BALD1	3.0	2.9	-0.1	0.0	-0.1	-0.1	0.0	0.0	+0.1	0.0
CHIR1	4.9	4.4	-0.5	-0.2	-0.1	-0.5	-0.1	0.0	0.0	0.0
GRCA2	2.2	2.2	0.0	+0.1	0.0	-0.1	0.0	0.0	0.0	0.0
IKBA1	5.4	5.1	-0.3	-0.3	-0.2	+0.1	0.0	-0.1	-0.1	+0.1
PEFO1	5.0	4.6	-0.4	-0.1	-0.2	-0.4	0.0	+0.1	0.0	0.0
SAGU1	6.9	6.7	-0.2	+0.1	-0.2	-0.2	-0.1	-0.3	+0.3	+0.1
SAWE1	8.6	8.0	-0.6	-0.2	-0.1	-0.5	-0.4	-0.3	+0.2	+0.2
SIAN1	6.2	5.3	-0.9	-0.3	-0.4	-0.7	-0.1	0.0	0.0	0.0
SYCA1	5.6	5.1	-0.5	+0.1	-0.1	-0.6	-0.2	-0.1	+0.1	0.0
TONT1	6.5	5.7	-0.8	-0.2	-0.2	-0.5	-0.2	-0.1	-0.2	+0.1

*Change is calculated as progress period average minus baseline period average. Values in red indicate increases in extinction and values in blue indicate decreases.



*Visibility impairment in deciviews (dv) is shown above respective bars.

Figure 6.2-5. Average Extinction for Baseline and Progress Period Extinction for Worst (Most Impaired) Days Measured at Arizona Class I Area IMPROVE Sites.



*Change in visibility impairment in deciviews (dv) is shown above respective bars.

Figure 6.2-6. Difference between Average Extinction for Current Progress Period (2005-2009) and Baseline Period (2000-2004) for the Worst (Most Impaired) Days Measured at Arizona Class I Area IMPROVE Sites.

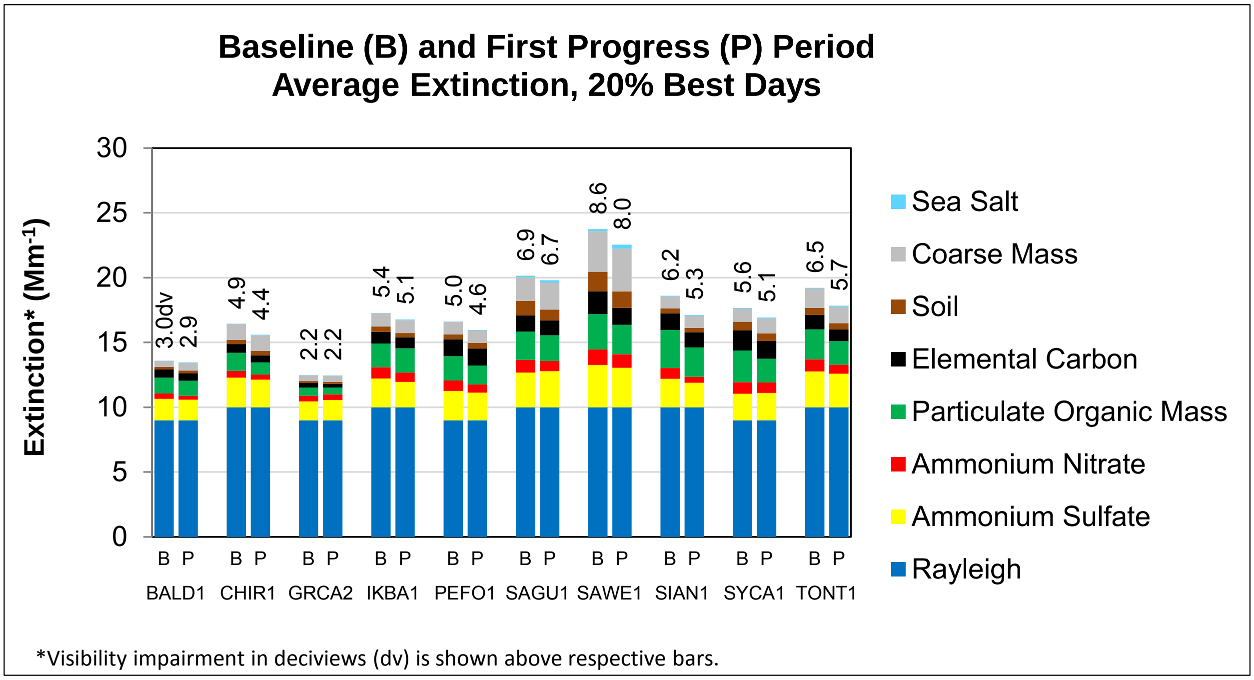


Figure 6.2-7. Average Extinction for Baseline and Progress Period Extinction for Best (Least Impaired) Days Measured at Arizona Class I Area IMPROVE Sites.

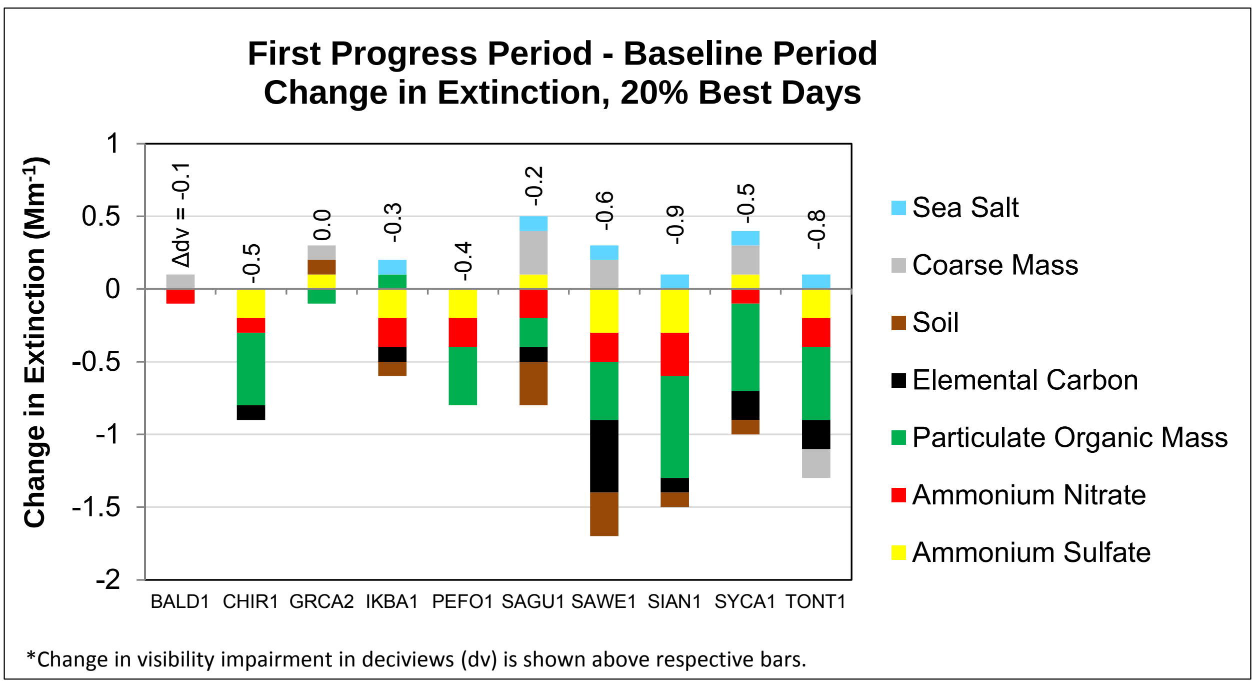


Figure 6.2-8. Difference between Average Extinction for Current Progress Period (2005-2009) and Baseline Period (2000-2004) for the Best (Least Impaired) Days Measured at Arizona Class I Area IMPROVE Sites.

