Regional Haze Implementation Plan Revision

State of Oklahoma

Department of Environmental Quality

November 13, 2009 Draft

After Preliminary Managerial Review

The Oklahoma Department of Environmental Quality (DEQ) wishes to acknowledge the Central Regional Air Planning Association (CENRAP) and the Mid-Atlantic/Northeast Visibility Union (MANE-VU) for providing the draft template that formed the basis for this implementation plan revision.

Table of Contents

LIST OF TABLES

List of Figures

List of Appendices

I. Background and Overview of the Federal Regional Haze Regulation

In the 1977 Clean Air Act (CAA) amendments, Congress added §169A (42 USC §7491), setting forth, "Congress hereby declares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from man-made air pollution." Mandatory Class I Federal areas include national parks and wilderness areas which meet particular criteria.

Oklahoma's only Class I Area is the Wichita Mountains Wilderness Area; however sources within the state may contribute to visibility impairment of Class I areas in other states. These potentially-impacted areas included Hercules Glades in Missouri, Salt Creek in New Mexico, and the Guadalupe Mountains in Texas. As the Oklahoma Department of Environmental Quality (DEQ) is empowered to administer the CAA within the State of Oklahoma, it is DEQ which implements rules to protect visibility at Class I areas. The current state implementation plan for addressing air quality concerns was approved by EPA on 8 November 1999. This implementation plan revision is set forth with the intention of addressing new legislation regarding regional haze. The revision addresses regional planning, discusses state/tribe and FLM coordination, and contains methods by which to provide plan revisions and adequacy determinations. DEQ has pre-existing rules and processes which protect against visibility impairment; primary among them is the Best Available Retrofit Technology (BART) rule. Because regional haze is an issue which crosses jurisdictional boundaries, DEQ makes further efforts to reduce visibility impairment through interagency cooperation. Members of Oklahoma DEQ have been actively involved in the Central Regional Air Planning Association (CENRAP) since 1999 and cooperate with tribes and federal land managers (FLMs).

A. Class I Areas

Promulgated 23 October 1970, Public Law No. 91-504, 84 Stat. 1104-06 designated 8,900 acres within the Wichita Mountains Wildlife Refuge, a tract of sixty-thousand acres of complex terrain in Comanche County, as a wilderness area. The federal Fish and Wildlife Service manages this Wichita Mountains Wilderness Area, hereinafter simply "Wichita Mountains." Oklahoma contains no other Class I areas for the purpose of regional haze.

This implementation plan revision also addresses visibility impairment in mandatory Class I federal areas located outside Oklahoma. Transport of pollutants from Oklahoma could potentially influence visibility in Class I areas elsewhere. These other Class I areas include Hercules Glades in Missouri, Salt Creek in New Mexico, and Guadalupe Mountains in Texas. Table I-I summarizes this information on affected Class I Areas.

Table I-I Class I Areas Possibly Affected by Oklahoma Emissions

Class I Area	Location of Class I Area	Area is in Oklahoma	Area possibly affected by Oklahoma emissions
Wichita Mountains	Oklahoma	Yes	Yes
Guadalupe Mountains	Texas	No	Yes
Hercules Glades	Missouri	No	Yes
Salt Creek	New Mexico	No	Yes

B. Reasonably Attributable Visibility Impairment

During the past few decades, various government entities have taken modest steps to address the visibility problems in Class I areas. Control measures mainly addressed "plume blight" attributable to specific pollution sources and did little to address regional haze issues. Plume blight results from individual sources emitting pollutants into a stable atmosphere, forming a plume which impairs visibility.

Oklahoma Governor Henry L. Bellmon submitted an implementation plan revision to address reasonably attributable visibility impairment at the Wichita Mountains on 18 June 1990, and EPA approved this implementation plan revision on 8 November 1999 (64 FR 60683), codified as 40 C.F.R. §52.1920(c)(49). Oklahoma State Department of Health and DEQ provided review reports regarding visibility protection triennially from 1986 to 2003 in accordance with CAA §169A (42 USC §7491) and 40 C.F.R. §51.306. No reasonably attributable visibility impairment exists at the Wichita Mountains and the Wichita Mountains include no integral vistas.

DEQ rules already address visibility impairment through its permitting process, requiring the owner or operator of any new or modified major stationary source to comply with prevention of significant deterioration of air quality requirements. These preexisting rules limit the establishment of sources of air pollution that may contribute to visibility impairment. DEQ will continue to implement these rules to protect visibility at Wichita Mountains and Class I areas in other states.

C. Regional Haze

Congress amended the Clean Air Act in 1990, adding §169B (42 USC §7492), authorizing further research and regular assessments of progress toward its statutory visibility goal. Under 42 USC §7492(f), EPA established the Grand Canyon Visibility Transport Commission, involving several southwestern states but not Oklahoma. This commission contributed valuable scientific and technical assessments and information to EPA and, after four years of research and policy development under 42 USC §7492(d), submitted a report in 1996. This report made recommendations for regulations to address long-range strategies for regional haze that EPA used in its development of the federal regional haze rule.

EPA promulgated the regional haze rule (40 C.F.R. 51, Subpart P), effective 30 August 1999, aiming to achieve national visibility goals by 2064. This rulemaking addressed the combined visibility effects of various pollution sources over a wide geographic region. This wide-reaching pollution net requires Oklahoma and every other State—even those without Class I Areas—to participate in haze reduction efforts. The regional haze rule also requires certain existing stationary facilities which contribute significantly to regional haze problems in Class I areas to install and maintain BART to reduce their respective contributions.

On 24 May 2002, the United States Circuit Court of Appeals for the District of Columbia ruled on the challenge that the American Corn Growers Association brought against the regional haze rule. *See* American Corn Growers *et al.* v. EPA, 291 F.3d 1 (D.C. Cir. 2002). The Court remanded the BART provisions of the rule to EPA and denied the challenge of the industry to the regional haze rule goal of natural visibility without degradation. EPA promulgated revisions to the regional haze rule pursuant to this remand.

