4

Chapter Four – Jarbidge: Assessment of Visibility Conditions (40 CFR 51.308(g)(3))

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4.1 Status Summary

Current visibility conditions measured at JARB1, the IMPROVE monitor representing Nevada's only mandatory Class I area (the Jarbidge WA), are shown in Table 4-1. On the worst days, visibility impairment is strongly influenced by light extinction due to particulate organic matter, followed by coarse mass and sulfate. For the best days, visibility impairment is dominated by light extinction due to sulfate, followed by particulate organic matter and coarse mass. Annual conditions for the worst days show considerable variation from year to year, while the best days show much less variability.

> *51.308(g)(3) For each mandatory Class I Federal area within the State, the State must assess the following visibility conditions and changes, with values for most impaired and least impaired days expressed in terms of 5-year averages of these annual values.*
>
> *(i) The current visibility conditions for the most impaired and least impaired days;*
> *(ii) The difference between current visibility conditions for the most impaired and least impaired days and baseline conditions;*
> *(iii) The change in visibility impairment for the most impaired and least impaired days over the past 5 years.*

The dominant source categories for sulfur dioxide (precursor of sulfate) are anthropogenic. In contrast, the dominant source categories for the particulate organic matter precursors, VOCs and primary organic aerosols, are natural. For coarse mass, the source categories are roughly equally divided between anthropogenic and natural sources in the WestJump2008 inventory. Section 5.5 of Chapter Five details the source categories for the emitted visibility impairing pollutants.

Visibility conditions based on the rolling 5-year annual average haze index (in units of deciviews) have improved slightly for the worst days. Progress for the worst days is impeded by large contributions to visibility impairment by particulate organic matter. This is well illustrated by the huge contribution to visibility impairment from wildfires in 2012, which caused a corresponding spike in the 2008-2012 period for worst days. See Section 4.4. Better progress is shown for the best days. It is noteworthy that on the best days in both 2002 and 2018 source areas outside the jurisdiction of state or federal regulation and/or control (i.e., Outside Domain, Canada, Mexico and Pacific Offshore) contribute more than two thirds to the sulfate concentration at JARB1. 2009 RH SIP, Section 4.3.1.

Trend analyses of the period 2000 to 2012 show that visibility impairment due to sulfate and nitrate light extinction is decreasing through time for both the worst and best days. The trend lines fitted to the annual data have slopes comparable or better than, i.e., showing greater improvement, the respective speciated glide slopes for the Jarbidge WA. See Section 4.6 for additional discussion.

4.2 Visibility Conditions

40 CFR 51.308(g)(3) requires the state to assess the visibility conditions for the 20 percent most impaired (worst) and least impaired (best) days expressed in terms of the 5-year averages. The visibility conditions that must be reviewed include: 1) the current visibility conditions, 2) the difference between current visibility conditions compared to the baseline, and 3) the change in visibility impairment for the most and least impaired days over the past 5 years.

4.3 Current Visibility Conditions

This section addresses the requirement to report the current visibility conditions for the most impaired and least impaired days. 40 CFR 51.308 (g)(3)(i). The following sections discuss the differences between the most impaired and least impaired days, current versus baseline visibility conditions and trends.

Table 4-1 presents the annual visibility conditions at JARB1, the IMPROVE monitor representing Nevada's Class I area (the Jarbidge WA), for the current planning period represented by the 5-year period 2008 to 2012 as well as the 5-year annual averages for the haze index and light extinction by species (inverse megameters[1] or Mm-1). In its discussion of visibility conditions, the NDEP is using the period 2008 through 2012 to define visibility conditions for the current progress period. The term "current planning period" refers to this current, most-recent planning period. The WRAP TSD (WRAP 2013) also assessed Nevada's visibility conditions for the planning period 2005 through 2009. See Appendix A, Sections 6.8.1.1 and 6.8.1.2.

Table 4-1. Current Planning Period Annual Visibility Conditions and 5-Year Annual Averages for the Worst and Best Days Measured at JARB1

Year	Haze Index (dv)	Sulfate (Mm^{-1})	Nitrate (Mm^{-1})	POM (Mm^{-1})	EC (Mm^{-1})	Soil (Mm^{-1})	Coarse Mass (Mm^{-1})	Sea Salt (Mm^{-1})
Worst Days								
2008	12.5	3.72	1.12	12.06	1.48	2.61	4.84	0.04
2009	11.1	4.43	0.53	7.32	1.12	2.31	5.66	0.30
2010	10.0	3.30	1.04	4.33	0.77	2.49	5.66	0.06
2011	11.7	4.16	0.67	7.71	1.21	2.49	6.85	0.40
2012	14.9	3.87	1.18	23.97	3.11	2.63	5.17	0.21

[1] An inverse megameter is a unit of light extinction that can be directly related to gaseous and aerosol concentrations, while a deciview is a metric of haze proportional to the logarithm of the light extinction.

Year	Haze Index (dv)	Sulfate (Mm^{-1})	Nitrate (Mm^{-1})	POM (Mm^{-1})	EC (Mm^{-1})	Soil (Mm^{-1})	Coarse Mass (Mm^{-1})	Sea Salt (Mm^{-1})
Average	**12.0**	**3.9**	**0.9**	**11.1**	**1.5**	**2.5**	**5.6**	**0.2**
Best Days								
2008	1.9	1.14	0.22	0.23	0.09	0.12	0.27	0.05
2009	1.8	0.95	0.16	0.31	0.11	0.12	0.28	0.03
2010	1.8	1.09	0.15	0.30	0.12	0.06	0.24	0.03
2011	2.1	1.21	0.19	0.39	0.13	0.10	0.26	0.07
2012	2.0	0.95	0.18	0.37	0.18	0.10	0.37	0.04
Average	**1.9**	**1.1**	**0.2**	**0.3**	**0.1**	**0.1**	**0.3**	**0.0**

4.4 Differences between Current and Baseline Conditions

This section addresses 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).

Table 4-2 presents the five-year annual average baseline and successive five-year planning period visibility conditions measured at JARB1 and the differences between the baseline and current conditions represented by the period 2008 to 2012 in units of haze index and speciated light extinction. A negative difference indicates a reduction in haze, i.e., improved visibility. The haze index declined slightly for the worst days, but showed a much greater reduction for the best days. Monitored light extinction due to sulfate, nitrate, and elemental carbon has decreased between the baseline and progress periods for the worst days, while light extinction resulting from all the monitored species has remained the same or decreased for the best days. Recall that the baseline period is represented by the years 2000 to 2004. Note the emissions sources for VOCs and primary organic aerosols, particulate organic matter precursors, are predominantly natural, while emissions sources for fine soil and coarse mass are approximately equally split between natural and anthropogenic sources in the WestJump2008 inventory. See Chapter Five.

Table 4-2. 5-Year Annual Average Baseline and Visibility Conditions for Successive 5-Year Planning Periods for the Worst and Best Days Measured at JARB1

Planning Period	Haze Index (dv)	Sulfate (Mm^{-1})	Nitrate (Mm^{-1})	POM (Mm^{-1})	EC (Mm^{-1})	Soil (Mm^{-1})	Coarse Mass (Mm^{-1})	Sea Salt (Mm^{-1})
Worst Days								
Baseline	12.1	4.0	1.1	10.0	1.6	2.4	5.5	0.1
2005-2009	12.4	4.4	1.4	10.0	1.7	2.6	5.9	0.2
2006-2010	12.2	4.0	1.1	9.6	1.6	2.7	6.1	0.1
2007-2011	11.7	3.9	1.0	8.4	1.2	2.7	6.2	0.2
2008-2012	12.0	3.9	0.9	11.1	1.5	2.5	5.6	0.2

Planning Period	Haze Index (dv)	Sulfate (Mm^{-1})	Nitrate (Mm^{-1})	POM (Mm^{-1})	EC (Mm^{-1})	Soil (Mm^{-1})	Coarse Mass (Mm^{-1})	Sea Salt (Mm^{-1})
Difference*	-0.1	-0.1	-0.2	1.1	-0.1	0.1	0.1	0.1
Best Days								
Baseline	2.6	1.2	0.3	0.8	0.3	0.1	0.3	0.0
2005-2009	2.2	1.1	0.2	0.5	0.2	0.1	0.3	0.0
2006-2010	2.0	1.1	0.2	0.4	0.1	0.1	0.3	0.0
2007-2011	2.0	1.1	0.2	0.3	0.1	0.1	0.3	0.0
2008-2012	1.9	1.1	0.2	0.3	0.1	0.1	0.3	0.0
Difference*	-0.7	-0.1	-0.1	-0.5	-0.2	0.0	0.0	0.0

* Calculated as the difference between the baseline period and current conditions represented by the 2008-2012 period. A negative difference indicates a reduction in haze, i.e., improved visibility.

USEPA guidance (USEPA 2013) suggests states consider a chart of rolling 5-year averages of the annual averages to avoid any confusion or discussion regarding whether the proper current planning period has been identified. Table 4-3 presents the current visibility conditions as rolling 5-year averages of the annual conditions in deciviews. Figure 4-1 and Figure 4-2 present the 5-year baseline average visibility conditions, average annual visibility conditions, and the 5-year rolling averages for the 20 percent worst days and 20 percent best days, respectively.