6.2.1.4 Changes in Visibility Impairment

This section addresses the regulatory question, ***what is the change in visibility impairment for the most impaired and least impaired days over the past 5 years (40 CFR 51.308 (g)(3)(iii))?*** Included here are changes in visibility impairment as characterized by annual average trend statistics, and some general observations regarding local and regional events and outliers on a daily and annual basis that affected the current 5-year progress period. The regulatory requirement asks for a description of changes over the past 5-year period, but trend analysis is better suited to longer periods of time, so trends for the entire 10-year planning period are presented here.

Trend statistics for the years 2000-2009 for each species at each site in Arizona are summarized in Table 6.2-6, and regional trends were presented earlier in Section 4.1.1.[72] Only trends for aerosol species trends with p-value statistics less than 0.15 (85% confidence level) are presented in the table here, with increasing slopes in red and decreasing slopes in blue.[73] In some cases, trends may show decreasing tendencies while the difference between the 5-year averages do not (or vice versa), as discussed in Section 3.1.2.2. In these cases, the 5-year average for the best and worst days is the important metric for RHR regulatory purposes, but trend statistics may be of value to understand and address visibility impairment issues for planning purposes.

For each site, a more comprehensive list of all trends for all species, including the associated p-values, is provided in Appendix B. Additionally, this appendix includes plots depicting 5-year, annual, monthly, and daily average extinction for each site. These plots are intended to provide a fairly comprehensive compilation of reference information for individual states to investigate local and regional events and outliers that may have influenced changes in visibility impairment as tracked using the 5-year deciview metrics. Note that similar summary products are also available from the WRAP TSS website (http://vista.cira.colostate.edu/tss/). Some general observations regarding changes in visibility impairment at sites in Arizona are as follows:

- The 5-year deciview metric increased for the 20% worst days at both the GRCA2 and IKBA1 sites. No statistically significant increasing trends were calculated at these sites, and a statistically significant decreasing trend of ~0.1 Mm^{-1}/year was observed for annual average ammonium nitrate.
- 5-year average particulate organic mass decreased at most Arizona sites, with the exception of GRCA2 and IKBA1. Neither site showed increasing trends in particulate organic mass. Higher progress period measurements at GRCA2 were influenced by

[72] Annual trends were calculated for the years 2000-2009, with a trend defined as the slope derived using Theil statistics. Trends derived from Theil statistics are useful in analyzing changes in air quality data because these statistics can show the overall tendency of measurements over long periods of time, while minimizing the effects of year-to-year fluctuations which are common in air quality data. Theil statistics are also used in EPA's National Air EPA's National Air Quality Trends Reports (http://www.epa.gov/airtrends/) and the IMPROVE program trend reports (http://vista.cira.colostate.edu/improve/Publications/improve_reports.htm)

[73] The significance of the trend is represented with p-values calculated using Mann-Kendall trend statistics. Determining a significance level helps to distinguish random variability in data from a real tendency to increase or decrease over time, where lower p-values indicate higher confidence levels in the computed slopes.

large events between June and August of 2009. Higher progress period measurements at IKBA1 were influenced by large events in July 2005.

- 5-year average ammonium sulfate increased at all Arizona sites except SAGU1 and SAWE1, but no statistically significant increasing annual trends in ammonium sulfate were measured. Decreasing annual ammonium sulfate trends on the order of about 0.1 Mm^{-1}/year were measured at the BALD1, CHIR1, SAGU1, and SAWE1 sites. Anomalously high ammonium sulfate averages occurred in 2005 at most Arizona sites, which influenced the increases in the 5-year average metrics.
- The 5-year average ammonium nitrate metric decreased at all Arizona sites for the worst, and either remained the same or decreased for the best days. Analysis of all measured days showed no increasing trends, and decreasing trends on the order of 0.1 Mm^{-1}/year at the IKBA1, SAGU1, SAWE1, SIAN1, and TONT1 sites.
- The BALD1 and PEFO1 sites showed a statistically significant increasing trend for coarse mass for all measured days on the order of approximately 0.1 Mm^{-1}/year. Neither site saw an increase in 5-year deciview metric for either the best or worst day averages, and the PEFO1 site measured a decrease in 5-year average coarse mass.
- Soil measured highest at the SYCA1 and SAGU1 sites, and the 5-year average metric for soil decreased at these sites for both the worst and best days. For the annual average of all measured days, no increasing trends were apparent, and the SYCA1 site measured a statistically significant decreasing trend on the order of approximately 0.1 Mm^{-1}/year.

Table 6.2-6
Arizona Class I Area IMPROVE Sites
Change in Aerosol Extinction by Species
2000-2009 Annual Average Trends

Site	Group	Annual Trend* (Mm^{-1}/year)						
		Ammonium Sulfate	**Ammonium Nitrate**	**Particulate Organic Mass**	**Elemental Carbon**	**Soil**	**Coarse Mass**	**Sea Salt**
BALD1	20% Best	--	0.0	--	0.0	--	0.0	0.0
	20% Worst	**-0.2**	--	--	--	**0.1**	**0.3**	0.0
	All Days	**-0.1**	0.0	--	--	--	**0.1**	0.0
CHIR1	20% Best	0.0	0.0	**-0.1**	0.0	--	0.0	0.0
	20% Worst	--	--	**-0.7**	**-0.1**	--	--	0.0
	All Days	**-0.1**	0.0	**-0.2**	**-0.1**	--	**-0.1**	0.0
GRCA2	20% Best	--	--	--	0.0	--	--	0.0
	20% Worst	--	**-0.1**	--	--	--	--	--
	All Days	--	0.0	--	--	--	--	--
IKBA1	20% Best	**-0.1**	**-0.1**	0.0	0.0	0.0	--	0.0
	20% Worst	--	--	--	0.0	--	--	0.0
	All Days	--	**-0.1**	--	0.0	--	--	0.0
PEFO1	20% Best	--	0.0	**-0.1**	--	--	--	0.0
	20% Worst	--	--	--	--	**0.1**	--	0.0
	All Days	--	0.0	--	--	0.0	**0.1**	0.0
SAGU1	20% Best	--	**-0.1**	**-0.1**	--	--	--	--
	20% Worst	**-0.4**	**-0.5**	**-0.6**	**-0.3**	--	--	**0.1**
	All Days	**-0.1**	**-0.1**	**-0.2**	**-0.1**	--	--	0.0
SAWE1	20% Best	0.0	0.0	**-0.1**	**-0.1**	**-0.1**	--	0.0
	20% Worst	**-0.3**	**-0.6**	**-0.5**	--	--	--	0.0
	All Days	**-0.1**	**-0.1**	**-0.3**	**-0.1**	--	--	0.0
SIAN1	20% Best	**-0.1**	**-0.1**	**-0.1**	0.0	--	--	0.0
	20% Worst	--	--	--	--	--	--	0.0
	All Days	--	**-0.1**	**-0.4**	**-0.1**	--	--	0.0
SYCA1	20% Best	--	--	**-0.1**	--	--	--	0.0
	20% Worst	--	--	--	**0.1**	**-0.3**	--	--
	All Days	--	0.0	--	--	**-0.1**	--	--
TONT1	20% Best	**-0.1**	**-0.1**	**-0.1**	**-0.1**	--	**-0.1**	0.0
	20% Worst	--	**-0.1**	**-0.8**	**-0.2**	--	--	**0.1**
	All Days	--	**-0.1**	**-0.2**	**-0.1**	--	--	0.0

*(--) Indicates statistically insignificant trend (<85% confidence level). Annual averages and complete trend statistics for all significance levels are included for each site in Appendix B.

