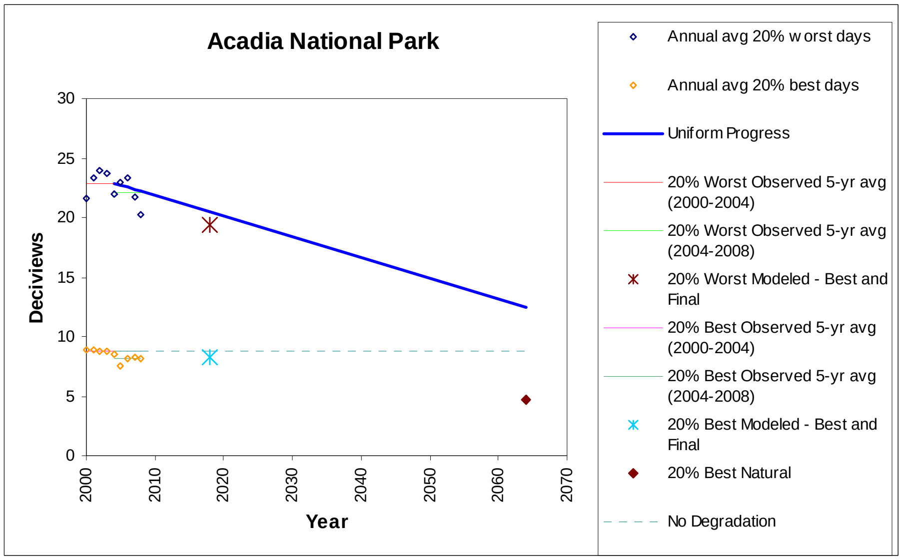
Tracking Visibility Progress 2004-2008



Prepared by
NESCAUM
For the
Mid-Atlantic/Northeast Visibility Union Regional Planning Organization

May 12, 2010

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Executive Summary

This report represents the most recent effort to assess progress along the glide-paths to natural background visibility for Class I areas under the federal Regional Haze Rule that lie within and near the Mid-Atlantic/Northeast Visibility Union (MANE-VU) states. The visibility progress presented here will be useful to the MANE-VU states as they implement measures that constitute the long-term emissions management strategies established as part of their reasonable progress goals.

Over the past several years, NESCAUM – as a partner in the MANE-VU regional planning organization – has coordinated and conducted regional air quality modeling and data analyses to better understand the implications of visibility impairment and the necessary steps to eliminate it. This technical memo provides an analysis of 2005-2008 IMPROVE data that includes new five-year averages (2004-2008) of the deciview index, which is the metric used by the regional haze program to track the progress of visibility improvement. In addition, comparisons are made to prior predictions of visibility based on modeling results for the 2009 time period. These results are discussed in the context of our best understanding of the actual implementation of control programs that were projected to occur.

Results from prior analyses have shown that sulfate aerosol – the dominant contributor to visibility impairment in the Northeast's Class I areas on the 20 percent worst visibility days – has significant contributions from states throughout the eastern U.S. While slight improvement in overall visibility has been observed, large contributions to sulfate aerosol remain from all three of the eastern regional planning organizations (RPOs).

INTRODUCTION

1.1. Background

This report presents information intended to assist states in establishing reasonable progress goals and fulfilling their long-term emissions management strategies under the 1999 U.S. Environmental Protection Agency (USEPA) "Regional Haze Rule" [64 Fed. Reg. 35714 (July 1, 1999)] for MANE-VU Class I areas.[1] NESCAUM has used in-house air quality modeling and data analysis capabilities to conduct regional air quality analyses for calendar year 2004 through 2008 (representative of the most recent five-year period for which data are available since the baseline period of 2000 to 2004).

In reviewing the results here, the reader should refer to prior reports prepared by NESCAUM that provide the foundation upon which these results are built. For example, dating back to the earliest overview of regional haze and visibility impairment in the Northeast and Mid-Atlantic U.S. (NESCAUM, 2001), NESCAUM presented a review of the available information on visibility impairment, monitoring programs, and available models. This served to inform the development of a visibility program and the weight of evidence modeling approach taken by MANE-VU in conducting a contribution assessment and pollution apportionment (NESCAUM 2004, 2006). NESCAUM presented a review of the 2002 base year from a meteorological and chemical perspective in its report *2002, A Year in Review* (NESCAUM, 2004). NESCAUM has also separately published several modeling analyses that have yielded projected visibility in 2009 and 2018 utilizing a MM5 meteorological model and the USEPA Community Multi-scale Air Quality (CMAQ) chemical transport model (NESCAUM, 2008a; 2008b). In this report, we do not repeat this information, but rather rely upon the prior documentation.