USEPA also suggests it may be useful to include additional monitoring data such as organic species. Figure 4-3 and Figure 4-4 present the annual speciated light extinction for the 20 percent worst and 20 percent best days, respectively, and also show the annual haze index (deciviews) for the period spanning the baseline to the current planning period. These figures show the large variability from year to year in light extinction by species. For the worst days, the variability between years ranges from 0.4 Mm^{-1} for Sea Salt (sea salt) to more than 18 Mm^{-1} for particulate organic matter, and are two to three Mm^{-1} for the remaining species: sulfate, nitrate, elemental carbon, soil, and coarse mass. The strong influence of particulate organic matter on the year-to-year variability in visibility conditions on the worst days is clearly shown on Figure 4-3 by the visibility trend mimicking the particulate organic matter trends. Levels of particulate organic matter spiked in 2012 as a result of huge fire emissions that year, causing a corresponding spike in the 2008-2012 period for worst days. As can be seen in Figure 4-4, visibility on the best days is generally improving with time with little variability from year to year.

Table 4-3. Five-Year Rolling Annual Average Haze Index for Baseline and Successive Planning Periods Measured at JARB1 (deciview)

2000 - 2004 (baseline)	2005 - 2009	2006 - 2010	2007 - 2011	2008 - 2012	Natural Conditions
20% Worst Days					
12.1	12.4	12.2	11.7	12.0	7.9
20% Best Days					
2.6	2.2	2.0	2.0	1.9	1.1

Figure 4-1. Worst Days: Annual Haze Index with 5-Year Baseline Average and 5-Year Rolling Averages (deciview)

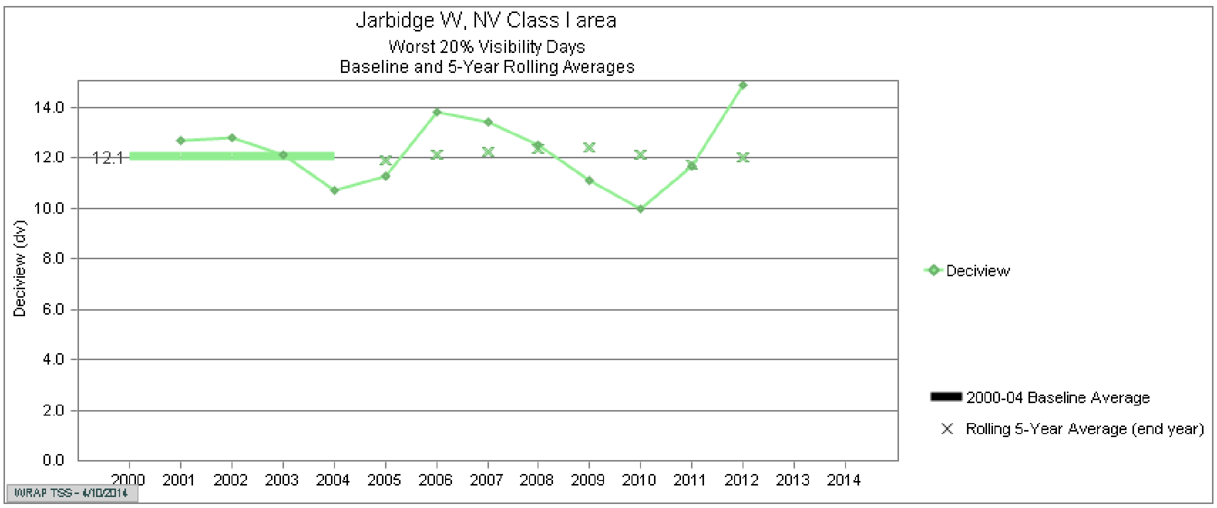


Figure 4-2. Best Days: Annual Haze Index with 5-Year Baseline Average and 5-Year Rolling Averages (deciview)

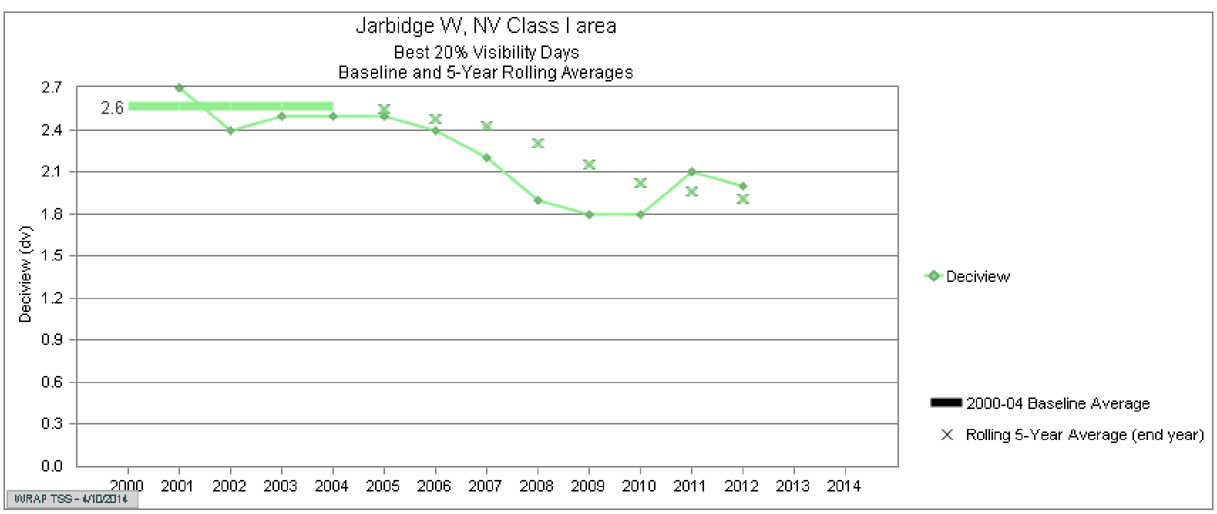


Figure 4-3. Worst Days: Average Annual Visibility Conditions at JARB1 Expressed in Deciviews and Speciated Light Extinction (Mm^{-1})

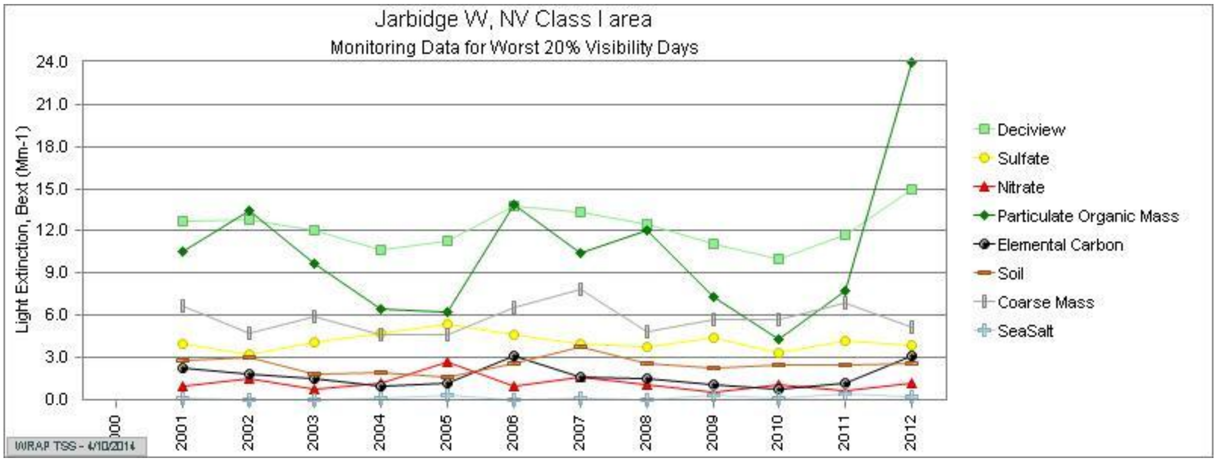


Figure 4-4. Best Days: Average Annual Visibility Conditions at JARB1 Expressed in Deciviews and Speciated Light Extinction (Mm^{-1})

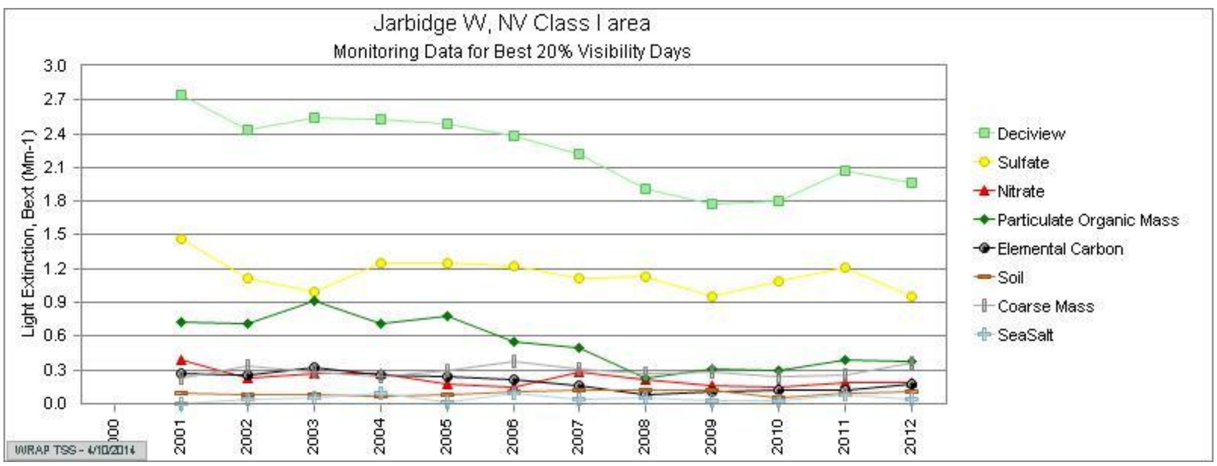


Figure 4-5 shows the differences between the 5-year average baseline speciated light extinction and the 5-year average speciated light extinction for each of the four successive progress periods on the worst days. Figure 4-6 presents the same information for the best days. For the worst days, the bars generally show the same contribution and magnitude for both the baseline and the current planning periods, although there are noticeable variations in visibility impairment due to particulate organic matter. For the best days, there is a noticeable reduction in visibility impairment due to sulfate, nitrate, particulate organic matter, and elemental carbon from the baseline to the current planning period with an overall reduction in visibility impairment on the best days.