To implement the national visibility goal enacted by Congress, the State of Oklahoma hereby submits this implementation plan revision to EPA in order to address requirements of the regional haze rule. This revision addresses regional planning, discusses State/Tribe and federal land manager coordination, and contains a commitment to provide plan revisions and adequacy determinations.

D. Legal Authority

27A O.S. §2-5-105 designates DEQ as the administrative agency for the Oklahoma CAA. DEQ's Air Quality Division (AQD) handles the statutory authorities and responsibilities concerning air quality under OAC 252:4-1-3(c). The air quality division has the authority to carry out all duties, requirements, and responsibilities necessary and proper for the implementation of the Oklahoma CAA and fulfilling the requirements of the federal CAA under 27A O.S. §§1-3-101(B)(8), 2-3-101(E)(1), and 2-5-105. Upon recommendation of the Air Quality Advisory Council, the Environmental Quality Board has the authority under Oklahoma statutory law 27A O.S. §2-5-106 to adopt air quality regulations for DEQ. DEQ has the authority under Oklahoma law to:

- Enforce those regulations and orders of DEQ [27A OS §§2-5-105(4) and 2-5-110];
- Maintain and update an inventory of air emissions from stationary sources [27A O.S. §2-5-105(19)];
- Establish a permitting program [27A O.S. §2-5-105(2)]; and
- Carry out all other duties, requirements and responsibilities necessary and proper for the implementation of the Oklahoma CAA and the fulfillment of the requirements of the Federal CAA [27A O.S. §§2-5-105(22)].

Specifically, the Environmental Quality Board and DEQ have the existing authority to:

- Adopt emissions standards and regulations to implement the Oklahoma CAA and fulfill requirements of the Federal CAA [27A O.S. §§2-2-104, 2-5-105, 2-5-106, 2-5-107, and 2-5-114];
- Enforce the relevant laws, regulations, standards, orders and compliance schedules authorized by the Oklahoma CAA [27A O.S. §§2-5-105(4) and 2-5-110], and seek injunctive relief when necessary [27A O.S. §§2-5-105(14) and 2-5-117(A)];
- Abate pollutant emissions on evidence that the source is presenting an immediate, imminent and substantial endangerment to human health [27A O.S. §2-5-105(15)];
- Prevent construction, modification, or operation of a source in violation of the requirement to have a permit, or in violation of any substantive provision or condition of any permit issued pursuant to the Oklahoma CAA [27A O.S. §2-5-117(A)(2)];
- Obtain information necessary to determine compliance [27A O.S. §§2-5-105(17), (18)];
- Require recordkeeping, make inspections, and conduct tests [27A O.S. §2-5-105(17)];
- Require the installation, maintenance and use of monitors and require emissions reports of owners or operators [27A O.S. §2-5-112(B)(5)]; and
- Make emissions data available to the public [51 O.S. §§24A.1 through 24A.27].

Appendix 1-1 contains these referenced statutes.

E. Central Regional Air Planning

In the regional haze rule preamble, EPA acknowledged the key role of regional pollutant transport in contributing to haze at the Wichita Mountains and other Class I areas and recognized the need for interstate coordination for program planning and implementation. In response to this need, EPA designated five regional planning organizations to assist with the coordination and cooperation needed to address the visibility issue. The federal government funded the following five regional planning organizations:

- Central Regional Air Planning Association (CENRAP),
- Western Regional Air Partnership (WRAP),
- Visibility Improvement State and Tribal Association of the Southeast (VISTAS),
- Midwest Regional Planning Organization, and
- Mid-Atlantic/Northeast Visibility Union.

DEQ joined state clean air agencies from Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, and Texas in forming CENRAP in 1999. CENRAP also includes federally recognized Indian tribes located within the geographic boundaries of its member states. Figure I-1 displays the membership of all five regional planning organizations on a map of the United States of America. CENRAP aims to provide information necessary to coordinate emissions reduction strategies to improve visibility at the Wichita Mountains and all other mandatory Class I areas.

Figure I-1: Geographical Areas of Regional Planning Organizations

The policy oversight group governs CENRAP and comprises of 18 voting members representing the states and tribes within the CENRAP region and non-voting members representing local agencies, EPA, Fish and Wildlife Service, Forest Service, and National Park Service. The policy oversight group facilitates communication with federal land management personnel, steakholders, the public, and CENRAP staff.

The committee structure of CENRAP addresses all technical and non-technical issues related to regional haze. CENRAP established five standing workgroups: monitoring, emissions inventory, modeling, communications, and implementation and control strategies. All interested parties can participate in and provide input openly to these workgroups.

This implementation plan revision uses data analysis, modeling results, and other technical support documents prepared for CENRAP members. DEQ coordinated with CENRAP and other regional planning organizations to ensure that its long-term strategy and BART determinations reduce emissions sufficiently to mitigate their visibility impairment at affected Class I areas. CENRAP provides data analyses, modeling results, and other technical support documents to members through its website and file transfer protocol.

In concurrence with EPA policy, bylaws of CENRAP state, “CENRAP has no regulatory authority and recognizes that its members in accordance with existing law retain all legal authority.” DEQ

therefore maintains sole authority and responsibility for the development of this implementation plan revision and regional haze rules.

F. History of Oklahoma Participation

DEQ began to participate actively in CENRAP upon its inception in 1999, when Central States Air Resource Association (CenSARA) held the first workshop to develop the foundational policies and long-range plans for CENRAP. Former DEQ air quality director Larry Byrum served as the first director of CenSARA/CENRAP; current air quality director Eddie Terrill serves on the policy oversight group. DEQ employees actively consulted in many workgroups and served as chairs and co-chairs for those workgroups. DEQ assistant air quality director Beverly Botchlet-Smith assumed a leadership role in the communications workgroup, which former staff member Michelle Martinez also participated in. Ray Bishop led the monitoring workgroup before his retirement in 2007. DEQ engineering manager Lee Warden served as co-chair of the modeling workgroup, and staff manager Scott Thomas participated in the strategy and implementation workgroup. In addition to workgroup leadership and participation, members of DEQ staff actively participated in CenSARA/CENRAP meetings, and former DEQ staff member Annette Sharp now works as director of CenSARA/CENRAP.