The following sections describe the IMPROVE data set being analyzed, the methods for tracking progress established by the USEPA for the Regional Haze Rule, and present the resulting visibility metrics in the context of prior modeling and the uniform rate of progress determined by baseline conditions and estimated natural visibility conditions for each MANE-VU Class I area.

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[1] There are seven designated Class I areas in the Northeast and Mid-Atlantic states. They include Acadia National Park and Moosehorn Wilderness Area in Maine; Roosevelt Campobello International Park in New Brunswick and Maine; the Lye Brook Wilderness Area in Vermont; the Great Gulf and Presidential Range-Dry River Wilderness Areas in New Hampshire; and the Brigantine Wilderness Area in New Jersey.

2. IMPROVE, VIEWS, AND TRACKING PROGRESS

2.1. The IMPROVE Program

A coalition composed of the National Park Service (NPS), the Fish and Wildlife Service (FWS), the Bureau of Land Management (BLM), the Forest Service (FS) and the USEPA established the Interagency Monitoring of Protected Visual Environments (IMPROVE) program in response to the 1977 amendments to the Clean Air Act. This monitoring network has collected speciated fine aerosol and related visibility data in or near Federal Class 1 areas in the United States since 1988.

In order to better support the Regional Haze Rule, the network was significantly expanded, extending spatial coverage of aerosol characterization. By 2002, there were 17 IMPROVE samplers in operation in the MANE-VU region. The IMPROVE sampling schedule was also harmonized with USEPA’s fine particulate matter ($PM_{2.5}$) sampling program at that time.

The IMPROVE aerosol sampler has four channels for particle collection. The A and D channels collect $PM_{2.5}$ and PM_{10} on Teflon filters and are weighed gravimetrically to yield the mass of fine and coarse particulate. The B channel uses a 25 or 37 mm nylon filter for collection of water soluble ions after the sample stream has passed through an annular sodium carbonate denuder to remove acid gases. Finally, quartz filters are used in the C channel and analyzed for elemental (EC) and organic (OC) carbon. The demarcation between these two carbon components is operationally defined based on the analytical technique and analysis protocol. The IMPROVE program uses Thermal Optical Reflectance (TOR) and splits EC and OC as the point during analysis at which the filter reflectance reaches its original value.

2.2. The VIEWS Data Exchange System

The Visibility Information Exchange Web System (VIEWS) is an online decision support system developed to help states, tribes, federal land managers (FLMs), scientists, planners, and students evaluate air quality and visibility in federally-protected ecosystems according to the stringent requirements of the USEPA’s Regional Haze Rule and the National Ambient Air Quality Standards. The VIEWS team maintains a comprehensive database of air quality data from over two dozen monitoring networks, including the IMPROVE program. Ongoing development and maintenance of VIEWS is conducted by Colorado State University’s Cooperative Institute for Research in the Atmosphere (CIRA) in Fort Collins, Colorado, a key partner in the IMPROVE program. Using the data from IMPROVE, the VIEWS team calculates and regularly posts updated metrics for tracking visibility across the country at the national parks and wilderness areas subject to the Regional Haze Rule.

2.3. Tracking Progress

The long-term visibility conditions that would exist in absence of human-caused impairment are referred to as *natural background* visibility conditions. Accurate assessment of these conditions is important due to their role in determining the uniform rate of progress that states must consider when setting reasonable progress goals for each mandatory Federal Class I area subject to the Regional Haze Rule. Baseline visibility conditions – based on monitored visibility during the five-year baseline period (2000-2004) – and estimated natural background visibility conditions will determine the uniform rate of progress states will consider when setting reasonable progress goals for any Class I site.

In September 2001, the USEPA issued draft methodological guidelines for the calculation of natural background and baseline visibility conditions as well as methods for tracking progress relative to the derived uniform rate of progress. USEPA subsequently finalized this draft guidance in September 2003. The final guidance recommends a default method and allows for certain refinements that states may wish to pursue in order to make these estimates more representative of a specific Class I area if it is poorly represented by the default method.

In the spring of 2006, the IMPROVE Steering Committee adopted an alternative formulation of the reconstructed extinction equation to address certain aspects of the default calculation method. These aspects were well understood from a scientific perspective and were felt to improve the performance of the equation at reproducing observed visibility at Class I sites. This alternative formulation of the reconstructed extinction equation was not adopted as a replacement to the default method, but as an alternative to the default method for states and RPOs to consider as they proceed with the regional haze planning process. In December of 2006, MANE-VU adopted this alternative formulation as the means by which it will calculate baseline conditions, natural background conditions, and track progress toward the national visibility goals under the Regional Haze Rule and we have followed that formulation here.