Figure 4-5. Worst Days: Five-Year Average Speciated Light Extinction for Baseline and Successive 5-Year Planning Periods Measured at JARB1

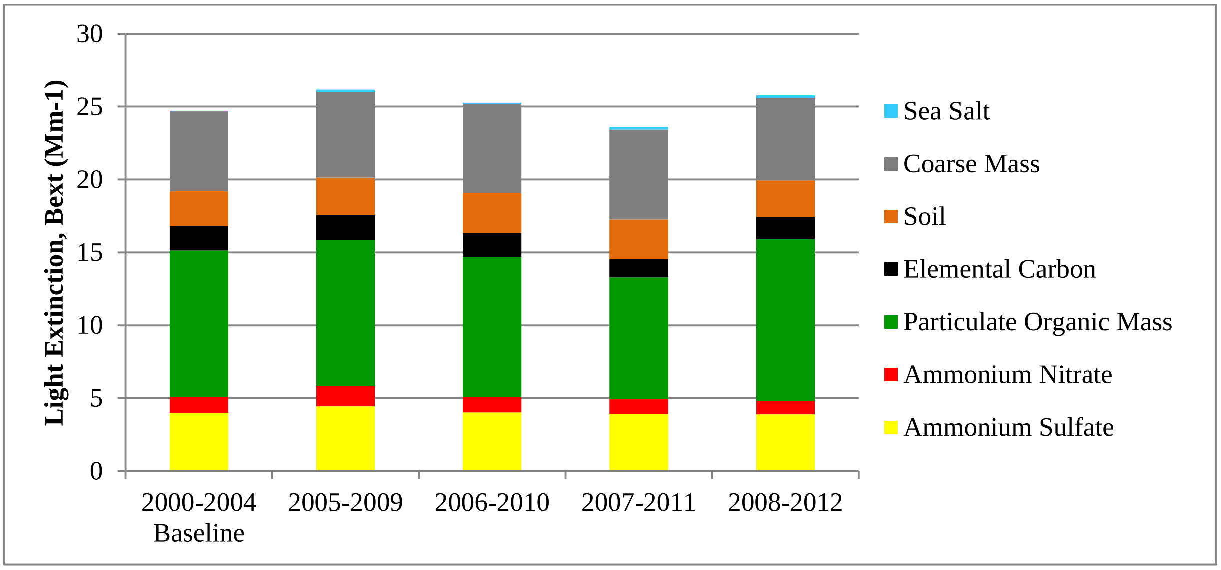


Figure 4-6. Best Days: Five-Year Average Speciated Light Extinction for Baseline and Successive 5-Year Planning Periods Measured at JARB1

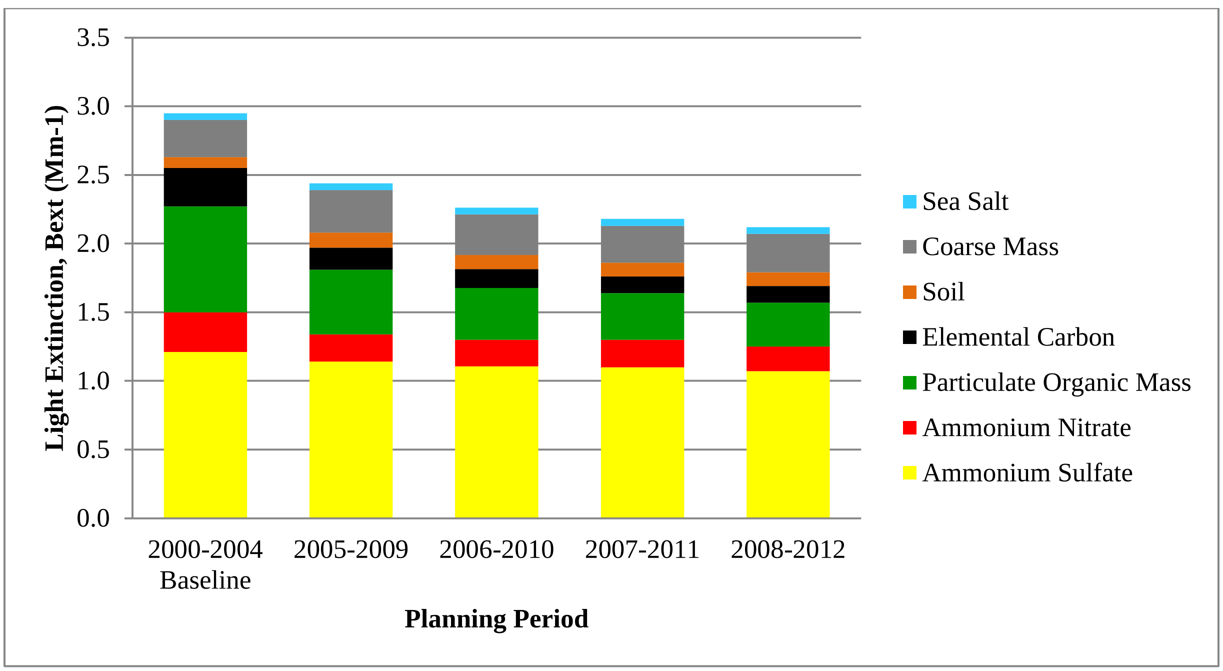


Table 4-4 presents the relative percentage contribution and rank of each species to worst and best day visibility impairment for the baseline and four subsequent planning periods as well as the 5-year average visibility impairment expressed in deciviews. The top three contributing species for each planning period are indicated on Table 4-4 by bold text.

For the worst days, particulate organic matter is by far the dominate contributor to visibility impairment for the baseline as well as all the subsequent planning periods, contributing between 35 and 43 percent of the visibility impairment. Particulate organic matter is followed by coarse mass, contributing between 22 and 26 percent of the impairment, and sulfate, contributing between 15 and 17 percent. Soil, elemental carbon, nitrate, and sea salt each contribute less to visibility impairment with contributions of roughly 10 percent for soil decreasing to less than one percent for sea salt.

For the best days, sulfate is the dominant contributor, contributing roughly 40 to 50 percent of the visibility impairment at JARB1. The sulfate contribution is most likely high because best days represent times when there are few emissions from natural sources, so emissions from anthropogenic source categories become more dominant. Although the percent contribution from sulfate increases from the baseline period to the progress period, Table 4-2 shows that monitored concentrations are in fact decreasing. Source apportionment modeling accessed in the TSS[2] indicates that Nevada emissions contribute only 12.4 percent to 15.4 percent to modeled sulfate concentrations at JARB1 on the best days for 2002 and 2018, respectively. 2009 RH SIP, Figures 4-10 and 4-11.

Particulate organic matter is the second largest contributor on best days with roughly a 25 percent contribution in the baseline period decreasing to 15 percent in the progress period. For the baseline period, nitrate is the third largest contributor with a contribution of roughly 10 percent, although elemental carbon and coarse mass also contribute roughly 10 percent each to baseline visibility impairment. Soil has a contribution of roughly three percent and sea salt roughly two percent during the baseline period. For the successive planning periods, the third largest contributor is coarse mass, contributing between 12 and 13 percent, followed by nitrate, contributing roughly eight to nine percent. Elemental carbon and soil contribute roughly six to seven percent and four to five percent, respectively. Sea salt contributes roughly two percent.

Although the ranking changes from worst days to best days, particulate organic matter, coarse mass, and sulfate are the three largest contributors to visibility impairment at JARB1 for the successive planning periods set forth in Figure 4-5 and Figure 4-6. As discussed in Chapter Five, emissions of VOCs and primary organic aerosols are primarily from non-anthropogenic sources. Gaseous VOCs are converted to particulate organic matter through chemical reactions in the atmosphere, while primary organic aerosols are emitted as particulate, both of these particulates are monitored as particulate organic matter. Roughly 40 percent of coarse mass emissions come from non-anthropogenic sources in the baseline period, while in the WestJump2008 inventory the source categories are roughly equally divided between anthropogenic and natural sources. SO_2, which combines with ammonia (NH_3) in the atmosphere to form ammonium sulfate, is the only one of the three largest contributors to visibility impairment at JARB1 that is dominantly

[2] http://vista.cira.colostate.edu/tss/, last viewed 8/25/2014.

emitted from anthropogenic sources; however, approximately two thirds of the sulfate monitored at JARB1 is attributed to sources out of Nevada's control (2009 RH SIP, Section 4.3.1).