6.2.2 Emissions Data

Included here are summaries depicting differences between two emission inventory years that are used to represent the 5-year baseline and current progress periods. The baseline period is represented using a 2002 inventory developed by the WRAP for use in the initial WRAP state SIPs, and the progress period is represented by a 2008 inventory which leverages recent WRAP inventory work for modeling efforts, as referenced in Section 3.2.1. For reference, Table 6.2-7 lists the major emitted pollutants inventoried, the related aerosol species, some of the major sources for each pollutant, and some notes regarding implications of these pollutants. Differences between these baseline and progress period inventories, and a separate summary of annual emissions from electrical generating units (EGUs), are presented in this section.

Table 6.2-7
Arizona
Pollutants, Aerosol Species, and Major Sources

Emitted Pollutant	Related Aerosol	Major Sources	Notes
Sulfur Dioxide (SO_2)	Ammonium Sulfate	Point Sources; On- and Off-Road Mobile Sources	SO_2 emissions are generally associated with anthropogenic sources such as coal-burning power plants, other industrial sources such and refineries and cement plants, and both on- and off-road diesel engines.
Oxides of Nitrogen (NO_X)	Ammonium Nitrate	On- and Off-Road Mobile Sources; Point Sources; Area Sources	NO_X emissions are generally associated with anthropogenic sources. Common sources include virtually all combustion activities, especially those involving cars, trucks, power plants, and other industrial processes.
Ammonia (NH_3)	Ammonium Sulfate and Ammonium Nitrate	Area Sources; On-Road Mobile Sources	Gaseous NH_3 has implications in particle formation because it can form particulate ammonium. Ammonium is not directly measured by the IMPROVE program, but affects formation potential of ammonium sulfate and ammonium nitrate. All measured nitrate and sulfate is assumed to be associated with ammonium for IMPROVE reporting purposes.
Volatile Organic Compounds (VOCs)	Particulate Organic Mass (POM)	Biogenic Emissions; Vehicle Emissions; Area Sources	VOCs are gaseous emissions of carbon compounds, which are often converted to POM through chemical reactions in the atmosphere. Estimates for biogenic emissions of VOCs have undergone significant updates since 2002, so changes reported here are more reflective of methodology changes than actual changes in emissions (see Section 3.2.1).
Primary Organic Aerosol (POA)	POM	Wildfires; Area Sources	POA represents organic aerosols that are emitted directly as particles, as opposed to gases. Wildfires in the west generally dominate POA emissions, and large wildfire events are generally sporadic and highly variable from year-to-year.
Elemental Carbon (EC)	EC	Wildfires; On- and Off-Road Mobile Sources	Large EC events are often associated with large POM events during wildfires. Other sources include both on- and off-road diesel engines.
Fine Soil	Soil	Windblown Dust; Fugitive Dust; Road Dust; Area Sources	Fine soil is reported here as the crustal or soil components of $PM_{2.5}$.
Coarse Mass (PMC)	Coarse Mass	Windblown Dust; Fugitive Dust	Coarse mass is reported by the IMPROVE Network as the difference between PM_{10} and $PM_{2.5}$ mass measurements. Coarse mass is not separated by species in the same way that $PM_{2.5}$ is speciated, but these measurements are generally associated with crustal components. Similar to crustal $PM_{2.5}$, natural windblown dust is often the largest contributor to PMC.

6.2.2.1 Changes in Emissions

This section addresses the regulatory question, ***what is the change over the past 5 years in emissions of pollutants contributing to visibility impairment from all sources and activities within the State (40 CFR 51.308 (g)(4))?*** For these summaries, emissions during the baseline years are represented using a 2002 inventory, which was developed with support from the WRAP for use in the original RHR SIP strategy development (termed plan02d). Differences between inventories are represented as the difference between the 2002 inventory, and a 2008 inventory which leverages recent inventory development work performed by the WRAP for the WestJumpAQMS and Deterministic and Empirical Assessment of Smoke's Contribution to Ozone (DEASCO$_3$) modeling projects (termed WestJump2008). Note that the comparisons of differences between inventories does not necessarily reflect a change in emissions, as a number of methodology changes and enhancements have occurred between development of the individual inventories, as referenced in Section 3.2.1. Inventories for all major visibility impairing pollutants are presented for major source categories, and categorized as either anthropogenic or natural emissions. State-wide inventories totals and differences are presented here, and inventory totals on a county level basis are available on the WRAP Technical Support System website (http://vista.cira.colostate.edu/tss/).

Table 6.2-8 and Figure 6.2-9 present the differences between the 2002 and 2008 sulfur dioxide (SO_2) inventories by source category. Tables 6.2-9 and Figure 6.2-10 present data for oxides of nitrogen (NO_X), and subsequent tables and figures (Tables 6.2-10 through 6.2-15 and Figures 6.2-9 through 6.2-14) present data for ammonia (NH_3), volatile organic compounds (VOCs), primary organic aerosol (POA), elemental carbon (EC), fine soil and coarse mass. General observations regarding emissions inventory comparisons are listed below.

- The largest differences for point source inventories were decreases in SO_2 and NO_X. Note that this is consistent with decreasing annual EGU emissions as presented in Section 6.2.2.2.
- Area source inventories showed increases in all parameters except VOCs, with the largest increases in SO_2 and NO_X. These increases may be due to a combination of population changes and differences in methodologies used to estimate these emissions, as referenced in Section 3.2.1. One methodology change was the reclassification of some off-road mobile sources (such as some types of marine vessels and locomotives) into the area source category in 2008, which may have contributed to increases in area source inventory totals, but decreases in off-road mobile totals.
- On-road mobile source inventory comparisons showed decreases in most parameters, especially NO_X and VOCs, with slight increases in POA, EC and coarse mass. Reductions in NO_X and VOC are likely influenced by federal and state emissions standards that have already been implemented. The increases in POA, EC and coarse mass occurred in all of the WRAP states for on-road mobile inventories, regardless of reductions in NO_2 and VOCs, indicating that these increases were likely due use of different on-road models, as referenced in Section 3.2.1.