The revised algorithm is shown in the equation below and is based on Hand and Malm (2005). The total sulfate, nitrate, and organic carbon compound concentrations are each split into two fractions, representing small and large size distributions of those components. Although not explicitly shown in the equation, the organic mass concentration used in this new algorithm is 1.8 times the organic carbon mass concentration, which is changed from 1.4 times the carbon mass concentration as used for input in the current IMPROVE algorithm. New terms have been added for sea salt (important for coastal locations) and for absorption by NO_2 (only used where NO_2 data are available). Site-specific Rayleigh scattering is calculated for the elevation and annual average temperature of each of the IMPROVE monitoring sites.

$$
\begin{aligned}
b_{ext} \approx\ & 2.2 \times f_S(RH) \times [\text{Small Sulfate}] + 4.8 \times f_L(RH) \times [\text{Large Sulfate}] \\
& + 2.4 \times f_S(RH) \times [\text{Small Nitrate}] + 5.1 \times f_L(RH) \times [\text{Large Nitrate}] \\
& + 2.8 \times [\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}] \\
& + 10 \times [\text{Elemental Carbon}] \\
& + 1 \times [\text{Fine Soil}] \\
& + 1.7 \times f_{SS}(RH) \times [\text{Sea Salt}] \\
& + 0.6 \times [\text{Course Mass}] \\
& + \text{Rayleigh Scattering (site specific)} \\
& + 0.33 \times [NO_2\ (\text{ppb})]
\end{aligned}
$$

The apportionment of the total concentration of sulfate compounds into the concentrations of the small and large size fractions is accomplished using the following equations.

$$[Large\ Sulfate] = \frac{[Total\ Sulfate]}{20\mu g/m^3} \times [Total\ Sulfate], \quad for\ [Total\ Sulfate] < 20\mu g/m^3$$

$$[Large\ Sultate] = [Total\ Sulfate], \quad for\ [Total\ Sulfate] \geq 20\ \mu g\ /\ m^3$$

$$[Small\ Sulfate] = [Total\ Sulfate] - [Large\ Sulfate]$$

The same equations are used to apportion total nitrate and total organic mass concentrations into the small and large size fractions.

Sea salt is calculated as 1.8 × [*Chloride*], or 1.8 × [*Chlorine*] if the chloride measurement is below detection limits, missing, or invalid. The algorithm uses three sets of water growth adjustment terms as shown in the equations above. They are for use with the small size distribution and the large size distribution sulfate and nitrate compounds and for sea salt ($f_S(RH)$, $f_L(RH)$, and $f_{SS}(RH)$, respectively).

Utilizing these equations, staff at IMPROVE and VIEWS have created ready-to-use datasets with these metrics pre-calculated for each Class I site in the U.S. The data are made available quarterly (with a typical lag time of six to nine months) on the VIEWS website. NESCAUM has extracted the appropriate data and conducted an analysis of the trend in visibility in the MANE-VU region for the most recent five-year period for which data are available (2004 through 2008). These results are presented in the next section.

3. RESULTS

Results of prior modeling suggest that individual MANE-VU Class I areas will be able to meet or exceed uniform rates of progress by 2018; however they also suggest that this will be difficult without including additional measures beyond what was to be in the Clean Air Interstate Rule (CAIR) program. As the USEPA considers alternatives for replacing the CAIR rule and states implement low sulfur fuel regulations and wood-burning restrictions, new data on visibility trends will help in determining the expected response to ongoing and potential future control programs.

The results presented below, based on newly available monitoring data, show that most areas are on track to achieve the uniform rate of progress. However, areas in the southern or western portion of the MANE-VU region and other Mid-Atlantic sites may have significant difficulty unless a CAIR replacement rule is implemented quickly.

Figures 3.1 through 3.7 show the most recent five-year visibility period in deciviews as a pair of green bars adjacent to the red bars that represents the 2000-2004 baseline visibility conditions. Data tables that correspond to the values plotted are listed in Appendix A and B.