DEQ provided emissions inventory information for all source categories to CENRAP and its membership. DEQ cooperated with all CENRAP states and tribes in developing information on baseline-period visibility impairment, an estimate of natural conditions, and a projection of emissions and visibility impairment in 2018.

G. State, Tribe, and Federal Land Manager Coordination

40 CFR § 51.308(i) requires coordination among states, tribes, and FLMs. FLMs serve on the policy oversight group of CENRAP and contribute to the membership on standing committees. This involvement enables FLMs to contribute to the development of technical and non-technical work of CENRAP. CENRAP additionally provided opportunities for FLMs to review and comment on each technical document developed toward the preparation of this implementation plan revision. In addition, the final draft of this implementation plan was uploaded to the internet for review by FLMs. FLMs were given thirty days to review and comment on the document prior to submittal. The FLM contact list used by DEQ in this process is provided in Chapter X, Consultation and Comments.

II. Visibility Monitoring and Conditions

The regional haze rule in 40 C.F.R. §51.308(d)(4) requires a monitoring strategy for measuring, characterizing, and reporting data representative of visibility impairment in the Wichita Mountains. An Interagency Monitoring of Protected Visual Environments (IMPROVE) monitor, established at Wichita Mountains in March 2001, fulfils this requirement. The IMPROVE monitor collects 24-hour samples every third calendar day. Later laboratory analysis gives dry concentrations for a wide variety of particulate components, including nitrate, various classes of carbonaceous aerosol, and many elements in the mixture. Application of the results then yields light extinction and visibility impairment during the sample period. This chapter details these analyses and calculations. Although the regional haze rule requires the establishment of baseline visibility conditions for 2000-2004, this implementation plan revision instead utilizes baseline conditions representative of 2002-2004 due to lack of data from previous years. Observations collected from the monitor indicate that sulfureous particulate causes a plurality of visibility impairment at the Wichita Mountains in every month of the year except January. On cold winter days, however, nitrate particulate dominates regional haze at the Wichita Mountains. Other components of regional haze spike during sporadic events. This chapter includes numerical values for all calculations, including baseline visibility.

A. Monitoring Strategy

Upon the creation of CENRAP, the Monitoring Workgroup identified a visibility data void in Oklahoma. At that time, an IMPROVE site for Upper Buffalo, Arkansas, in a wetter climate several hundred miles to the east-northeast, provided the closest data in the network. Lacking more proximate data, some analyses early in the regional haze planning process assigned this Arkansas data to the Wichita Mountains, but DEQ finds such data unrepresentative and inappropriate.

Wichita Mountains Wildlife Refuge personnel began operating an IMPROVE particle sampler in March 2001. Maintenance of this monitor with the current sampling protocol enables the assessment of reasonable progress toward addressing regional haze. This monitor represents conditions throughout the Wichita Mountains well, and because Oklahoma lacks any other Class I areas, this monitoring site alone provides all necessary data.

Within communications, technological, and financial constraints, this site will adhere to IMPROVE analysis methods and techniques. The IMPROVE program makes data available on the Internet and submits them to EPA's air quality system. DEQ does not operate the IMPROVE monitor at the Wichita Mountains and therefore takes no responsibility for analyzing filters or disseminating and submitting data. DEQ nevertheless intends to ensure the operation of a visibility monitoring site at the Wichita Mountains as long as funding allows. DEQ cannot assess the achievement of reasonable progress at the Wichita Mountains without the continuation of this monitoring.

B. Monitor Operation

Under IMPROVE protocol, Wichita Mountains Wildlife Refuge personnel send filter modules for analysis to the Crocker Nuclear Laboratory at the University of California in Davis every Tuesday. The modules collect 24-hour samples every third calendar day. Each monitoring site contains four independent modules connected only through a common clock. Each module contains a separate inlet, filtering system, and pump.

In module *B*, a carbonate denuder removes nitric acid and other acidic gases before particles of aerodynamic diameter 0.2 µm to 2.5 µm collect on a nylon filter. This filter goes to the Research Triangle Institute for ion chromatography analysis to establish concentrations of nitrate (NO_3^-), nitrite (NO_2^-), and chloride (Cl^-) in the collected particulate. This arrangement of denuder and nylon filter best preserves the nitrate and nitrite particulates that ordinarily volatilize readily, especially in warm, dry conditions typical of indoor air.

Module *C* collects particles of aerodynamic diameter 0.2 µm to 2.5 µm on a tandem quartz filter. Desert Research Institute analyzes these filters to measure carbonaceous particulate in eight temperature-based categories using the thermal optical reflectance combustion method. First placed in a pure helium atmosphere, the organic carbon combusts, producing measured quantities of carbon dioxide. After heating the sample and adding some oxygen to the helium atmosphere, even light-absorbing elemental carbon combusts, producing measurable carbon dioxide. Most error in these measurements results from the assignment of carbon among several temperature categories; the total organic carbon and total elemental carbon concentrations carry considerably less uncertainty.

Module *D* collects particles of aerodynamic diameter less than 10 µm on a Teflon polytetrafluoroethylene filter; the Crocker Nuclear Laboratory uses a gravimetric electro-microbalance method to determine the mass. The larger particles on this filter generally represent local and regional windblown dust and sand but include pollen and other organic materials too.

Most information from IMPROVE filters in module *A*, a Teflon polytetrafluoroethylene filter that collects fine particles of aerodynamic diameter 0.2 µm to 2.5 µm. Gravimetric electro-microbalance mass analysis of this filter approximates but does not match the federal reference method for measuring fine particulate matter ($PM_{2.5}$) within the national ambient air quality standard, so determinations of attainment and non-attainment cannot include this protocol. Most nitrates and some organics volatilize during and after sampling on this module.

On each module *A* sample, Crocker Nuclear Laboratory performs proton elastic scattering analysis (PESA) for hydrogen. Proton induced *x*-ray emission yields values for sodium, magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, potassium, calcium, titanium, vanadium, chromium, and manganese. *X*-ray fluorescence analysis gives mass concentrations of iron, cobalt, nickel, copper, zinc, arsenic, gallium, selenium, bromine, rubidium, strontium, zirconium, molybdenum, and lead.