Table 4-4. Average Visibility Conditions by Species for the Successive 5-Year Progress Periods at JARB1

Planning Period	Haze Index (dv)	Percent Contribution to Aerosol Extinction by Species (Excludes Rayleigh) Expressed as % of Mm^{-1} and [Rank]*						
		Sulfate* (%)	Nitrate (%)	POM* (%)	EC (%)	Soil (%)	Coarse Mass* (%)	Sea Salt (%)
20% Worst Days								
2000 - 2004	12.1	**16.2 [3]**	4.4 [6]	**40.6 [1]**	6.7 [5]	9.7 [4]	**22.1 [2]**	0.2 [7]
2005 - 2009	12.4	**17.0 [3]**	5.3 [6]	**38.2 [1]**	6.6 [5]	9.8 [4]	**22.5 [2]**	0.6 [7]
2006 - 2010	12.2	**15.9 [3]**	4.2 [6]	**38.0 [1]**	6.4 [5]	10.8 [4]	**24.1 [2]**	0.4 [7]
2007 - 2011	11.7	**16.6 [3]**	4.2 [6]	**35.5 [1]**	5.3 [5]	11.6 [4]	**26.1 [2]**	0.7 [7]
2008 - 2012	12.0	**15.1 [3]**	3.5 [6]	**43.0 [1]**	6.0 [5]	9.7 [4]	**21.9 [2]**	0.8 [7]
20% Best Days								
2000 - 2004	2.6	**41.0 [1]**	**9.8 [3]**	**26.1 [2]**	9.5 [4]	2.7 [6]	9.2 [5]	1.7 [7]
2005 - 2009	2.2	**46.7 [1]**	8.2 [4]	**19.3 [2]**	6.6 [5]	4.5 [6]	**12.7 [3]**	2.0 [7]
2006 - 2010	2.0	**48.9 [1]**	8.6 [4]	**16.6 [2]**	6.1 [5]	4.6 [6]	**13.1 [3]**	2.1 [7]
2007 - 2011	2.0	**50.5 [1]**	9.2 [4]	**15.6 [2]**	5.5 [5]	4.6 [6]	**12.4 [3]**	2.3 [7]
2008 - 2012	1.9	**50.5 [1]**	8.5 [4]	**15.1 [2]**	5.7 [5]	4.7 [6]	**13.2 [3]**	2.4 [7]

*Highest three aerosol species contributions per planning period are presented in bold font.

Table 4-5, drawing from the data in Table 4-2, presents the change in haze index as well as speciated light extinction from the baseline to the successive planning periods for both the worst and best days measured at JARB1. The change in light extinction is calculated as the planning period average minus the baseline period average. A negative difference indicates a reduction in haze, i.e., improved visibility. Figure 4-7 and Figure 4-8 portray these same data graphically for the worst and best days, respectively.

Table 4-5. Change in Aerosol Light Extinction by Species from 2000-2004 Baseline Period to Each Successive 5-Year Progress Period Measured at JARB1.*

Planning Period	Change in Haze Index (dv)	Change in Light Extinction by Species (Mm^{-1})						
		Sulfate	Nitrate	POM	EC	Soil	CM	Sea Salt
Worst Days								
2005 - 2009	0.3	0.44	0.30	*-0.04*	0.07	0.16	0.42	0.10
2006 – 2010	0.1	0.02	*-0.04*	*-0.43*	*-0.02*	0.33	0.63	0.04
2007 – 2011	*-0.4*	*-0.08*	*-0.10*	*-1.67*	*-0.41*	0.32	0.70	0.11
2008 - 2012	*-0.1*	*-0.10*	*-0.19*	1.04	*-0.11*	0.10	0.17	0.14
Best Days								
2005 - 2009	*-0.4*	*-0.07*	*-0.09*	*-0.30*	*-0.12*	0.03	0.04	0.00
2006 – 2010	*-0.6*	*-0.10*	*-0.10*	*-0.39*	*-0.14*	0.02	0.03	0.00
2007 – 2011	*-0.6*	*-0.11*	*-0.09*	*-0.43*	*-0.16*	0.02	0.00	0.00
2008 - 2012	*-0.7*	*-0.14*	*-0.11*	*-0.45*	*-0.16*	0.02	0.01	0.00

*Change in light extinction is calculated as the planning period average minus the baseline period average. Italicized, negative values indicate decreases in light extinction or improvement in visibility.

Table 4-5 shows that for the best days, visibility impairment decreases from baseline to planning period for the haze index, as well as light extinction due to sulfate, nitrate, particulate organic matter, and elemental carbon with 5-year each period, demonstrating continued improvements in visibility impairment with each successive 5-year planning period. Light extinction due to soil, coarse mass, and sea salt show little change between the baseline and planning periods.

Similarly, for the worst days, sulfate and nitrate show continued improvement beginning with the 2007 to 2010 and 2006 to 2010 planning periods, respectively. Sulfate and nitrate monitoring data measured at JARB1 during 2005 have some interesting characteristics that affect the 5-year averages and are discussed further in Section 4.5. Also noteworthy for the worst days is the large variability of impairment due to particulate organic matter light extinction, which demonstrates that one year of data can result in a difference of more than 2.5 Mm^{-1} in extinction from one 5-year planning period to the next (2007-2011 and 2008-2012). The haze index does not show any clear trends for the worst days due to the significant contributions to visibility impairment from particulate organic matter. Changes in light extinction due to elemental carbon, soil, coarse mass and sea salt varies from planning period to planning period.

Figure 4-7 presents the changes in speciated light extinction between 5-year planning periods and very clearly shows the variability between planning periods discussed above for worst days, particularly for particulate organic matter extinction. It also shows the reduction in sulfate and nitrate extinction for the most recent 5-year planning periods. Figure 4-8 shows the steady reduction of sulfate, nitrate, particulate organic matter, and elemental carbon contributions to light extinction with each successive planning period for the best days.

Figure 4-7. Worst Days: Change in 5-Year Average Light Extinction between Baseline and Successive Planning Periods Measured at JARB1

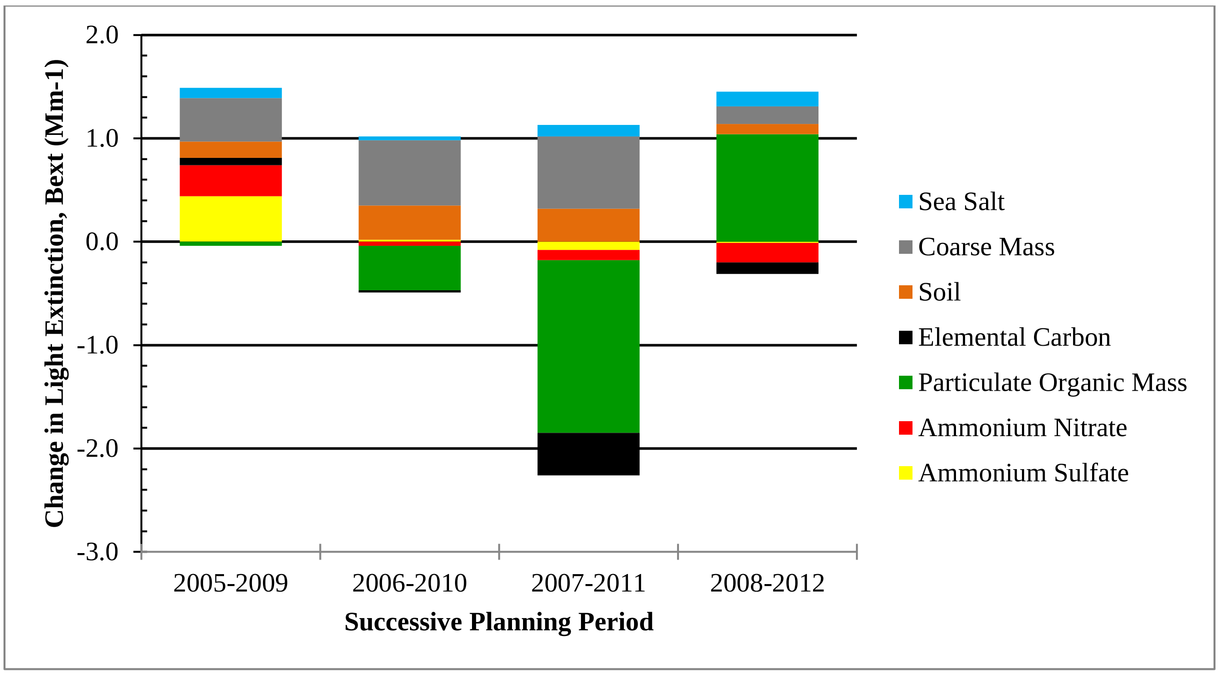
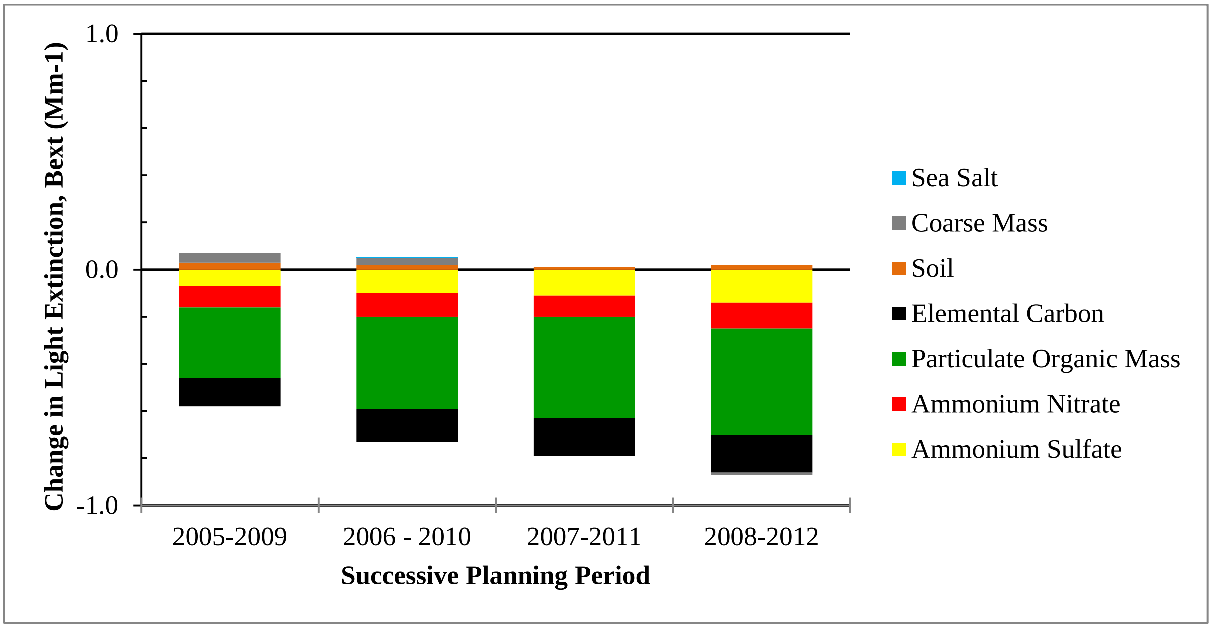


Figure 4-8. Best Days: Change in 5-Year Average Light Extinction between Baseline and Successive Planning Periods Measured at JARB1



4.5 Changes in Visibility Impairment

This section addresses 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).