Figure 3-1. Historical observed visibility, five-year averages, and projected improvement in visibility based on 2018 "Best and Final" projections at Acadia National Park, Maine

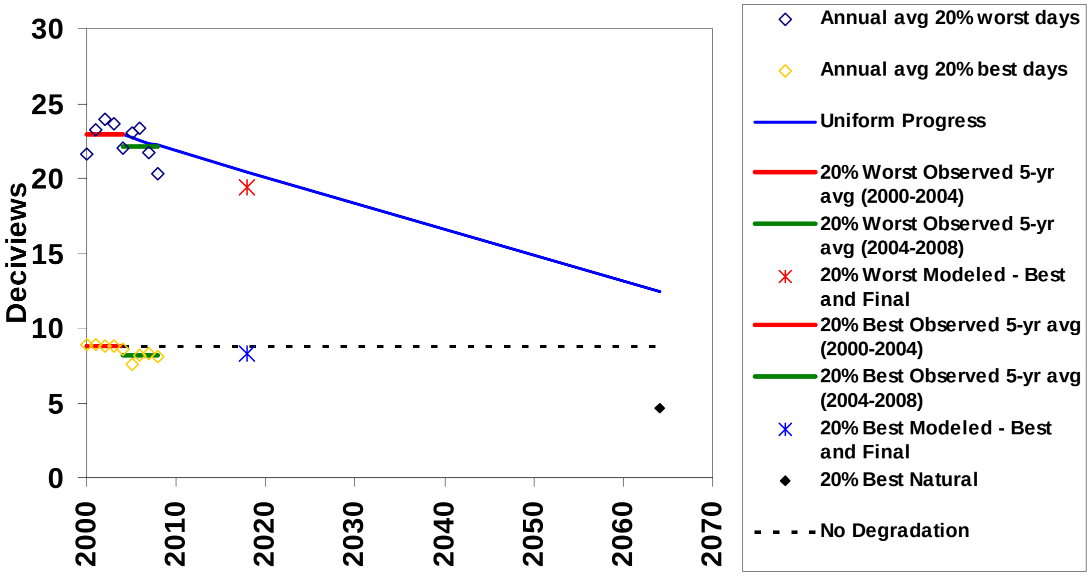


Figure 3-2. Historical observed visibility, five-year averages, and projected improvement in visibility based on 2018 "Best and Final" projections at Brigantine National Wildlife Refuge, New Jersey

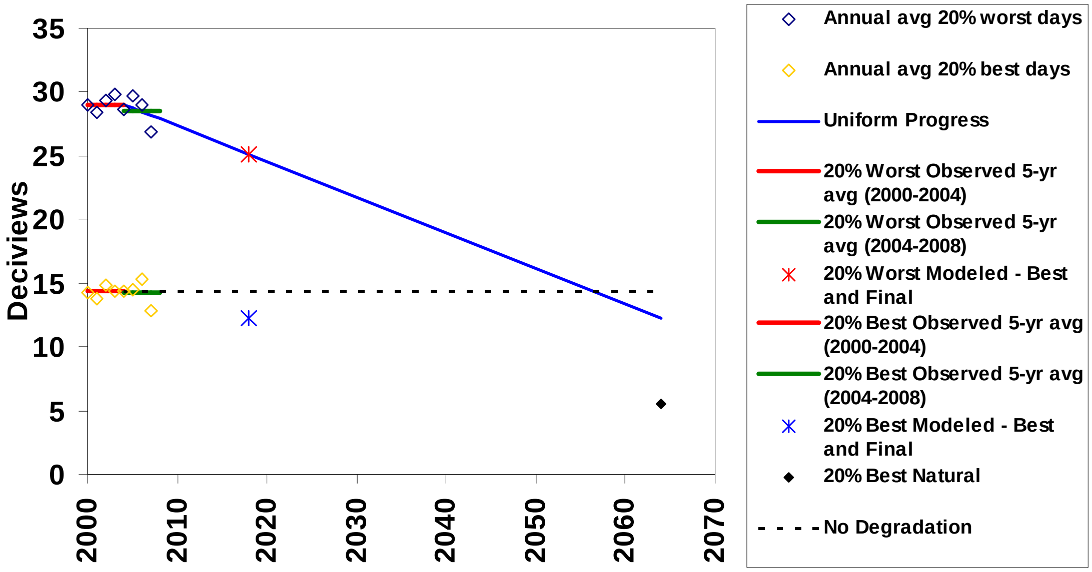


Figure 3-3. Historical observed visibility, five-year averages, and projected improvement in visibility based on 2018 "Best and Final" projections at Great Gulf Wilderness, New Hampshire