When combined with measurements of the volume of air that passes through each filter, these analysis methods yield a mass concentration in µg m^{-3} for each constituent in the lower atmosphere. DEQ presumes that samples from the monitors contain chemical constituents distributed uniformly

throughout the field of view and therefore represent visibility impairment throughout the Wichita Mountains. IMPROVE technique notably does not measure ammonium (NH^+) despite its significant contribution to visibility impairment. The protocol hereinafter described presumes that ammonium binds to all nitrate and sulfurous particulate.

C. Calculating Light Extinction from Particulate Concentrations

Throughout the planning process, CENRAP entertained several possible methods for determining a representative daily light extinction coefficient from the particle concentrations that IMPROVE data provides. In 40 C.F.R. §51.308(d)(2), the regional haze rule assigns the determination of visibility conditions from monitoring data to the States. DEQ chooses to follow the approach of Pitchford *et al.* (2007) (Pitchford, Marc; William Malm, Bret Schichtel, Naresh Kumar, Douglas Lowenthal, and Jenny Hand, 2007: Revised algorithm for estimating light extinction from IMPROVE particle speciation data. *J. Air & Waste Manage. Assoc.*, **57**, 1326-1336.). This approach utilizes an equation often called the "new" or "revised" IMPROVE algorithm but herein simply called the "algorithm" unless otherwise noted.

The algorithm estimates additive extinction coefficients for each of several chemical constituents of particulate matter: sulfurous, nitrate, organic carbonaceous, elemental "light-absorbing" carbonaceous, fine soil, chlorine or chloride, and coarse matter. The algorithm accounts for Rayleigh scattering of light and for deliquescence on sulfurous, nitrate, and chlorine or chloride particulates with an estimate of particle-bound water as a function of relative humidity. The monitor at the Wichita Mountains currently does not measure the light-absorbing gas nitrogen dioxide (NO_2).

1. Sulfurous Particulate

The algorithm for calculating light extinction considers all sulfur detected via proton-induced *x*-ray emission as a part of $(NH_4)_2SO_4$ (ammonium sulfate). The samplers do not measure ammonium cation concentration. This fully neutralized and ammoniated compound usually dominates in most field studies elsewhere around the country, but sulfureous aerosols can form in ammonia- and ammonium-poor environments. Some acidic sulfate particulate commonly mixes with ammonium sulfate, and the sulfurous particulate statistics also include any other particulate sulfur compounds. Accounting for the other elements in ammonium sulfate gives an assumed mass of $(NH_4)_2SO_4$ equal to 4.125 times the measured mass of sulfur.

At high concentrations, sulfurous particulate tends toward larger particles within the accumulation mode (generally 0.1-1.0 µm aerodynamic diameter) rather than occurring as more numerous smaller particles. The algorithm assumes that this shift progresses linearly with measured sulfur concentration until the faux ammonium sulfate concentration reaches 20 µg m^{-3}, beyond which level all sulfurous particulate presumably takes the larger particle size. Because light extinction depends on the particle size distribution, the algorithm supplies two separate dry scattering efficiencies: $f_{sml}(R_H)$ for "small" particles and $f_{lrg}(R_H)$ for "large" particles within the accumulation mode. A single large particle within the accumulation mode scatters light more efficiently than several smaller particles with the same combined mass.

Because its dipole between the ammonium cations and the sulfate anion resembles the polarity of the water molecule, ammonium sulfate effectively nucleates cloud droplets. Ammonium sulfate deliquesces at a relative humidity considerably below 100%, acquiring water and forming haze droplets that enhance visible light scattering efficiency. As the relative humidity approaches 100%, these haze droplets swell rapidly, and their scattering efficiency increases correspondingly. This growth enhances the scattering efficiency of smaller aerosols more effectively than that of their larger counterparts.

The algorithm includes lookup tables for the proportional enhancement of scattering efficiency as a function of relative humidity rounded to the nearest percent. Relative humidity varies considerably within each calendar day; minima of relative humidity typically occur with temperature maxima and conversely. The monitoring equipment, however, collects only one sample for an entire calendar day. As relative humidity approaches 100%, fog forms entirely naturally and restricts visibility quite severely even without anthropogenic visibility-impairing particulate.

Rather than attempt to address these issues regarding each particular day, the algorithm uses climatic monthly-average relative humidity functions for visibility restriction through vapor growth of haze droplets. Because of the nonlinearity of these functions of relative humidity, the average value of a function of relative humidity differs from the value of the function of the average relative humidity. The average values of the two functions moreover vary independently but similarly; despite a strong correlation between the monthly-averaged value for small particles and that for larger particles within the accumulation mode, no strict relation exists between the time-averaged values of these functions.

The algorithm mathematically expresses the sulfurous contribution as:

$$\beta_{ext_S} = 2.2\frac{\mathrm{m}^2}{\mathrm{g}}\overline{f_{sml}(R_H)}_{nrm}\max\left\{4.125[\mathrm{S}] - \frac{(4.125[\mathrm{S}])^2}{20\frac{\mu\,\mathrm{g}}{\mathrm{m}^3}}\middle| 0\frac{\mu\,\mathrm{g}}{\mathrm{m}^3}\right\} + 4.8\frac{\mathrm{m}^2}{\mathrm{g}}\overline{f_{lrg}(R_H)}_{nrm}\min\left\{\frac{(4.125[\mathrm{S}])^2}{20\frac{\mu\,\mathrm{g}}{\mathrm{m}^3}}\middle| 4.125[\mathrm{S}]\right\}$$

The algorithm requires factors to account for the effects of relative humidity on light scattering specific to the Wichita Mountains, but IMPROVE generally does not deploy humidity sensors. EPA instead derived monthly climatological mean relative humidity function values from hourly relative humidity measurements in 1988-1997 at 292 National Weather Service sites, 29 IMPROVE sites (not including the Wichita Mountains), 48 Clean Air Status and Trends Network sites, and 13 National Park Service sites. These interpolated monthly climatological “normal” relative humidity function values approximate deliquescence that increases the light extinction from suspended particles. Table II-1 gives climatic normal values of the functions of relative humidity.