The uniform rate of progress glidepath for Jarbidge WA is shown in Figure 4-9. The glidepath is one of the indicators used to set reasonable progress goals and is simply a graph portraying a straight line drawn from the level of visibility impairment for the worst days baseline period to the natural background level with 2064 as the attainment date. The glidepath in Figure 4-9 is represented by the sloping line with the open triangles identifying the uniform rate of progress at five year intervals. The uniform rate of progress value at Jarbidge in 2018 is 11.09 deciviews. The 2018 reasonable progress goal for Jarbidge WA is 11.05 deciviews. [3]

[3] See the discussion in Chapter One of the correction to the 2018 visibility projection for Jarbidge WA conducted by the Regional Modeling Center. Nevada concludes that it is reasonable to retain the reasonable progress goal of 11.05 deciviews, which aligns closely with the 2018 uniform rate of progress value for Jarbidge WA.

Figure 4-9. Uniform Rate of Progress Glidepath for the Jarbidge Wilderness Area

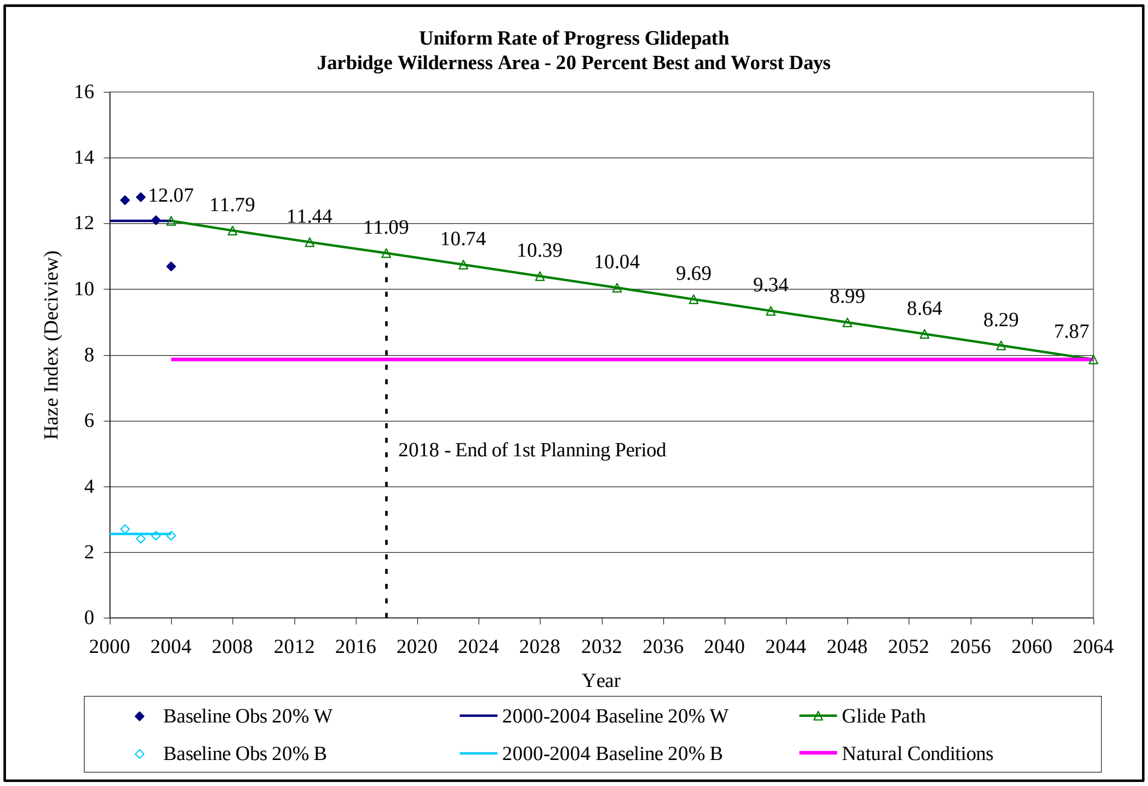


Table 4-6 presents the visibility change between the current and baseline worst days and best days, including the visibility changes as required by the RHR. It also compares worst days current conditions with the 2018 reasonable progress goal to show the percent progress achieved since the baseline using the 2008-2012 five-year average. Visibility impairment on the best days shows substantial improvement, while only modest progress is shown for the worst days due to significant contribution of particulate organic matter extinction, which results from emissions of VOCs and primary organic aerosols from natural sources.

Table 4-6. 2018 Reasonable Progress Goal Summary for JARB1

Best Days Baseline (dv)	Best Days 2008-2012 (dv)	Visibility Improvement (dv)	Worst Days Baseline (dv)	Worst Days 2008-2012 (dv)	Visibility Improvement (dv)	2018 RPG (dv)	Worst Days Progress to 2018 RPG by 2012
2.6	1.9	0.7	12.1	12.0	0.1	11.05	9.5%

Figure 4-10 and Figure 4-11 present the annual visibility conditions for the current planning period. Figure 4-10 shows the large year-to-year variability of particulate organic matter extinction for the worst days and its influence on the haze index as measured in deciviews. The large variability in particulate organic matter extinction during the 2008-2012 period overwhelms the relatively flat trends in all of the other species extinction for the 2008-2012 period when calculating the haze index. The annual extinction values for all of the monitored species other than particulate organic matter vary by 2.34 Mm^{-1} or less, whereas particulate organic matter varies by almost 20 Mm^{-1}. See Figure 4-1. The timelines representing the best days show much less year-to-year variability. See Figure 4-11.

Figure 4-10. Worst Days: Annual Visibility Conditions Measured at JARB1 for the Current Progress Period

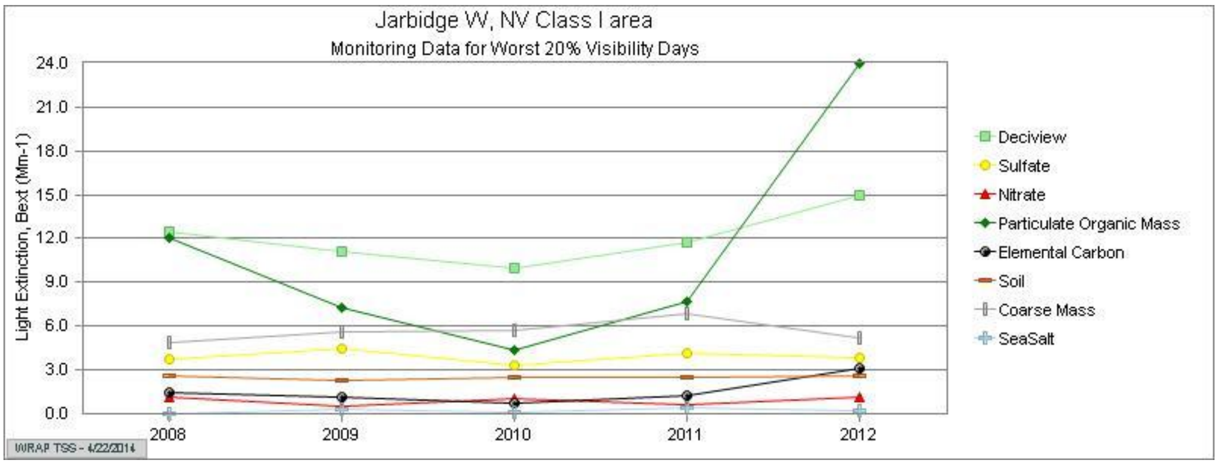
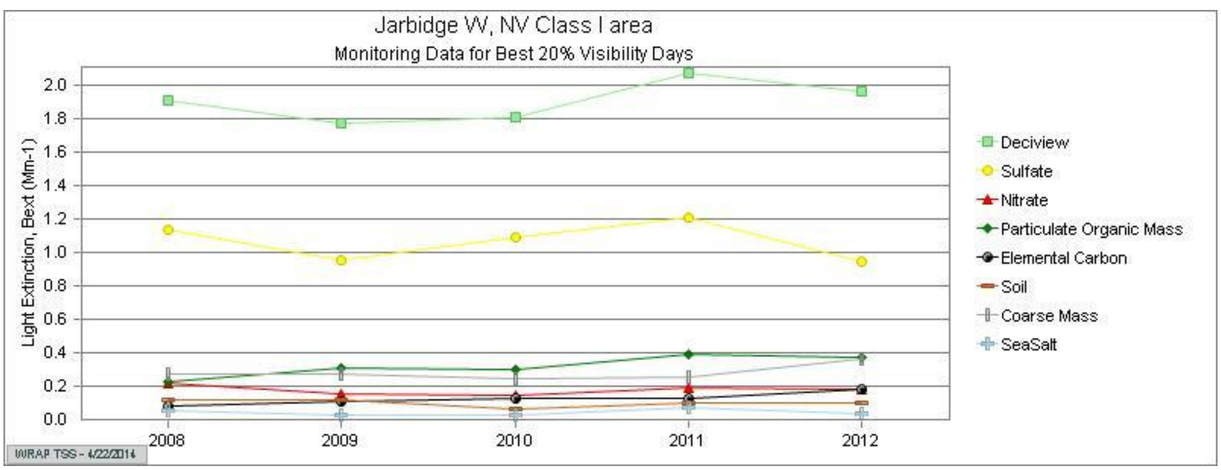