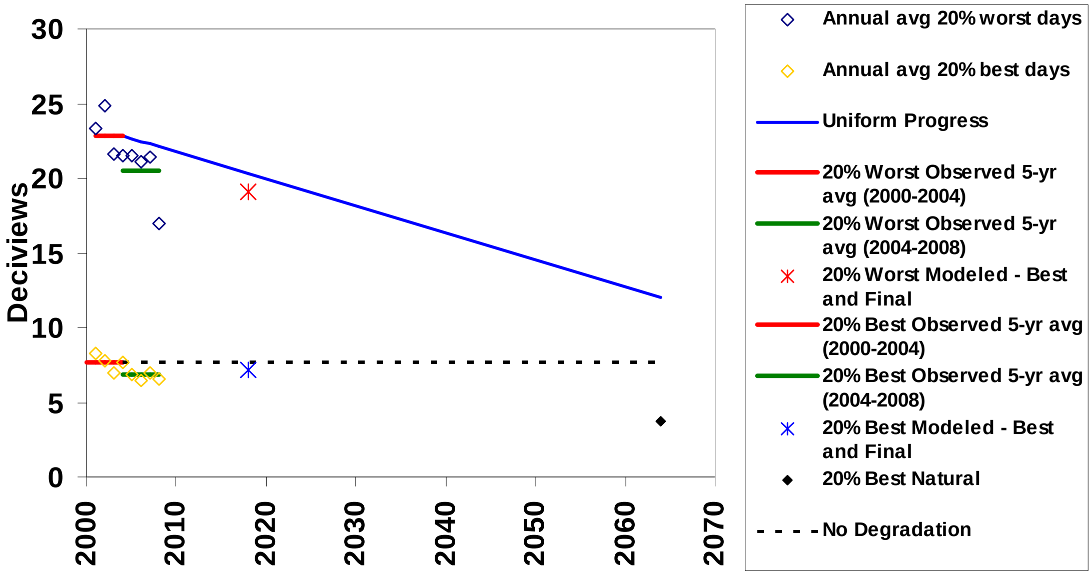


Figure 3-4. Historical observed visibility, five-year averages, and projected improvement in visibility based on 2018 "Best and Final" projections at Lye Brook Wilderness, Vermont

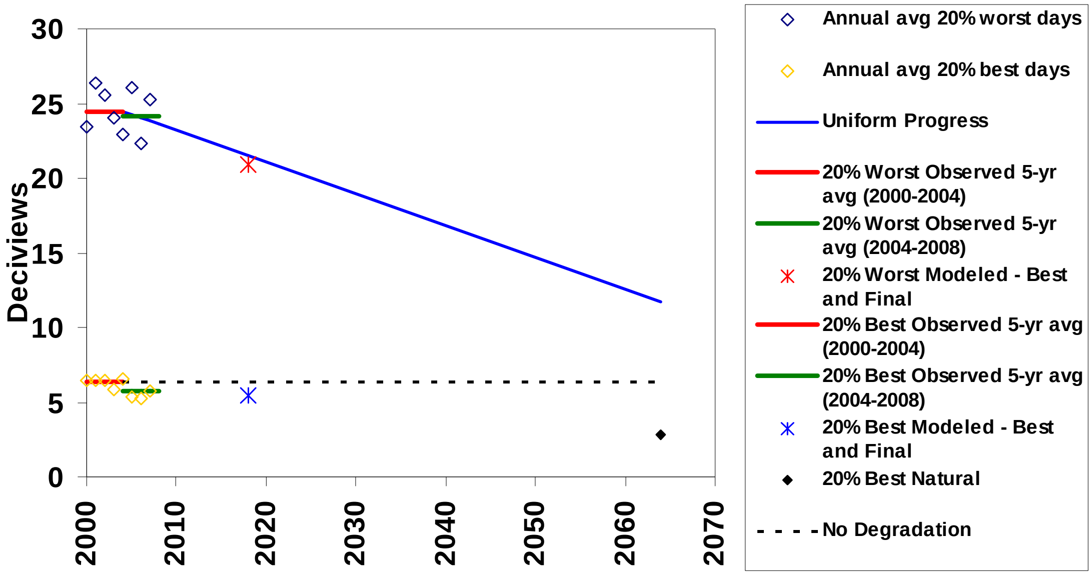


Figure 3-5. Historical observed visibility, five-year averages, and projected improvement in visibility based on 2018 "Best and Final" projections at Moosehorn National Wildlife Refuge, Maine