Table II-1: Monthly normal relative humidity functions at the Wichita Mountains

Month	$f_{sml}(R_H)_{nrm}$	$f_{lrg}(R_H)_{nrm}$	$f_{slt}(R_H)_{nrm}$
January	3.17	2.39	3.35
February	2.94	2.25	3.12
March	2.69	2.10	2.91
April	2.68	2.11	2.94
May	3.15	2.39	3.40
June	2.86	2.24	3.21
July	2.49	2.02	2.84
August	2.70	2.13	3.01
September	3.07	2.35	3.32
October	2.87	2.22	3.10
November	2.97	2.28	3.20
December	3.20	2.41	3.40

2. Nitrate Particulate

The algorithm uses nitrate concentrations derived from the ion chromatography analysis and maps them exclusively to ammonium nitrate (NH_4NO_3) despite the presence of other nitrates. The mass of an ammonium nitrate molecule equals 1.29 times the mass of a nitrate anion. Nitrate aerosols exhibit similar hygroscopicity to sulfurous aerosols, and their size distribution shifts toward larger particles within the accumulation mode at greater concentrations. The algorithm treats these properties in a manner mathematically identical to its treatment of such properties in sulfurous aerosols; however, nitrate aerosols exhibit slightly greater dry extinction efficiency. As an equation:

$$\beta_{ext_{NO_3^-}} = 2.4\frac{m^2}{g}\overline{f_{sml}(R_H)}_{nrm}\max\left\{1.29[NO_3^-] - \frac{(1.29[NO_3^-])^2}{20\frac{\mu g}{m^3}}\middle| 0\frac{\mu g}{m^3}\right\} + 5.1\frac{m^2}{g}\overline{f_{lrg}(R_H)}_{nrm}\min\left\{\frac{(1.29[NO_3^-])^2}{20\frac{\mu g}{m^3}}\middle| 1.29[NO_3^-]\right\}$$

3. Organic Carbonaceous Particulate

IMPROVE quantifies only the carbon in carbonaceous particulate. The thermal optical reflectance technique produces measurements of carbon derived from carbon dioxide produced when the particulate combusts within certain temperature ranges. Only oxygenated organic carbon compounds can combust in the pure helium atmosphere used for the first four temperature steps. This combustion and the attendant thermal energy induce pyrolysis that darkens the remaining sample with other organic carbon. After the introduction of some oxygen gas into the combustion chamber, this "pyrolyzed" organic carbon O_P combusts. When the reflectance of the sample returns to its original level, the combustion of organic carbon ends and that of refractory carbon begins. The algorithm must approximate the contribution of organic carbonaceous aerosols to light extinction as a function of their mass concentration. Scientific techniques still cannot assess accurately the abundance of particular carbonaceous compounds among this diverse mixture; therefore, the algorithm must make rough assumptions based upon observation. The algorithm employs the same split between large and small particles within the accumulation mode as it does for sulfurous and nitrate particulate. Because of the commonality of non-polar and weakly polar covalent bonds in carbonaceous aerosols, the algorithm assumes that they nucleate haze droplets poorly and do not swell whatsoever regardless of the relative humidity. The algorithm also assumes that the mass of the aggregate of this group approximately equals 1.8 times the mass of the carbon atoms contained therein.

The mathematical formula for the derivation of the light extinction attributed in this algorithm to organic carbonaceous aerosols follows:

$$\beta_{ext_{organic}}$$
$$= 2.8\frac{\mathrm{m}^2}{\mathrm{g}} \max\left\{1.8([O_1]+[O_2]+[O_3]+[O_4]+[O_p]) - \frac{\left(1.8([O_1]+[O_2]+[O_3]+[O_4]+[O_p])\right)^2}{20\frac{\mu\mathrm{g}}{\mathrm{m}^3}} \middle| 0\frac{\mu\mathrm{g}}{\mathrm{m}^3}\right\}$$
$$+ 6.1\frac{\mathrm{m}^2}{\mathrm{g}} \min\left\{\frac{\left(1.8([O_1]+[O_2]+[O_3]+[O_4]+[O_p])\right)^2}{20\frac{\mu\mathrm{g}}{\mathrm{m}^3}} \middle| 1.8([O_1]+[O_2]+[O_3]+[O_4]+[O_p])\right\}$$

The monitor at Wichita Mountains operates consistently under the same sampling protocol whatever its artifacts and limitations.

4. Elemental Carbonaceous Particulate

Refractory carbon combusts only in the presence of oxygen after the reflectance of the sample increases to or beyond its original value. The algorithm considers all such carbon as light-absorbing elemental carbon. IMPROVE provides elemental carbonaceous particulate data in three temperature bins; these three bins include the "pyrolyzed" carbon already considered among the organic carbonaceous particulate.

The algorithm assumes that elemental carbonaceous particulate both absorbs and scatters visible light. The algorithm excludes the size-shifting phenomenon in extinction efficiency and assumes that these particles do not deliquesce. The equation follows:

$$\beta_{ext_{elemental}} = 10\frac{m^2}{g}([E_1] + [E_2] + [E_3] - [O_p])$$

5. Fine Soil Particulate

Most windblown dust occupies the coarse mode with aerodynamic diameters too large for the accumulation-mode samplers. The Teflon filter on the accumulation mode sampler, however, does collect some fine soil particulate. Soils comprise many different components, most notably oxides and other compounds of silicon, aluminum, calcium, iron, and titanium. The coefficients in the equation effectively convert the molar mass of each element except iron into that of its oxide. Iron contributes to ferric and ferrous oxides, and the algorithm presumes an equal split between the two valence states. Potassium also commonly occurs in soils and smoke, so the algorithm assumes that the potassium concentration equals 60 percent of the iron concentration and adds an appropriate factor to the coefficient for iron. Most fine soils presumably scatter light rather inefficiently compared to the other fine components. The algorithm then divides the coefficient for each element by 0.86 to account for miscellaneous soil elements.