- Off-road mobile source inventories showed decreases in NO_X, SO_2, and VOCs, and increases in fine soil and coarse mass, which was consistent with most contiguous WRAP states. These differences were likely due to a combination of actual changes in source contributions and methodology differences, as referenced in Section 3.2.1. As noted previously, one major methodology difference was the reclassification of some off-road mobile sources (such as some types of marine vessels and locomotives) into the area source category in 2008, which may have contributed to decreases in the off-road inventory totals, but increases in area source totals.
- For most parameters, especially POAs, VOCs, EC, and fine soil, fire emission inventory estimates decreased. Note that these differences are not necessarily reflective of changes in monitored data, as the baseline period is represented by an average of 2000-2004 fire emissions, and the progress period is represented only by the fires that occurred in 2008, as referenced in Section 3.2.1.
- Comparisons between VOC inventories showed large decreases in biogenic emissions, which was consistent with other contiguous WRAP states. Estimates for biogenic emissions of VOCs have undergone significant updates since 2002, so changes reported here are more reflective of methodology changes than actual changes in emissions, as referenced in Section 3.2.1.
- Fine soil and coarse mass increased for the windblown dust inventory comparisons and the combined fugitive/road dust inventories. Large variability in changes in windblown dust was observed for the contiguous WRAP states, which was likely due in large part to enhancements in dust inventory methodology, as referenced in Section 3.2.1, rather than changes in actual emissions.

Table 6.2-8
Arizona
Sulfur Dioxide Emissions by Category

Source Category	Sulfur Dioxide Emissions (tons/year)		
	2002 (Plan02d)	2008 (WestJump2008)	Difference (Percent Change)
Anthropogenic Sources			
Point	94,716	79,136	-15,580
Area	2,677	3,678	1,001
On-Road Mobile	2,715	812	-1,904
Off-Road Mobile	4,223	673	-3,550
Area Oil and Gas	0	0	0
Fugitive and Road Dust	0	0	0
Anthropogenic Fire	190	668	478
Total Anthropogenic	**104,521**	**84,967**	**-19,554 (-19%)**
Natural Sources			
Natural Fire	4,369	187	-4,182
Biogenic	0	0	0
Wind Blown Dust	0	0	0
Total Natural	**4,369**	**187**	**-4,182 (-96%)**
All Sources			
Total Emissions	**108,890**	**85,154**	**-23,736 (-22%)**

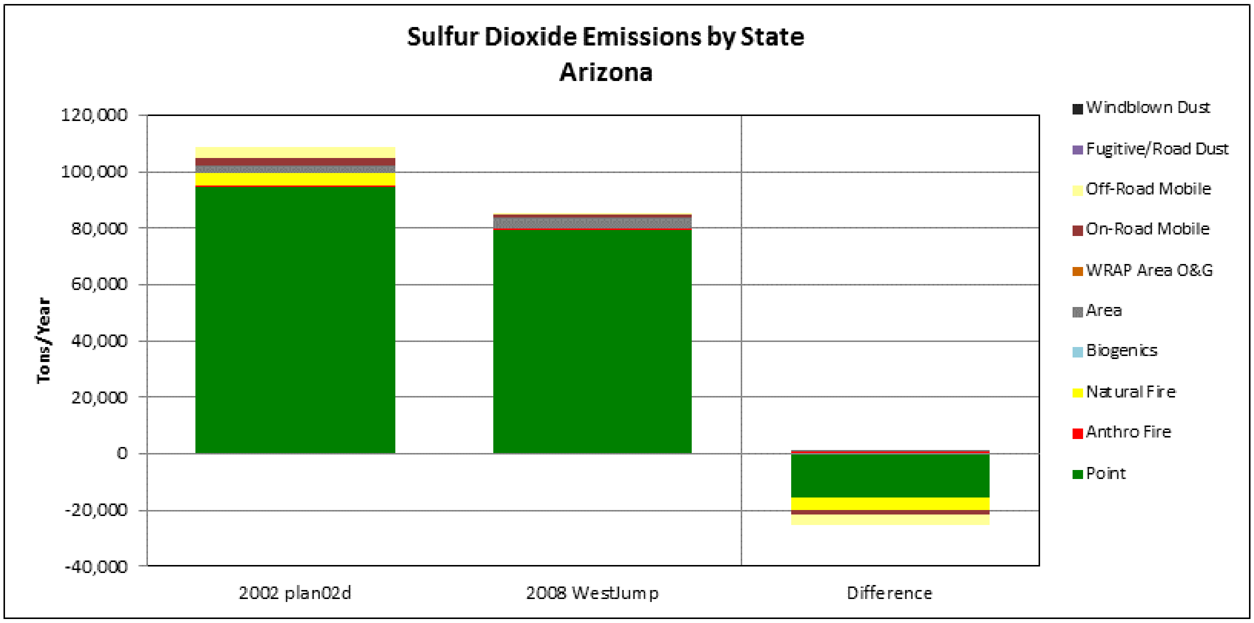


Figure 6.2-9. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Sulfur Dioxide by Source Category for Arizona.

Table 6.2-9
Arizona
Oxides of Nitrogen Emissions by Category

Source Category	Oxides of Nitrogen Emissions (tons/year)		
	2002 (Plan02d)	**2008 (WestJump2008)**	**Difference (Percent Change)**
Anthropogenic Sources			
Point	69,968	60,876	-9,092
Area	9,049	39,403	30,354
On-Road Mobile	178,009	137,555	-40,453
Off-Road Mobile	66,414	33,857	-32,557
Area Oil and Gas	17	0	-17
Fugitive and Road Dust	0	0	0
Anthropogenic Fire	725	4,713	3,988
Total Anthropogenic	**324,182**	**276,405**	**-47,777 (-15%)**
Natural Sources			
Natural Fire	16,493	1,319	-15,174
Biogenic	27,664	15,256	-12,408
Wind Blown Dust	0	0	0
Total Natural	**44,157**	**16,575**	**-27,582 (-62%)**
All Sources			
Total Emissions	**368,339**	**292,980**	**-75,359 (-20%)**