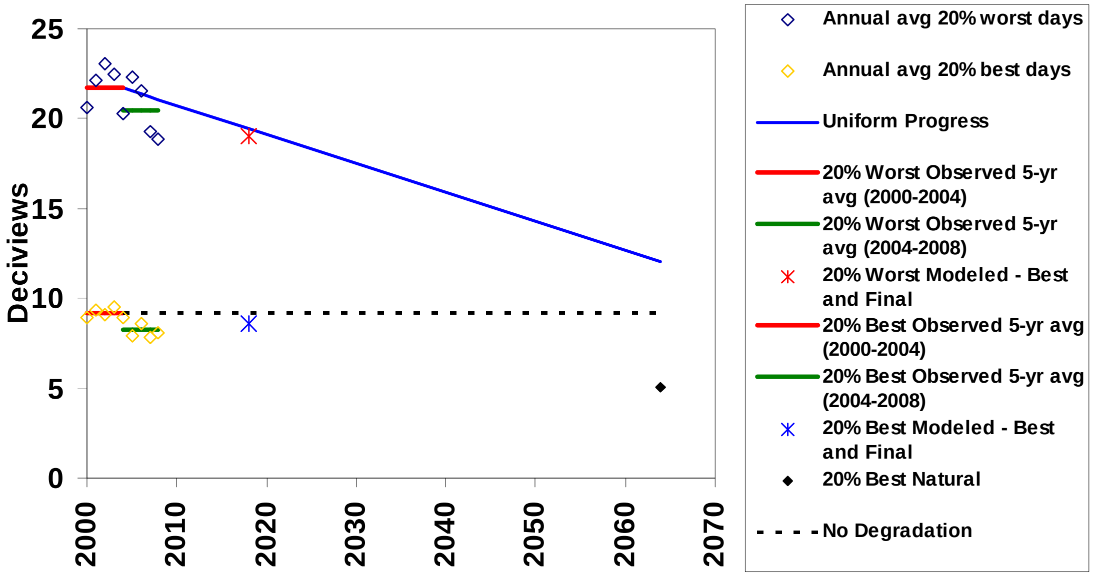


Figure 3-6. Historical observed visibility, five-year averages, and projected improvement in visibility based on 2018 "Best and Final" projections at Dolly Sods Wilderness, West Virginia

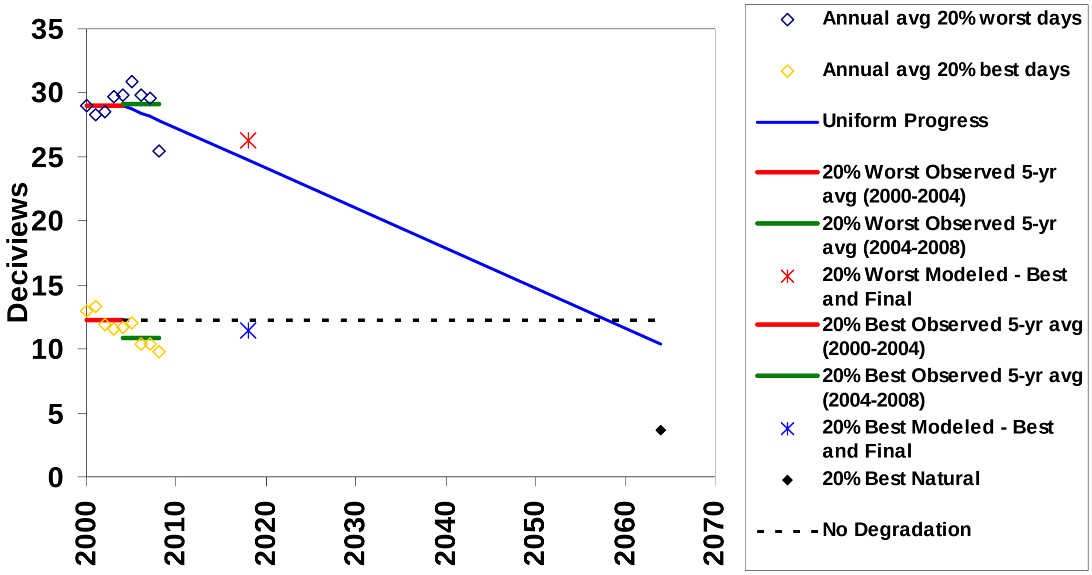
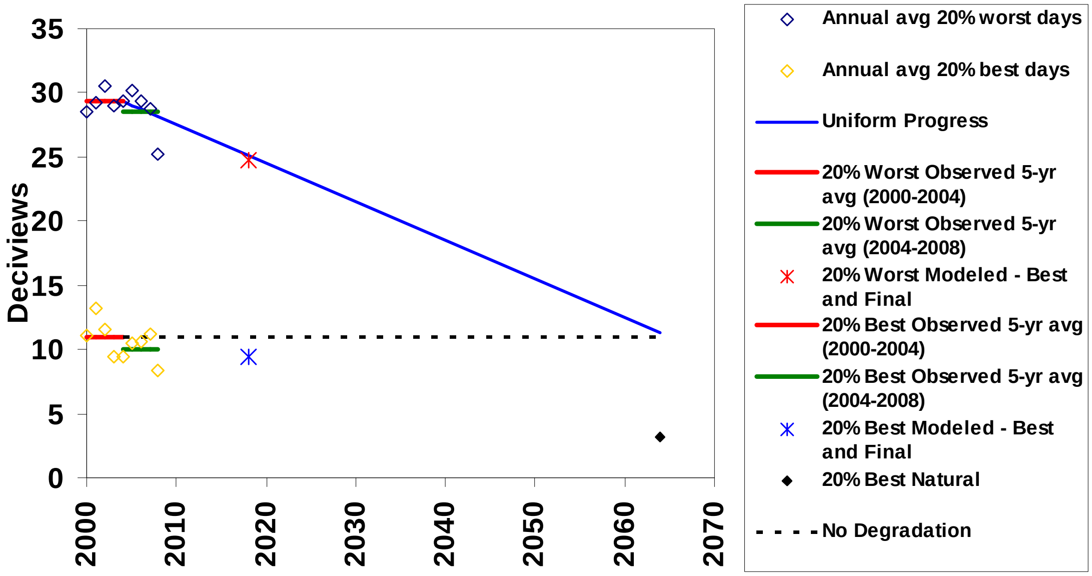