The particle-induced *x*-ray emissions and *x*-ray fluorescence methods cannot detect the signals of elements that occur in such small quantities that the analysis cannot distinguish between noise and signal. The algorithm assumes that every sample contains each element in the soil equation even if the measurement does not detect it. If the raw data give a concentration of any component element less than the minimum detectable limit, the algorithm substitutes one-half the minimum detectable limit. Soil dust generally occurs most commonly in very dry environments and does not deliquesce readily.

$$\beta_{ext_{soil}} = 1\frac{m^2}{g}(2.20[\mathrm{Al}] + 2.49[\mathrm{Si}] + 1.63[\mathrm{Ca}] + 2.42[\mathrm{Fe}] + 1.94[\mathrm{Ti}])$$

6. Coarse Particulate

The algorithm defines coarse particulate mass concentration as the difference between that of particulate with aerodynamic diameter less than 10 µm and that of particulate with aerodynamic diameter less than 2.5 µm, both measured from gravimetric electro-microbalance on separate Teflon filters. IMPROVE does not determine routinely the chemical composition of coarse particulate. Limited studies elsewhere suggest that coarse matter comprises mostly soils, organic particulates, and nitrate particulate. The algorithm assumes that all coarse matter does not deliquesce and assigns it a relatively low dry scattering efficiency.

$$\beta_{ext_{coarse}} = 0.6\frac{m^2}{g}([PM_{10}] - [PM_{2.5}])$$

7. Chlorine or Chloride Particulate

Designed for use throughout the United States of America, the algorithm includes a provision for saline aerosols that account for a considerable proportion of the total fine particulate mass in coastal regions. To estimate the fine sea salt concentration, the algorithm uses the chloride anion measurement from ion chromatography and assumes that saline aerosol always takes the form of NaCl. Chlorides in the real atmosphere can take other chemical forms, but the algorithm includes all chlorides here. In the event of a missing chloride ion concentration or one below the minimum detectable limit, the algorithm can substitute chlorine concentration measured with proton-induced *x*-ray emissions from the Teflon filter. Hygroscopic growth of saline aerosol greatly enhances its scattering efficiency with increasing relative humidity. The algorithm estimates this effect in a manner analogous to its treatment of hygroscopic growth of large and small sulfurous aerosol but uses an entirely independent curve designed especially for sodium chloride aerosol.

$$\beta_{ext_{Cl^-}} = 1.7\frac{m^2}{g}\overline{f_{slt}(R_H)}_{nrm}1.8[Cl^-]$$

8. Rayleigh scattering

All gaseous molecules scatter light and Rayleigh theory describes this scattering, depending on atmospheric density and varying with actual meteorological conditions. The algorithm assumes a constant Rayleigh scattering for the Wichita Mountains based upon its elevation and mean annual temperature.

$$\beta_{ext_{Rayleigh}} = 11\ Mm^{-1}$$

(Malm 1999). Source: William Malm, *Introduction to Visibility*, 1999, National Park Service?]

D. Deciview Haze Index

The laws of physics that govern scattering of light allow for additive extinction coefficients. Expressed mathematically for the application to regional haze:

$$\beta_{ext} = \beta_{ext_S} + \beta_{ext_{NO_3^-}} + \beta_{ext_{organic}} + \beta_{ext_{elemental}} + \beta_{ext_{soil}} + \beta_{ext_{coarse}} + \beta_{ext_{Cl^-}} + \beta_{ext_{Rayleigh}}$$

The regulatory law defines the deciview haze index such that:

$$d_v = 10\ln_e\left(\frac{1}{10\ Mm^{-1}}\beta_{ext}\right)$$

In the case of visibility, aerosol light extinction β_{ext} represents the inverse of the characteristic distance that light travels before reflection or absorption.

IMPROVE data includes concentrations of various trace elements not considered here. The algorithm ignores these measured concentrations entirely because their minimal concentrations correspond to an insignificantly small proportion of total visibility impairment.

DEQ considered refining the algorithm to use hourly relative humidity data available from the remote automated weather sensor (RAWS) at the Wichita Mountains or from the Medicine Park site of the Oklahoma Mesonet. This potential change raises several issues related to discernment between humid haze and unpolluted fog or mist on some days and selects dramatically different days as the worst quintile for visibility impairment. Desiring to select days among the best and worst quintiles consistent with available guidance and with the methods of other States in CENRAP, DEQ decided against this approach for this implementation plan revision; however, DEQ may consider such refinements in future submissions to EPA.

E. Monitoring Data and Light Extinction Calculations

The regional haze rule requires the establishment of baseline visibility conditions for 2000-2004. DEQ must establish the average visibility impairment on the best quintile and worst quintile of monitored days in each year. Progress toward natural visibility conditions requires a reduction in the five-year rolling average visibility impairment in deciviews. No monitor existed at the Wichita Mountains during the year 2000, and no data from any other monitor provides a reasonable substitute. Because monitoring began in March 2001, data from that year does not meet EPA's completeness criteria. This implementation plan revision presents the incomplete visibility data for 2001, complete data for 2002-2004, and provisional data for 2005 and 2006. Baseline conditions represent the average for 2002-2004.

1. Sulfureous Particulate

Table II-2~~Table II-2~~ summarizes measurements of sulfureous particulate concentration and estimates of the light extinction attributed to sulfureous particulate. The values listed in several tables in this chapter include significant figures reflecting uncertainty in measurements.

Table II-2: Measured particulate sulfur concentrations at Wichita Mountains

Year	[S] (μg m^{-3})			β_{extS} (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	.74			24.		
2002	.79	.19	1.8	25.	5.4	62.
2003	.74	.185	1.32	22.3	5.0	43.
2004	.71	.18	1.28	21.4	5.0	42.
2005	1.00	.28	2.3	32.	7.	80
2006	.70	.21	1.3	21.	6.	43.
2007	.69			20.7		
Baseline	.75	.187	1.48	22.7	5.1	49.

Sulfureous aerosol bears culpability for half of visibility impairment at the Wichita Mountains and constitutes a majority on most days among the worst quintile. High sulfureous particulate concentrations generally occur on days when broad anticyclonic flow moves air from the Eastern states through Texas to the Wichita Mountains on prevailing southerly flow. Days with high sulfureous aerosol concentrations and consequent visibility impairment occur year-round but most commonly from April through October.