Figure 4-11. Best Days: Annual Visibility Conditions Measured at JARB1 for the Current Progress Period



4.6 Visibility Trends

This section discusses changes in visibility impairment as characterized by annual average trend statistics as well as rolling 5-year average trend statistics for sulfate and nitrate. The regulatory requirement calls for an analysis of change over the past 5-year period, but does not preclude looking at a longer time frame. Since trend analysis is better suited to longer periods of time, trends for the entire 13-year period, 2000 to 2012, are presented here. The trend lines represent linear regressions generated in Excel©.

Figure 4-12 presents the annual average sulfate light extinction trends for the worst days, all IMPROVE sampled days (all days), and the best days. The annual trends for the worst and best days are downward, indicating improvement in visibility impairment from light extinction due to sulfate. There is a slight upward trend for all days. The slope of the worst days trend line is -0.0187 Mm^{-1}/yr, comparable to the slope of the sulfate glideslope for Jarbidge WA from baseline conditions to natural conditions (-0.0533 Mm^{-1}/yr).

Figure 4-12. Annual Average Sulfate Light Extinction and Trends

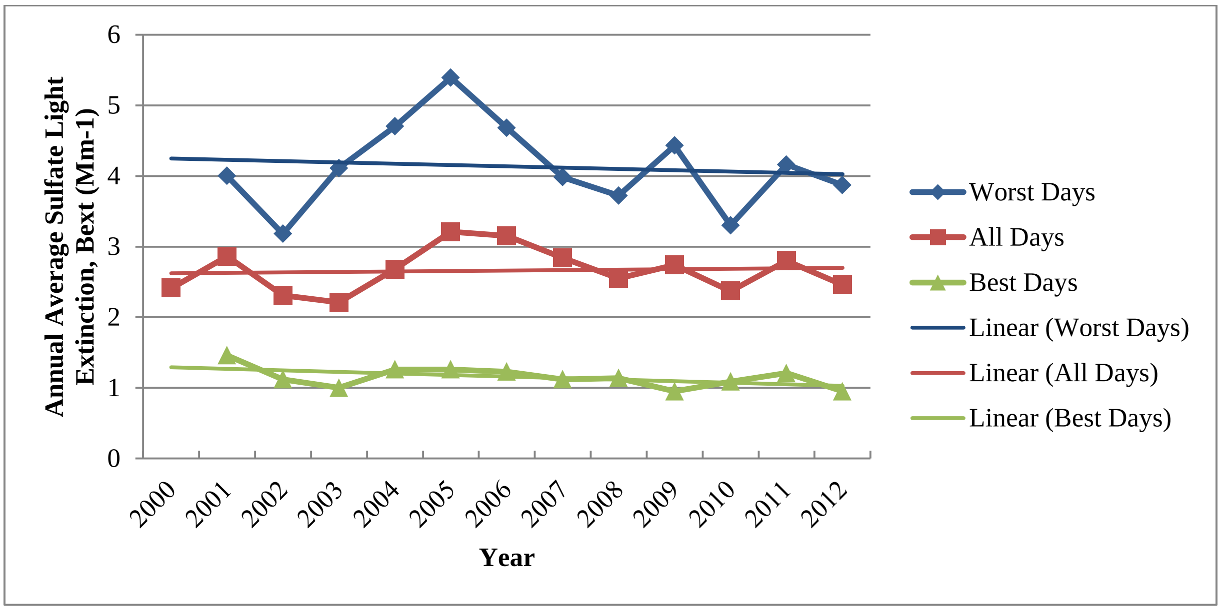


Figure 4-13 presents the light extinction trends due to sulfate for the worst days, all days, and best days based on rolling 5-year averages. The 5-year trends for the worst and best days are downward, again indicating improvements in visibility impairment resulting from sulfate extinction, while the all days data show variability with a slight upward slope. Thus, both the annual and the 5-year average data demonstrate improvement in visibility impairment due to sulfate light extinction on the worst and best days.

Figure 4-13. Rolling Five-Year Average Sulfate Light Extinction and Trends

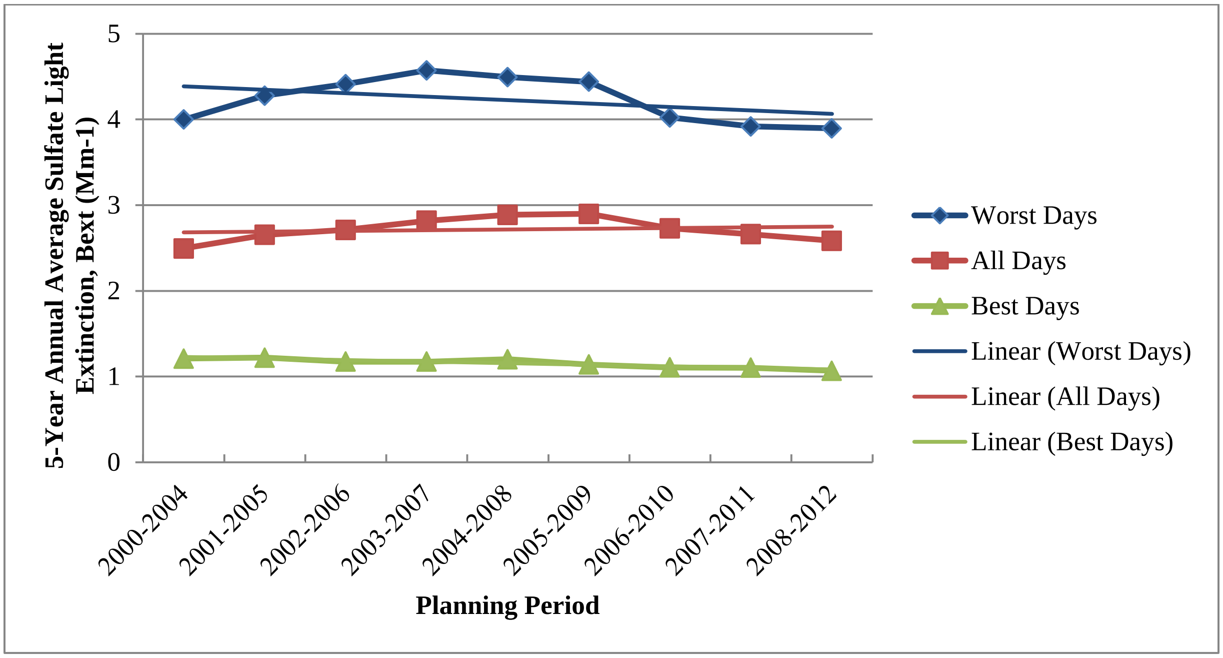


Figure 4-14 and Figure 4-15 present similar data for nitrate extinction. These data all show downward trends, clearly demonstrating improvement in annual visibility impairment resulting from light extinction due to nitrate for the worst, best, and all days. If the December 18, 2005 nitrate spike discussed in the next section were omitted from the data set, the downward slope on the worst days would be even stronger. The slope of both the annual average worst days trend line (-0.0373 Mm^{-1}/yr) and the 5-year average worst days trend line are an order of magnitude better than the slope of the nitrate glideslope for Jarbidge WA from baseline conditions to natural conditions (-0.0033 Mm^{-1}/yr).