Figure 3-7. Historical observed visibility, five-year averages, and projected improvement in visibility based on 2018 "Best and Final" projections at Shenandoah National Park, Virginia



4. OBSERVATIONS AND CONCLUSIONS

Reductions in emissions from the EGU sector, heavy duty vehicles, and from residential and commercial heating devices continue to bring down levels of fine particulate matter leading to improvements in visibility at most MANE-VU sites. Interestingly, the one site that MANE-VU had predicted would have difficulty meeting a uniform rate of progress based on our most recent modeling – Dolly Sods Wilderness in West Virginia – does appear to have a slightly increasing trend in deciview, which reflects further visibility degradation relative to the baseline conditions. Other sites appear to be making progress.

Lye Brook and Brigantine, which are respectively the furthest west and south Class I sites in MANE-VU, are experiencing visibility improvement on the twenty percent worst days, but only just at the uniform rate. This does closely parallel the modeled predictions, which suggest that the uniform rate of progress was expected at Brigantine and only slightly greater progress at Lye Brook through 2018. This is also supported by independent results from a CT Department of Environmental Protection site in Northwestern CT (Kurt Kebshull, personal communication) that show rural background sulfate is not decreasing consistently. Generally speaking, the sites in the northern and eastern parts of the MANE-VU region (New Hampshire and Maine sites) show greater progress than was anticipated by the modeled simulations. This suggests that control programs in major sulfur dioxide (SO_2) source regions are effectively curtailing some transport of secondary sulfate, but that intermediate-range transport continues to be an issue for several MANE-VU sites.

It is also interesting to note that every area except Brigantine has experienced significant visibility improvement on the twenty percent best days. This is not a requirement of the Regional Haze Rule and all sites – including Brigantine – are able to claim “no degradation” of visibility on the best days as required by the Rule. Prior work has shown that the principle determinant of best versus worst visibility is the prior path of the airmass associated with the measurements. The improvement in best visibility days suggests that SO_2 emissions reductions are taking place in regions that are upwind on these days, which are different from the upwind regions contributing to the worst visibility days. The contributing regions on best visibility days include portions of eastern Canada and northern New England for the northern New England sites, and the upper Midwest and southern Ontario for Brigantine.

As MANE-VU prepares for the five-year look back, updated monitoring results will have to be examined in the context of CAIR replacement regulations, federal legislation, and implementation of low-sulfur heating oil regulations, low sulfur mobile source regulations, and potential SO_2 NAAQS revisions that are all expected to affect ambient sulfate levels and visibility.

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Appendix A

Tracking Progress Data for MANE-VU Class I Sites (in deciview)