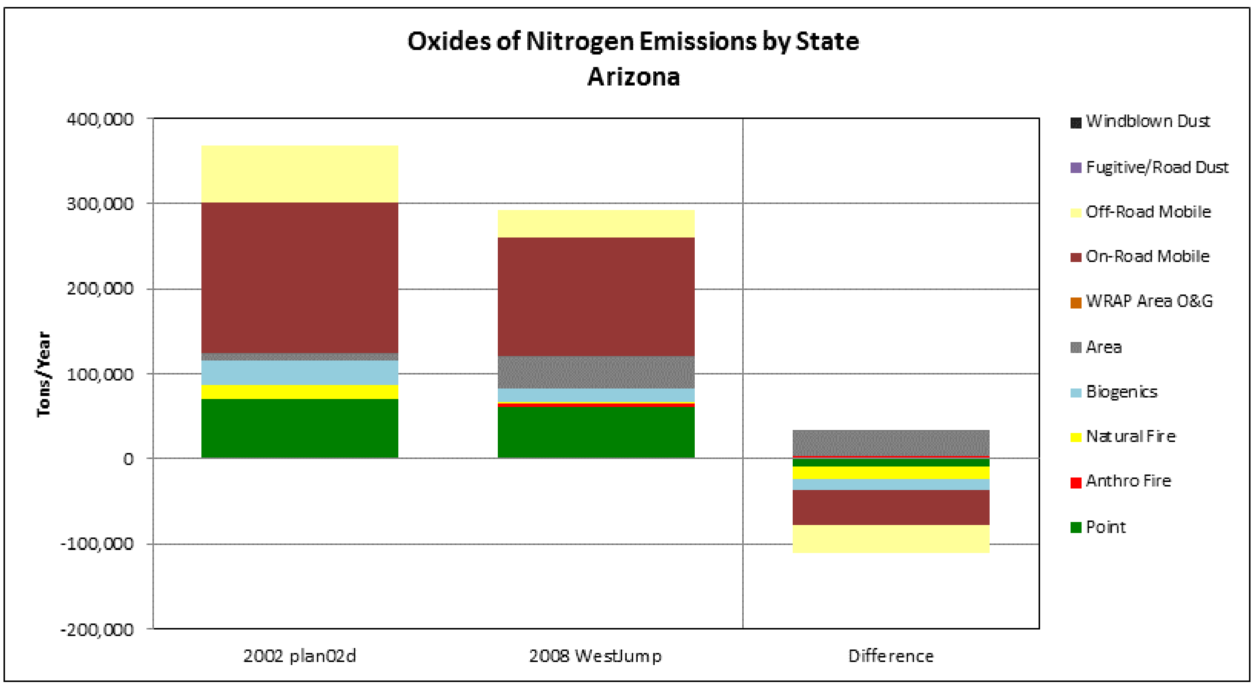


Figure 6.2-10. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Oxides of Nitrogen by Source Category for Arizona.

Table 6.2-10
Arizona
Ammonia Emissions by Category

Source Category	Ammonia Emissions (tons/year)		
	2002 (Plan02d)	**2008 (WestJump2008)**	**Difference (Percent Change)**
Anthropogenic Sources			
Point	531	973	443
Area	32,713	34,878	2,165
On-Road Mobile	5,035	2,377	-2,658
Off-Road Mobile	48	40	-8
Area Oil and Gas	0	0	0
Fugitive and Road Dust	0	0	0
Anthropogenic Fire	97	3,273	3,181
Total Anthropogenic	**38,423**	**41,546**	**3,123 (8%)**
Natural Sources			
Natural Fire	3,781	912	-2,869
Biogenic	0	0	0
Wind Blown Dust	0	0	0
Total Natural	**3,781**	**912**	**-2,869 (-76%)**
All Sources			
Total Emissions	**42,203**	**42,457**	**254 (1%)***

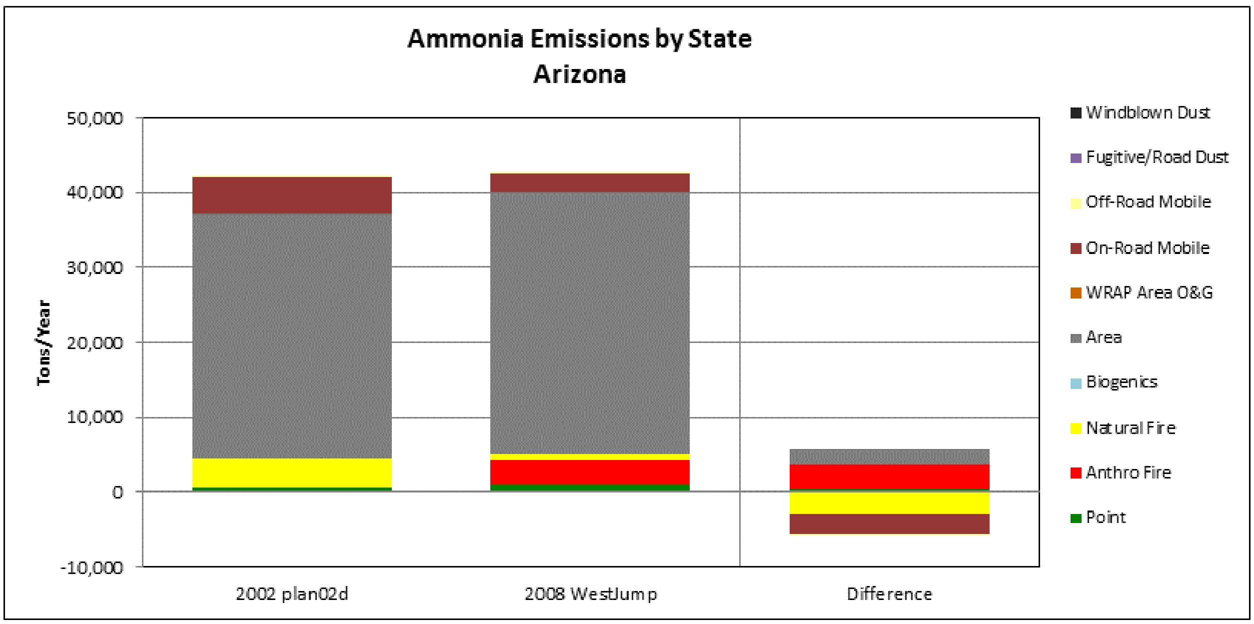


Figure 6.2-11. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Ammonia by Source Category for Arizona.

Table 6.2-11
Arizona
Volatile Organic Compound Emissions by Category

Source Category	Volatile Organic Compound Emissions (tons/year)		
	2002 (Plan02d)	2008 (WestJump2008)	Difference (Percent Change)
Anthropogenic Sources			
Point	5,464	3,490	-1,974
Area	102,918	100,256	-2,661
On-Road Mobile	110,424	54,589	-55,834
Off-Road Mobile	56,901	42,297	-14,604
Area Oil and Gas	46	12	-34
Fugitive and Road Dust	0	0	0
Anthropogenic Fire	855	5,781	4,926
Total Anthropogenic	**276,608**	**206,426**	**-70,182 (-25%)**
Natural Sources			
Natural Fire	36,377	1,330	-35,047
Biogenic	1,576,698	686,255	-890,443
Wind Blown Dust	0	0	0
Total Natural	**1,613,075**	**687,585**	**-925,490 (-57%)**
All Sources			
Total Emissions	**1,889,682**	**894,011**	**-995,672 (-53%)**