2. Nitrate Particulate

Table II-3~~Table II-3~~ summarizes measurements of nitrate particulate concentration and estimates of the light extinction attributed to nitrate particulate.

Table II-3: Measured particulate nitrate concentrations at Wichita Mountains

Year	$[NO_3^-]$ (μg m^{-3})			$\beta_{ext_{NO_3^-}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	1.0			10.		
2002	.91	.33	1.0	8.9	3.2	10.
2003	1.06	.29	2.6	10.8	2.7	29.
2004	1.10	.27	2.7	11.9	2.5	32.
2005	.8	.26	1.0	9.	2.	10.
2006	.72	.21	1.1	7.	2.0	11.
2007	1.00			10.8		
Baseline	1.02	.30	2.1	10.5	2.8	24.

Nitrate particulate haze occurs primarily during the winter months, typically contributing just 2 Mm^{-1} to visibility impairment from June through September and more than ten times that from January through March. This constituent alone comprises a majority of visibility impairment on one-eighth of days among the worst quintile at the Wichita Mountains. Those days occur exclusively in December, January, and February. Lower temperatures and a relative lack of bright sunshine inhibit photochemical reactions involving oxides of nitrogen during the winter season. Prevailing southerly flow most frequently reverses into northerly winds behind Arctic cold fronts that slide down the Plains during this hibernal season. Most sources of nitrate aerosols and their precursors therefore must lie on the rural to remote regions of the Great Plains north of the Wichita Mountains.

3. Organic Carbonaceous Particulate

Table II-4~~Table II-4~~ summarizes measurements of each category of organic carbonaceous particulate concentration and estimates of the light extinction attributed to organic carbonaceous particulate.

Table II-4: Measured fine particulate organic carbon concentrations at Wichita Mountains

Year	[O_1] (µg m^{-3})			[O_2] (µg m^{-3})			[O_3] (µg m^{-3})			[O_4] (µg m^{-3})			[O_P] (µg m^{-3})			$\beta_{ext_{organic}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	.07			.27			.44			.35			.20			8.0		
2002	.069	.03	.16	.24	.09	.50	.38	.21	.71	.31	.14	.61	.22	.13	.29	7.2	3.2	15.
2003	.07	.03	.12	.26	.10	.44	.56	.26	.86	.40	.15	.65	.20	.14	.17	9.1	3.7	15.
2004	.08	.04	.18	.30	.11	.63	.57	.26	1.2	.42	.16	.9	.18	.13	.18	9.9	3.9	22.
2005	.08	.02	.2	.35	.14	.7	.26	.14	.4	.24	.10	.4	.44	.20	.8	8.3	3.	17.
2006	.05	.02	.2	.27	.09	.5	.27	.14	.4	.21	.10	.4	.33	.15	.6	6.7	2.7	13.
2007	.04			.26			.26			.20			.37			6.6		
Baseline	.070	.03	.15	.266	.10	.52	.50	.24	.92	.378	.15	.72	.201	.13	.21	8.7	3.6	17.

The organic carbonaceous particulate concentrations show some seasonal cycle with a pronounced hibernal minimum from November through early February. Extreme concentrations and related visibility impairment occur on a few days in March. Visibility impairment attributable to organic carbonaceous particulate generally averages double its hibernal minimum from April through September.

4. Elemental Carbonaceous Fine Particulate

Formatte

4. Table II-5

~~Table II-5~~ summarizes measurements of each category of elemental carbonaceous particulate concentration and estimates of the light extinction attributed to elemental carbonaceous particulate.

Table II-5: Measured fine particulate elemental carbon concentrations at Wichita Mountains

Year	$[E_1]$ (µg m^{-3})			$[E_2]$ (µg m^{-3})			$[E_3]$ (µg m^{-3})			$[O_1]$ (µg m^{-3})			$\beta_{ext_{elemental}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	.38			.079			.004			.20			2.7		
2002	.36	.17	.63	.086	.08	.07	.006	.005	.002	.22	.13	.29	2.3	1.2	4.2
2003	.37	.17	.50	.107	.09	.11	.010	.010	.009	.20	.14	.17	3.0	1.3	4.5
2004	.36	.19	.58	.070	.06	.07	.004	.004	.005	.18	.13	.18	2.6	1.3	4.7
2005	.65	.26	1.3	.101	.09	.11	.004	.006	.002	.44	.20	.8	3.2	1.5	6.
2006	.51	.19	1.0	.089	.07	.12	.0023	.001	.005	.33	.15	.6	2.6	1.1	5.
2007	.53			.078			.002			.37			2.4		
Baseline	.364	.18	.57	.088	.079	.083	.0066	.007	.005	.201	.13	.21	2.6	1.2	4.5

Despite high dry extinction efficiency, elemental carbonaceous particulate contributes less than one-eighth of total visible light extinction on every day among the worst quintile. The total concentration exhibits little seasonal variation.

5. Fine Soil Particulate

Table II-6~~Table II-6~~ summarizes measurements of each category of fine soil particulate concentration and estimates of the light extinction attributed to fine soil particulate.

Table II-6: Measured Fine Soil Particulate Concentrations at Wichita Mountains

Year	[Si] (μg m^{-3})			[Al] (μg m^{-3})			[Ca] (μg m^{-3})			[Fe] (μg m^{-3})			[Ti] (μg m^{-3})			$\beta_{ext_{soil}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	.22			.072			.067			.056			.0080			.98		
2002	.19	.065	.20	.057	.010	.03	.052	.026	.060	.042	.013	.037	.0045	.0012	.0035	.79	.26	.8
2003	.219	.088	.24	.028	.018	.009	.064	.038	.065	.051	.019	.049	.0050	.0018	.0045	.85	.38	.9
2004	.196	.072	.19	.063	.017	.026	.049	.024	.062	.041	.015	.033	.0040	.0015	.0024	.82	.30	.7
2005	.14	.09	.27	.045	.03	.04	.057	.05	.07	.037	.022	.04	.0035	.0020	.004	.64	.4	.7
2006	.21	.11	.3	.084	.041	.13	.078	.05	.11	.052	.025	.08	.0050	.002	.007	.98	.5	1.5
2007	.20			.070			.057			.048			.0048			.87		
Base-line	.201	.075	.21	.049	.015	.023	.055	.029	.062	.044	.016	.039	.0045	.0015	.0035	.82	.31	.79

Meteorological conditions explain the similarity between the mean concentration of fine soil particulate and the average concentration on the worst quintile days. Sulfates and wintertime nitrates dominate the current worst quintile days but tend to occur in flow that passes over the continental eastern United States and Canada.