Site	Year	Annual Average 20% Worst Days	Annual Average 20% Best Days	Uniform Progress	20% Worst Observed 5-yr Avg (2000-2004)	20% Worst Observed 5-yr Avg (2004-2008)	20% Worst Modeled - Best and Final	20% Best Observed 5-yr Avg (2000-2004)	20% Best Observed 5-yr Avg (2004-2008)	20% Best Modeled - Best and Final	20% Best Natural
Acadia	2000	21.64	8.89		22.89			8.77			
	2001	23.28	8.87		22.89			8.77			
	2002	23.91	8.77		22.89			8.77			
	2003	23.65	8.77		22.89			8.77			
	2004	21.98	8.56	22.89	22.89	22.06		8.77	8.06		
	2005	23.01	7.58	22.72		22.06			8.06		
	2006	23.37	8.17	22.54		22.06			8.06		
	2007	21.74	8.21	22.37		22.06			8.06		
	2008	20.21	7.76	22.19		22.06			8.06		
	2018			20.45			19.40			8.30	
	2064			12.43							4.66
Brigantine	2000	28.95	14.26		29.01			14.33			
	2001	28.38	13.82		29.01			14.33			
	2002	29.31	14.83		29.01			14.33			
	2003	29.79	14.39		29.01			14.33			
	2004	28.59	14.36	29.01	29.01	28.41		14.33	14.26		
	2005	29.62	14.61	28.73		28.41			14.26		
	2006	28.50	15.35	28.45		28.41			14.26		
	2007	26.91	12.74	28.17		28.41			14.26		
	2008			27.89		28.41			14.26		
	2018			25.09			25.10			12.20	
	2064			12.24							5.51
Great Gulf	2000				22.82			7.66			
	2001	23.29	8.26		22.82			7.66			
	2002	24.84	7.77		22.82			7.66			
	2003	21.59	6.94		22.82			7.66			
	2004	21.56	7.68	22.82	22.82	20.47		7.66	6.81		
	2005	21.53	6.90	22.64		20.47			6.81		
	2006	21.12	6.43	22.46		20.47			6.81		
	2007	21.35	6.86	22.28		20.47			6.81		
	2008	16.78	6.20	22.10		20.47			6.81		
	2018			20.29			19.10			7.20	
	2064			11.99							3.73
Lye Brook	2000	23.45	6.49		24.45			6.36			
	2001	26.32	6.47		24.45			6.36			
	2002	25.52	6.43		24.45			6.36			
	2003	24.02	5.83		24.45			6.36			
	2004	22.91	6.61	24.45	24.45	24.13		6.36	5.82		
	2005	26.04	5.74	24.23		24.13			5.82		
	2006	22.31	5.24	24.02		24.13			5.82		
	2007	25.25	5.68	23.81		24.13			5.82		
	2008			23.60		24.13			5.82		
	2018			21.48			20.90			5.50	
	2064			11.73							2.79
Moosehorn	2000	20.63	8.93		21.72			9.15			
	2001	22.13	9.30		21.72			9.15			
	2002	23.06	9.12		21.72			9.15			
	2003	22.50	9.48		21.72			9.15			
	2004	20.28	8.93	21.72	21.72	20.43		9.15	8.21		
	2005	22.36	7.99	21.56		20.43			8.21		
	2006	21.55	8.60	21.40		20.43			8.21		
	2007	19.24	7.79	21.24		20.43			8.21		
	2008	18.73	7.75	21.07		20.43			8.21		
	2018			19.46			19.00			8.60	
	2064			12.01							5.01

Appendix B

Tracking Progress Data for Virginia and West Virginia Class I Sites (in deciview)

Site	Year	Annual Average 20% Worst Days	Annual Average 20% Best Days	Uniform Progress	20% Worst Observed 5-yr Avg (2000-2004)	20% Worst Observed 5-yr Avg (2004-2008)	20% Worst Modeled - Best and Final	20% Best Observed 5-yr Avg (2000-2004)	20% Best Observed 5-yr Avg (2004-2008)	20% Best Modeled - Best and Final	20% Best Natural
Dolly Sods	2000	29.03	12.96		29.04			12.28			
	2001	28.24	13.30		29.04			12.28			
	2002	28.47	11.91		29.04			12.28			
	2003	29.73	11.54		29.04			12.28			
	2004	29.76	11.67	29.04	29.04	29.07		12.28	10.81		
	2005	30.89	12.09	28.73		29.07			10.81		
	2006	29.80	10.57	28.42		29.07			10.81		
	2007	29.52	10.27	28.11		29.07			10.81		
	2008	25.39	9.44	27.80		29.07			10.81		
	2018			24.69			26.30			11.40	
	2064			10.39							3.63
Shenandoah	2000	28.53	11.07		29.31			10.93			
	2001	29.21	13.21		29.31			10.93			
	2002	30.54	11.49		29.31			10.93			
	2003	28.94	9.48		29.31			10.93			
	2004	29.32	9.37	29.31	29.31	28.76		10.93	9.95		
	2005	30.75	10.48	29.01		28.76			9.95		
	2006	29.30	10.59	28.71		28.76			9.95		
	2007	28.79	11.13	28.41		28.76			9.95		
	2008	25.65	8.16	28.11		28.76			9.95		
	2018			25.12			24.70			9.40	
	2064			11.35							3.14