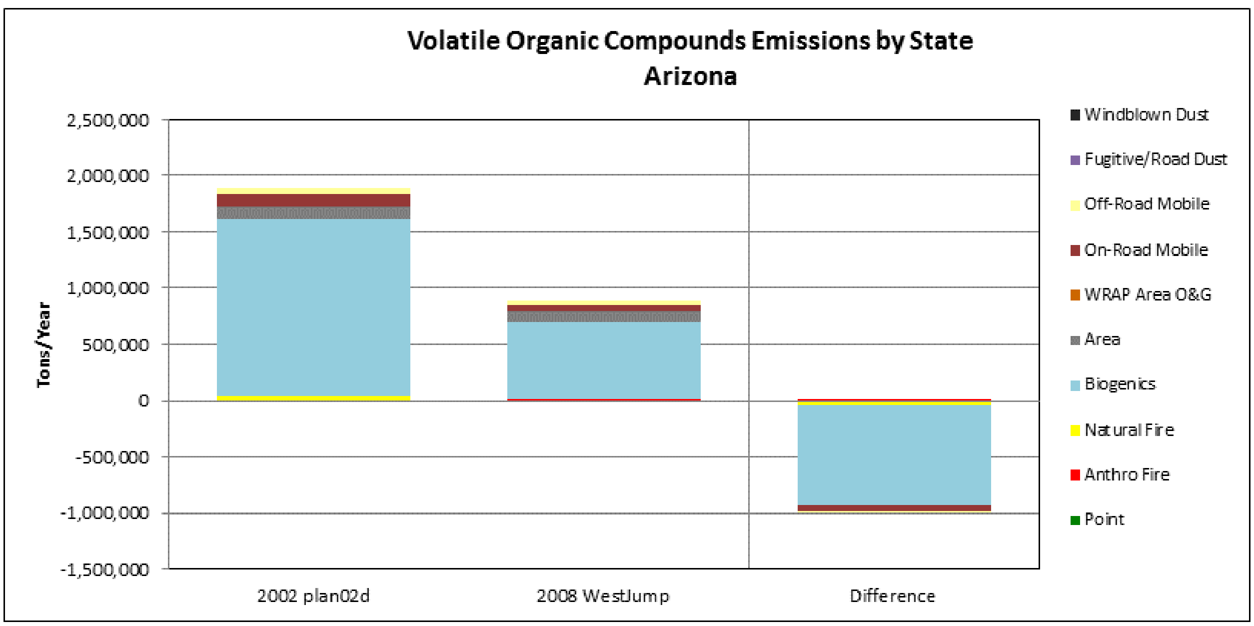


Figure 6.2-12. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Volatile Organic Compounds by Source Category for Arizona.

Table 6.2-12
Arizona
Primary Organic Aerosol Emissions by Category

Source Category	**Primary Organic Aerosol Emissions (tons/year)**		
	2002 (Plan02d)	**2008 (WestJump2008)**	**Difference (Percent Change)**
Anthropogenic Sources			
Point*	276	143	-134
Area	4,728	6,445	1,718
On-Road Mobile	1,583	2,666	1,083
Off-Road Mobile	2,006	1,383	-624
Area Oil and Gas	0	0	0
Fugitive and Road Dust	535	1,393	858
Anthropogenic Fire	816	9,818	9,002
Total Anthropogenic	**9,944**	**21,848**	**11,904 (>100%)**
Natural Sources			
Natural Fire	47,810	2,124	-45,685
Biogenic	0	0	0
Wind Blown Dust	0	0	0
Total Natural	**47,810**	**2,124**	**-45,685 (-96%)**
All Sources			
Total Emissions	**57,754**	**23,972**	**-33,782 (-58%)**

*Point source data includes only oil and gas and regulated CEM sources. More comprehensive point source data were not available at the time this report was prepared but will be made available through the WRAP TSS (http://vista.cira.colostate.edu/tss/).

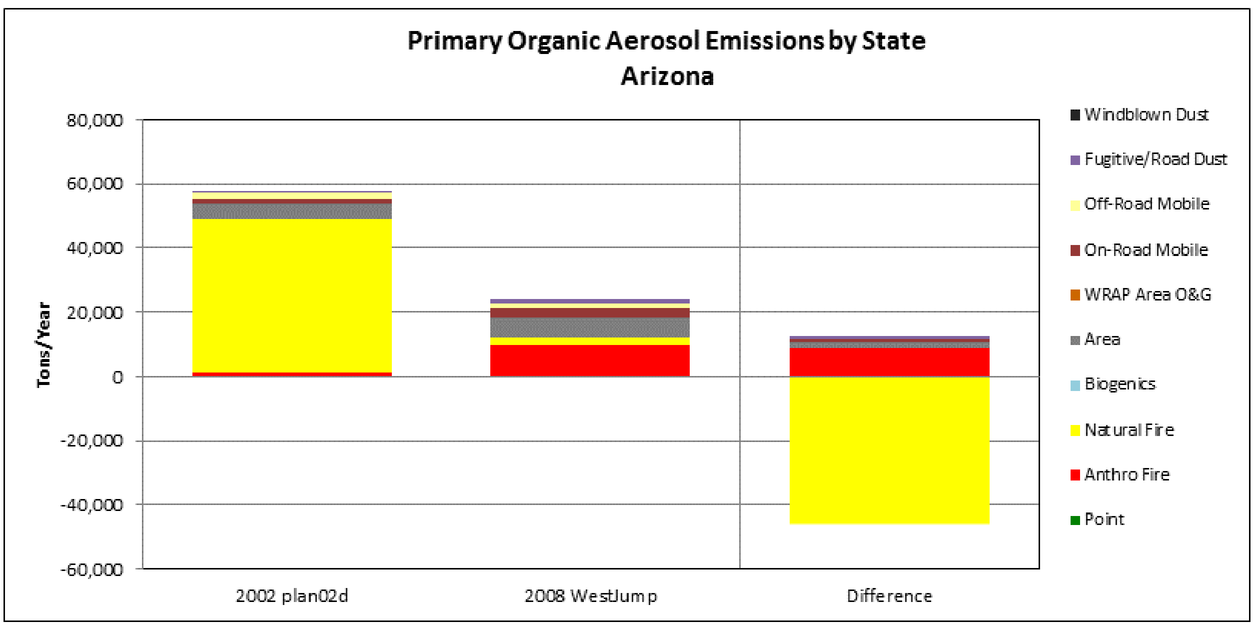


Figure 6.2-13. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Primary Organic Aerosol by Source Category for Arizona.

Table 6.2-13
Arizona
Elemental Carbon Emissions by Category

Source Category	Elemental Carbon Emissions (tons/year)		
	2002 (Plan02d)	2008 (WestJump2008)	Difference (Percent Change)
Anthropogenic Sources			
Point*	26	37	11
Area	449	1,337	889
On-Road Mobile	1,761	5,559	3,798
Off-Road Mobile	2,752	1,813	-940
Area Oil and Gas	0	0	0
Fugitive and Road Dust	39	47	8
Anthropogenic Fire	149	1,582	1,433
Total Anthropogenic	**5,176**	**10,375**	**5,199 (>100%)**
Natural Sources			
Natural Fire	9,570	415	-9,155
Biogenic	0	0	0
Wind Blown Dust	0	0	0
Total Natural	**9,570**	**415**	**-9,155 (-96%)**
All Sources			
Total Emissions	**14,745**	**10,789**	**-3,956 (-27%)**

*Point source data includes only oil and gas and regulated CEM sources. More comprehensive point source data were not available at the time this report was prepared but will be made available through the WRAP TSS (http://vista.cira.colostate.edu/tss/).