Figure 4-14. Annual Average Nitrate Light Extinction and Trends

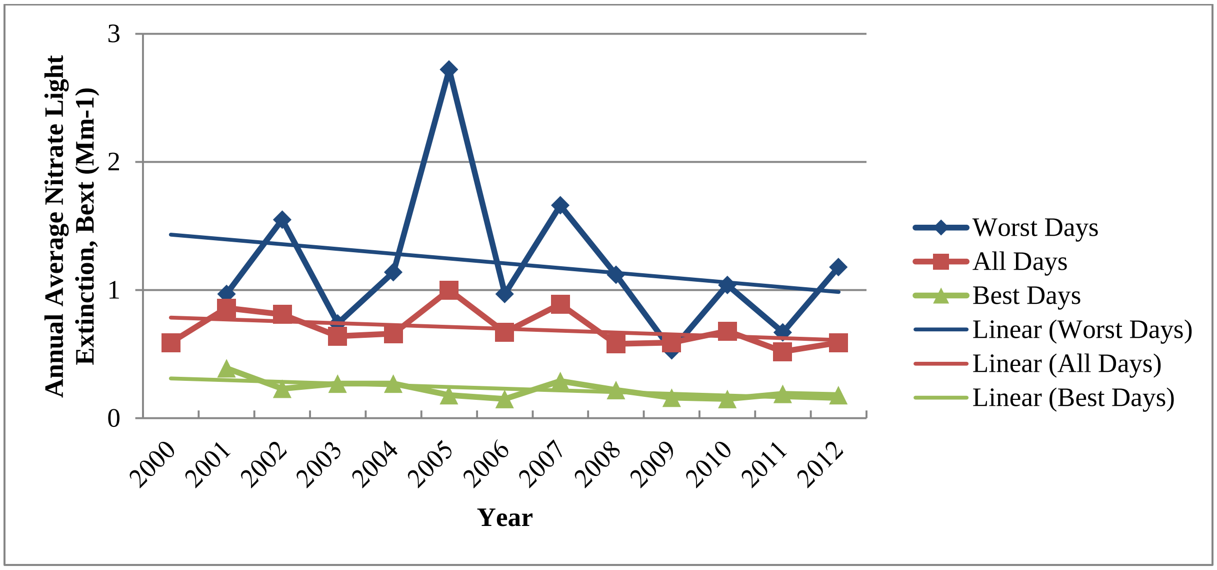


Figure 4-15. Rolling Five-Year Average Nitrate Light Extinction and Trends

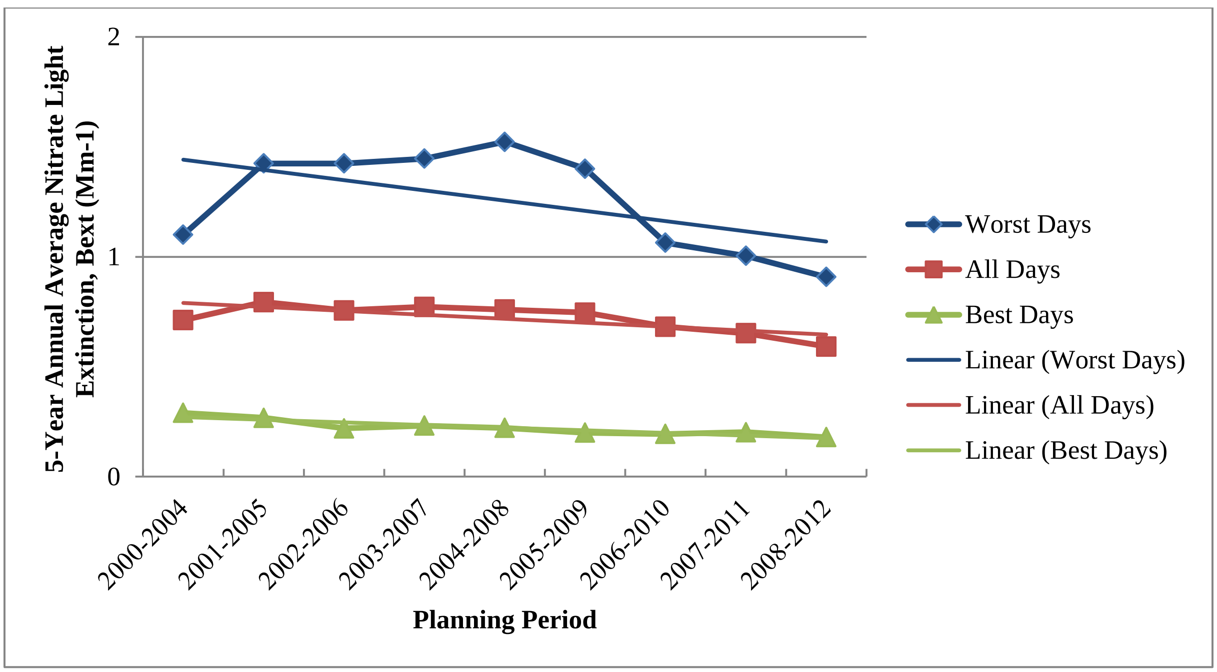


Figure 4-11 through Figure 4-15 all demonstrate that JARB1 worst and best days visibility impairment resulting from light extinction due to sulfate and nitrate is improving over time, both on an annual basis as well as for the 5-year planning period averages. The slopes of the annual trend lines for the worst days are comparable or better than the respective glideslopes for sulfate and nitrate light extinction. Sulfate and nitrate form from SO_2 and NO_x emissions, which are dominated by anthropogenic sources. Emission sources contributing to light extinction due to sulfate and nitrate at the Jarbidge WA are discussed in Chapter Six.

4.7 Effects of Outliers

As mentioned above, the 2005 monitor data from JARB1 has some interesting characteristics, especially in late December when a large spike (40+ Mm^{-1}, which is twice the next highest value recorded from 2000 to 2012) in monitored nitrate extinction occurred, corresponding to a smaller but distinct sulfate spike, as shown on Figure 4-16. The event that produced these spikes is not known to the NDEP, but similar spikes were seen across a wide-ranging geographic extent in the western United States, from Mount Hood Wilderness Area (WA) in Oregon (Figure 4-17) to Great Sand Dunes National Monument in Colorado (Figure 4-18). These figures present the nitrate and sulfate light extinction for all IMPROVE sample days in 2005 and show a consistent pattern of monitored nitrate light extinction during the December 2005 event although the values vary from site to site. Other IMPROVE monitoring sites across this vast region of the western United States record similar patterns of monitored nitrate light extinction for this event including, but not limited to, Mount Jefferson WA/Mount Washington WA/Three Sisters WA in Oregon; Great Basin National Park in Nevada; Zion Canyon National Park and Capital Reef National Park in Utah; Grand Canyon National Park and Petrified Forest National Park in Arizona; Rocky Mountain National Park in Colorado; and Bandelier National Monument in New Mexico.

Figure 4-16. 2005 Nitrate and Sulfate Monitor Data for the Jarbidge WA, Nevada

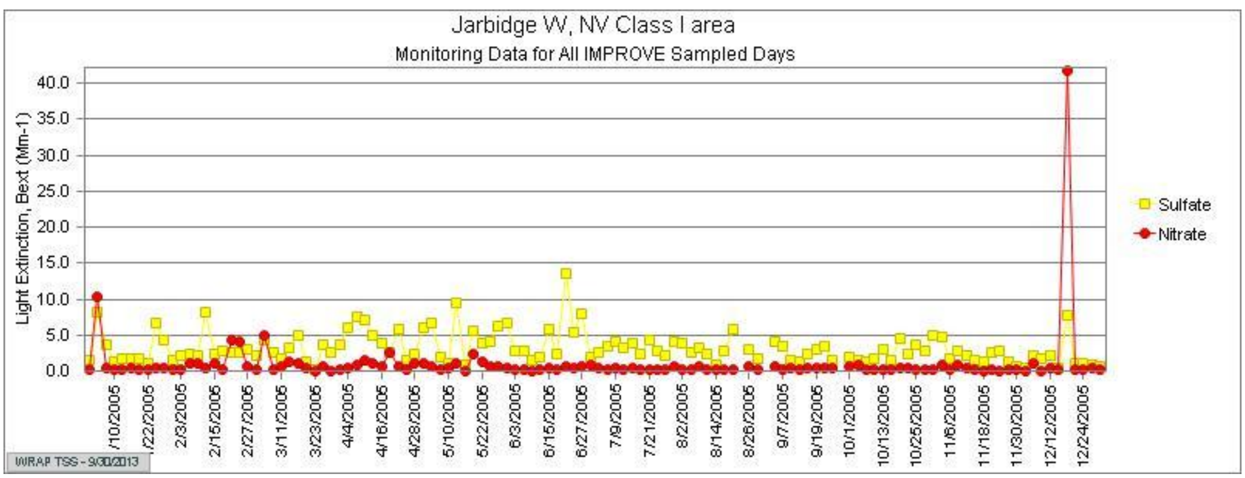


Figure 4-17. 2005 Nitrate and Sulfate Monitor Data for the Mount Hood WA, Washington