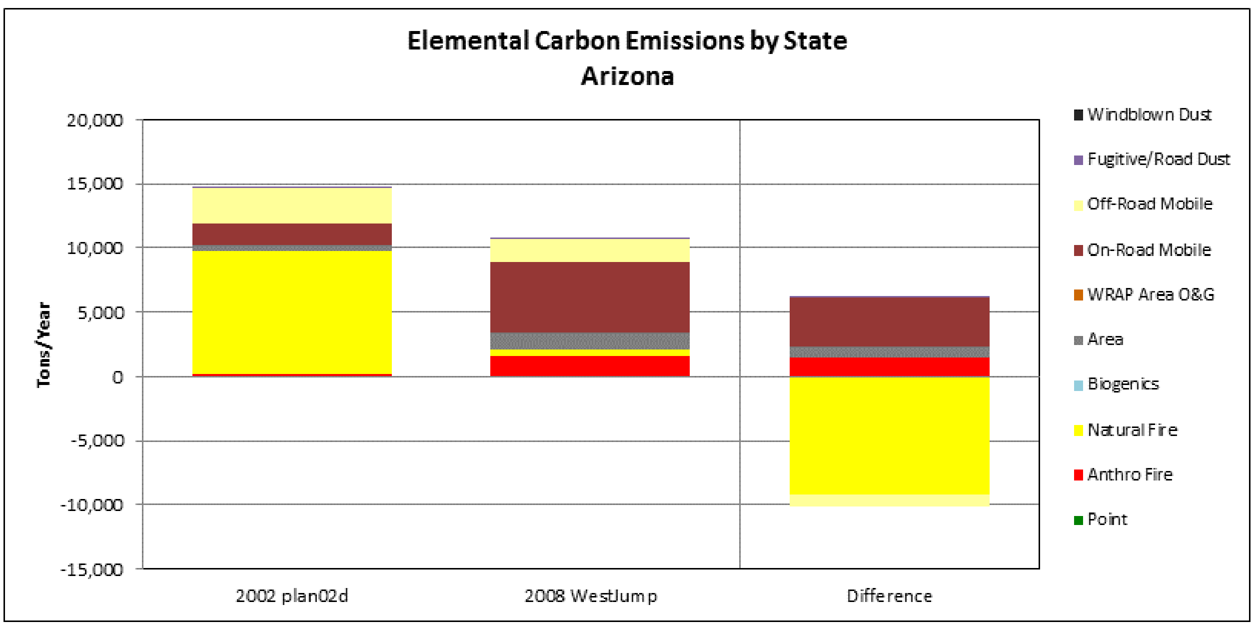


Figure 6.2-14. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Elemental Carbon by Source Category for Arizona.

Table 6.2-14
Arizona
Fine Soil Emissions by Category

Source Category	Fine Soil Emissions (tons/year)		
	2002 (Plan02d)	2008 (WestJump2008)	Difference (Percent Change)
Anthropogenic Sources			
Point*	632	1,515	883
Area	4,223	7,906	3,684
On-Road Mobile	1,080	511	-569
Off-Road Mobile	0	97	97
Area Oil and Gas	0	0	0
Fugitive and Road Dust	10,072	24,592	14,520
Anthropogenic Fire	100	3,584	3,484
Total Anthropogenic	**16,107**	**38,205**	**22,098 (>100%)**
Natural Sources			
Natural Fire	3,845	776	-3,069
Biogenic	0	0	0
Wind Blown Dust	6,422	9,307	2,885
Total Natural	**10,267**	**10,083**	**-183 (-2%)**
All Sources			
Total Emissions	**26,373**	**48,288**	**21,915 (83%)**

*Point source data includes only oil and gas and regulated CEM sources. More comprehensive point source data were not available at the time this report was prepared but will be made available through the WRAP TSS (http://vista.cira.colostate.edu/tss/).

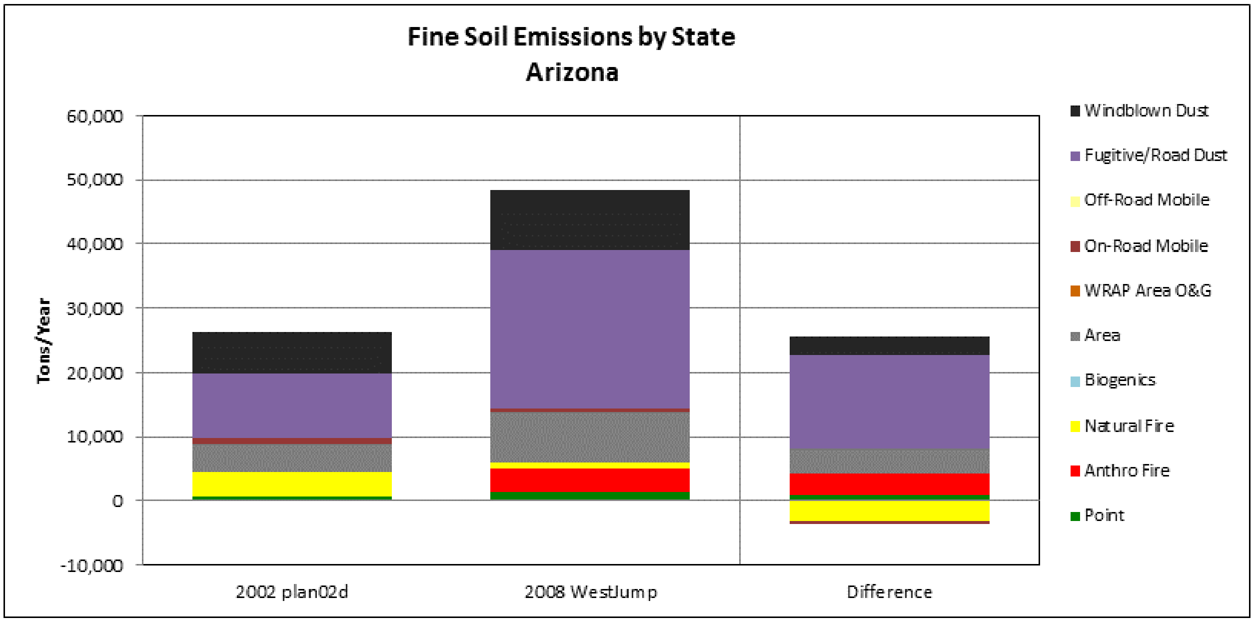


Figure 6.2-15. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Fine Soil by Source Category for Arizona.

Table 6.2-15
Arizona
Coarse Mass Emissions by Category

Source Category	Coarse Mass Emissions (tons/year)		
	2002 (Plan02d)	2008 (WestJump2008)	Difference (Percent Change)
Anthropogenic Sources			
Point*	8,473	4,406	-4,068
Area	1,384	2,389	1,005
On-Road Mobile	1,004	5,597	4,593
Off-Road Mobile	0	162	162
Area Oil and Gas	0	0	0
Fugitive and Road Dust	79,316	141,117	61,801
Anthropogenic Fire	17	1,873	1,856
Total Anthropogenic	**90,195**	**155,545**	**65,350 (72%)**
Natural Sources			
Natural Fire	10,107	403	-9,704
Biogenic	0	0	0
Wind Blown Dust	57,796	83,765	25,969
Total Natural	**67,904**	**84,169**	**16,265 (24%)**
All Sources			
Total Emissions	**158,099**	**239,714**	**81,615 (52%)**

*Point source data includes only oil and gas and regulated CEM sources. More comprehensive point source data were not available at the time this report was prepared but will be made available through the WRAP TSS (http://vista.cira.colostate.edu/tss/).