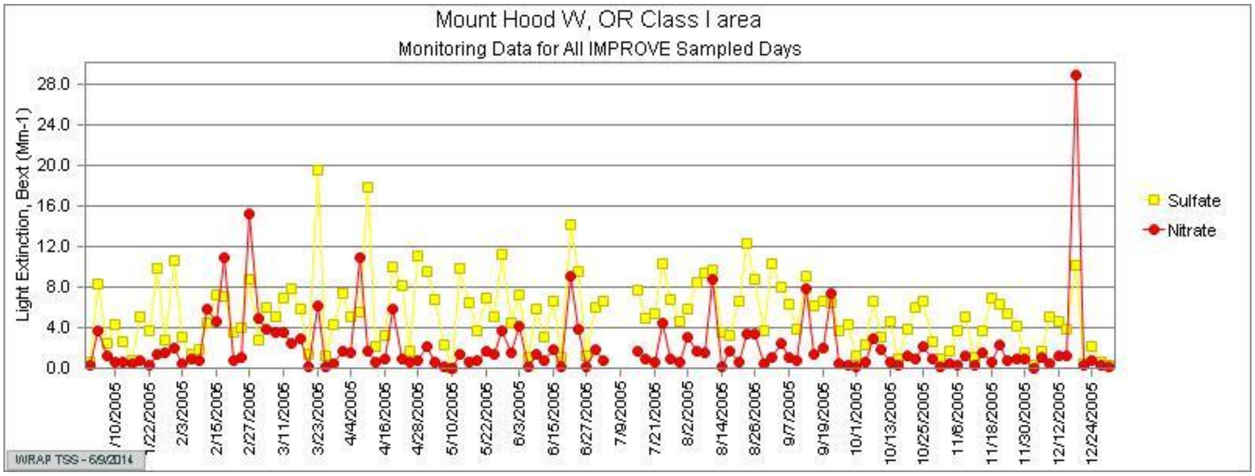
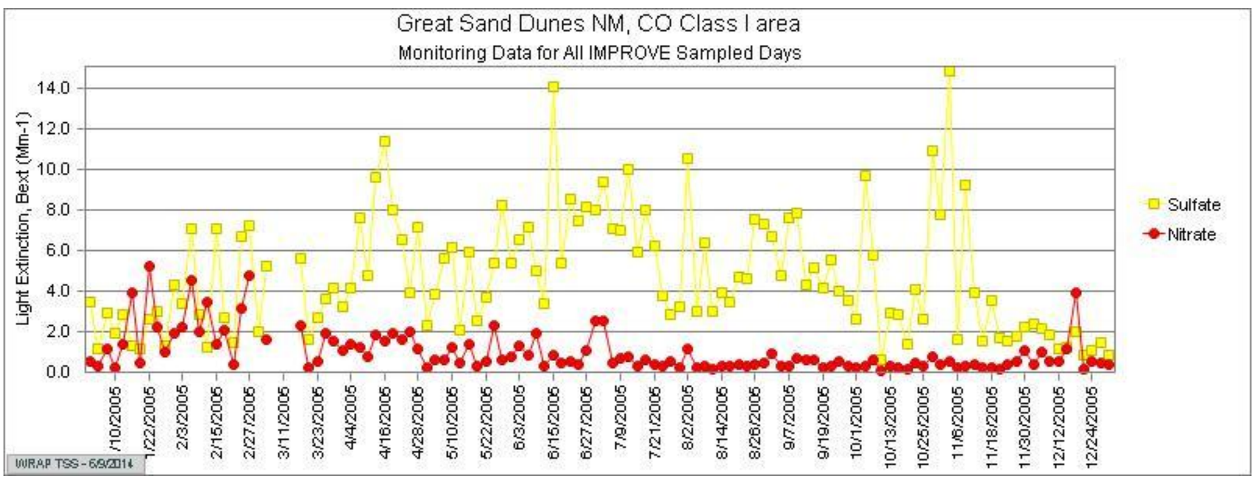


Figure 4-18. 2005 Nitrate and Sulfate Monitor Data for Great Sand Dunes NM, Colorado



The NDEP evaluated the impact of the December 18th nitrate extinction value on the annual average as well as the 5-year annual averages that include 2005 data. The 2005 41.88 Mm^{-1} extinction value was replaced with the average worst days nitrate light extinction (with the spike included in the average) from 2005, which is 2.72 Mm^{-1}. The worst days were re-identified and the substituted December 18th data remained as one of the worst days (2.72 Mm^{-1} is still the second highest nitrate light extinction for the 2005 worst days). The substituted data was used to re-calculate the worst days and all days annual light extinction and haze index, and the annual averages were then used to calculate the 5-year averages. This substitution lowered the average annual nitrate light extinction from 2.72 Mm^{-1} to 1.09 Mm^{-1} and lowered the annual average haze index from 11.3 deciviews to 10.9 deciviews. These are significant revisions based on conservative substitution of a single data point.

Figure 4-19 presents the annual nitrate light extinction for the worst, all, and best days using the substituted data for comparison with Figure 4-14, which presents the original data. Note the slope for both the worst days and all sample days decreased slightly from the original data. The best days data remain unchanged by the substitution. The slope of the worst days nitrate light extinction trend line still exceeds the glideslope by an order of magnitude.

Figure 4-19. Annual Average Nitrate Light Extinction and Trends, Substituted Data

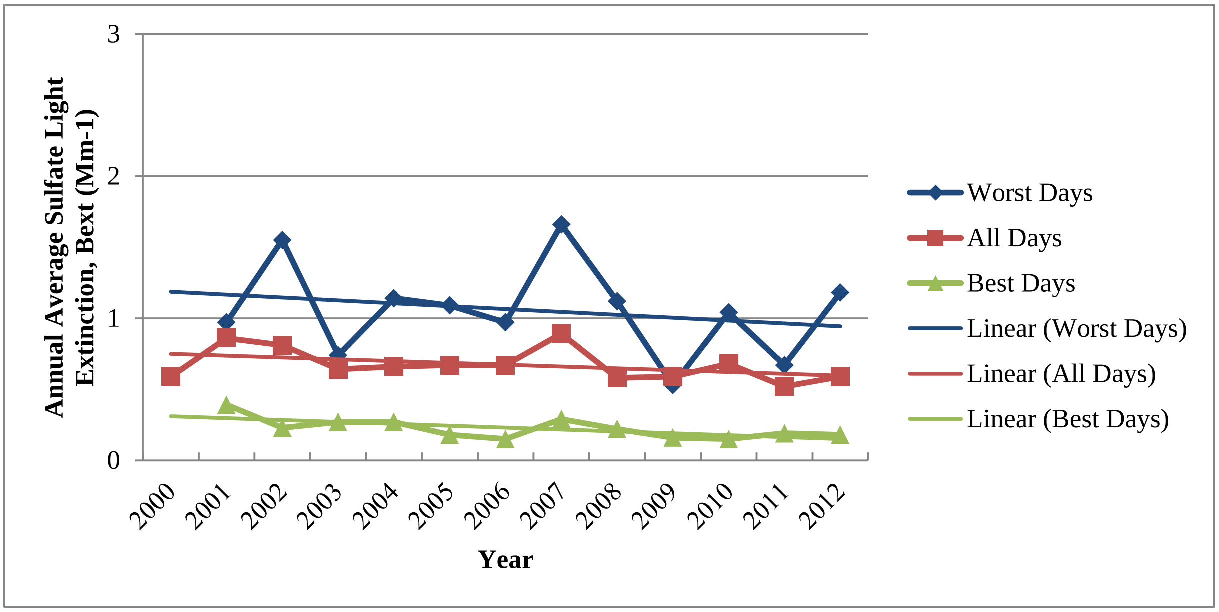
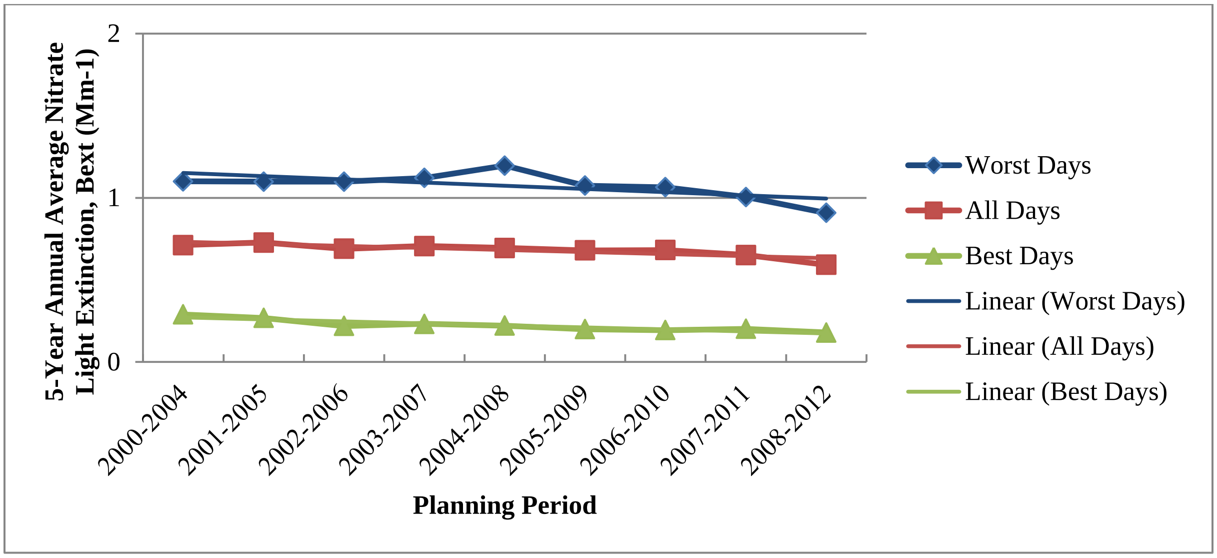


Figure 4-20 presents the 5-year average nitrate light extinction for the worst, all, and best days using the substituted data for comparison with Figure 4-15. Note on Figure 4-15 how the inclusion of the December 18th event increases all the 5-year averages that include data from 2005 (beginning with 2001-2005) and how quickly the 5-year averages drop when 2005 data is no longer included in the average (2006-2010). In addition, all the 5-year averages that include 2005 data exceed 1.4 Mm^{-1} with a high of 1.52 Mm^{-1}, while the high 5-year average of the substituted data is 1.2 Mm^{-1}.

Figure 4-20. Rolling Five-Year Annual Average Nitrate Light Extinction and Trends, Substituted Data



This data substitution exercise demonstrates the influence of one outlier data point on the annual average as well as the 5-year averages that incorporate the outlier data and how demonstration of progress can be stymied by a single data point. A more refined data substitution mechanism could be developed and may further reduce the annual nitrate extinction and haze index as well as the 5-year average nitrate extinction and haze index. Nevada urges the USEPA to acknowledge the influence of outliers and develop an acceptable regulatory mechanism to minimize the impact of outlier data on the evaluation of a state's status in meeting its reasonable progress goal.