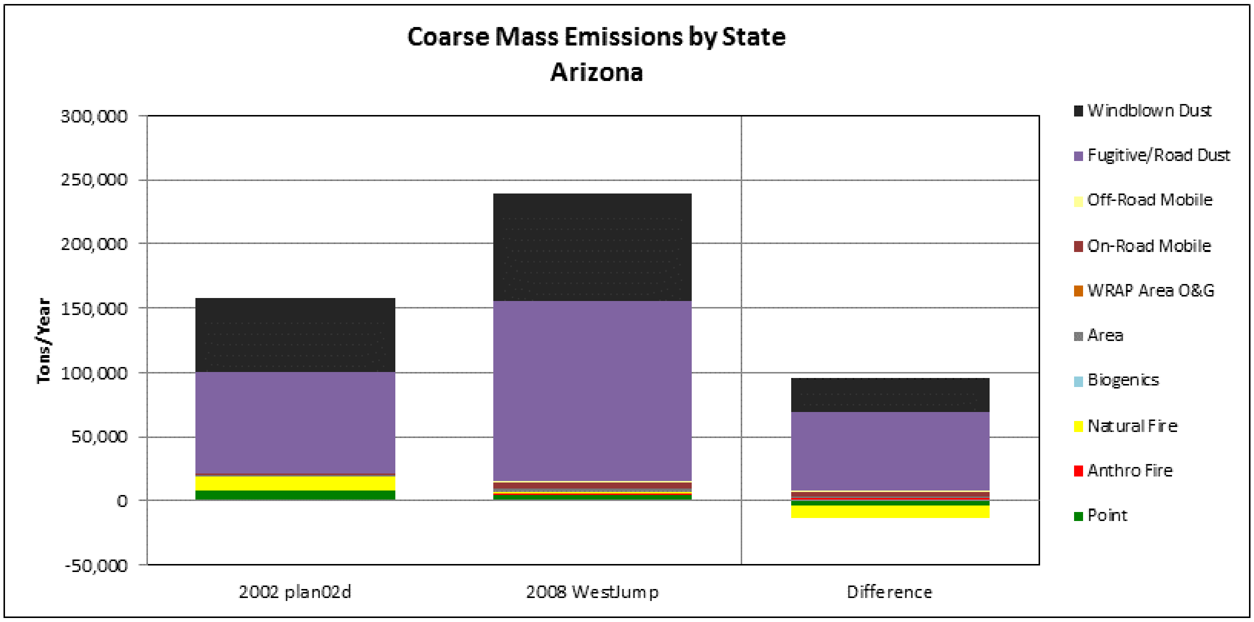


Figure 6.2-16. 2002 and 2008 Emission and Difference between Emissions Inventory Totals, for Coarse Mass by Source Category for Arizona.

6.2.2.2 EGU Summary

As described in previous sections, differences between the baseline and progress period inventories presented here do not necessarily represent changes in actual emissions because numerous updates in inventory methodologies have occurred between the development of the separate inventories. Also, the 2002 baseline and 2008 progress period inventories represent only annual snapshots of emissions estimates, which may not be representative of entire 5-year monitoring periods compared. To better account for year-to-year changes in emissions, annual emission totals for Arizona electrical generating units (EGU) are also presented. EGU emissions are some of the more consistently reported emissions, as tracked in EPA's Air Markets Program Database for permitted Title V facilities in the state (http://ampd.epa.gov/ampd/). RHR implementation plans are required to pay specific attention to certain major stationary sources, including EGUs, built between 1962 and 1977.

Figure 6.2-17 presents a sum of annual NO_X and SO_2 emissions as reported for Arizona EGU sources between 1996 and 2010. While these types of facilities are targeted for controls in state regional haze SIPs, it should be noted that many of the controls planned for EGUs in the WRAP states had not taken place yet in 2010, while other controls separate from the RHR may have been implemented. The chart shows a period of decline for SO_2 between 2003 and 2009. NO_X emissions have been decreasing fairly steadily since 2000. Reductions for both SO_2 and NO_X were interrupted by slight increases in 2007.

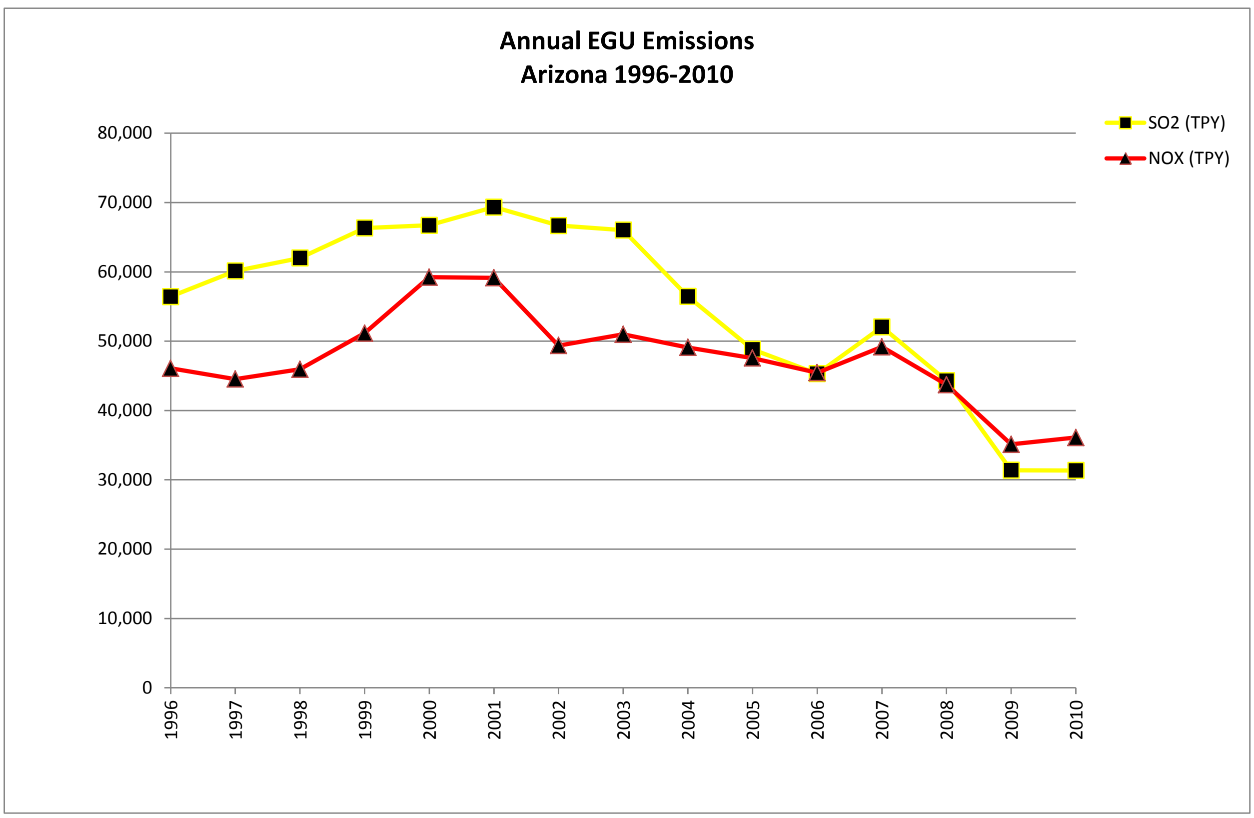


Figure 6.2-17. Sum of EGU Emissions of SO_2 and NOx Reported between 1996 and 2010 for Arizona.