Back trajectories indicate that long-range transport of dust from the Sahara Desert also contributes significantly to the fine soil particulate, even on days with relatively low concentrations of coarse-mode particulate. Saharan dust reaches the Wichita Mountains regularly, beginning in late spring and continuing until hurricanes develop in the tropical Atlantic Ocean. Higher fine soil concentrations occur most notably in dry years with late or inactive Atlantic hurricane seasons.

Fine soil generally contributes less than 1 Mm^{-1} to light extinction from September through February and increases rapidly through June and July to peak at an average greater than 2 Mm^{-1}.

6. Coarse Particulate

Table II-7~~Table II-7~~ summarizes measurements of coarse particulate concentration and estimates of the light extinction attributed to coarse particulate.

Table II-7: Measured Coarse Particulate Concentrations at Wichita Mountains

Year	$[PM_{10}]$ ($\mu g\ m^{-3}$)			$[PM_{2.5}]$ ($\mu g\ m^{-3}$)			$\beta_{ext\ coarse}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	15.9			7.8			4.7		
2002	14.7	6.5	24.	7.4	2.2	15.	4.4	2.5	5.
2003	15.3	8.0	21.0	7.9	2.5	14.0	4.5	3.3	4.
2004	14.1	5.5	22.	7.8	2.4	15.2	3.8	2.2	4.
2005	15.5	8.	26.	8.1	2.8	17.	4.5	4.	5.
2006	15.1	8.	24.	6.6	2.4	12.	5.1	4.	7.
2007	13.8			7.2			4.0		
Baseline	14.7	6.7	22.4	7.71	2.35	14.6	4.2	2.7	4.6

Coarse particulate exhibits little seasonal variation with a normal minimum in January near 3 Mm^{-1} of visibility impairment and a broad peak near July with 6 Mm^{-1} of visibility impairment. Variation from day to day, however, overwhelms any seasonal trends. Dust storms which cause the most extreme concentrations of coarse particulate matter usually originate in the deserts and semiarid short-grass prairies of the High Plains, the American Southwest, and northern Mexico.

7. Chloride Particulate

Table II-8~~Table II-8~~ summarizes measurements of chloride and chlorine particulate concentrations and estimates of consequent light extinction at the Wichita Mountains.

Table II-8: Measured Chloride and Chlorine Particulate Concentrations at Wichita Mountains

Year	$[Cl^-]$ (µg m^{-3})			[Cl] (µg m^{-3})			$\beta_{ext_{Cl^-}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	.00			.0000			.06		
2002	.00	.0	0.	.0000	.0000	.0000	.006	.000	.000
2003	.02	.0	0.	.0002	.0002	.0000	.07	.06	.02
2004	.041	.028	.048	.0003	.0002	.0003	.37	.23	.44
2005	.020	.01	.02	.00001	.0000	.0000	.20	.08	.2
2006	.023	.01	.05	.00003	.0001	.0000	.24	.09	.5
2007	.050			.00002			.52		
Baseline	.02	.00	0.	.00016	.0002	.0001	.15	.10	.15

IMPROVE samples at the Wichita Mountains generally contain negligible or barely detectable chloride and chlorine concentrations. Considerable contributions occur only rarely, and the apparent increase over the past few years may indicate only improved detection.

Other ParticulateTable II-9~~Table II-9~~ summarizes measurements of various other chemicals that the IMPROVE monitor detects, using units of ng m^{-3} where appropriate because of their miniscule concentrations.

Table II-9: Measured concentrations of various elements and nitrite in fine particulate matter at Wichita Mountains

Year	[H] (µg m^{-3})			[Na] (µg m^{-3})			[K] (µg m^{-3})			[NO_2^-] (µg m^{-3})			[Mg] (µg m^{-3})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	.33			.056			.049			.013			.002		
2002	.35	.12	.76	.08	.02	.17	.044	.016	.074	.012	.007	.016	.010	.007	.01
2003	.345	.124	.60	.10	.07	.18	.055	.020	.078	.017	.01	.02	.008	.01	.01
2004	.359	.134	.71	.05	.01	.11	.051	.020	.079	.013	.007	.01	.02	.01	.02
2005	.43	.16	.9	.031	.02	.04	.046	.023	.07	.003	.00	.004	.003	.005	.001
2006	.35	.15	.62	.064	.005	.12	.052	.022	.10	.002	.00	.000	.006	.003	.01
2007	.32			.055			.045			.003			.008		
Baseline	.352	.127	.69	.08	.03	.15	.050	.0186	.077	.014	.009	.016	.012	.010	.01

Year	[Zn] (**ng** m^{-3})			[Br] (**ng** m^{-3})			[Pb] (**ng** m^{-3})			[Mn] (**ng** m^{-3})			[P] (**ng** m^{-3})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	3.5			2.01			1.39			1.5			.1		
2002	3.42	1.7	5.6	1.95	.88	3.7	1.11	.69	1.6	.94	.34	1.0	2.1	1.	0.
2003	3.61	1.76	5.5	1.96	1.00	2.5	1.14	.50	1.70	.90	.46	.63	.1	.3	.0
2004	4.0	2.7	6.4	2.18	1.07	3.4	1.34	.58	2.0	1.05	.39	1.1	.5	.0	.0
2005	4.1	2.3	6.	2.06	1.1	3.2	1.24	.7	1.7	.98	.6	1.2	3.3	.0	5
2006	3.7	1.8	6.	1.82	.9	2.7	1.21	.5	1.9	1.27	.6	1.9	.1	.0	.0
2007	3.6			2.02			1.09			1.07			.9		
Baseline	3.69	2.06	5.8	2.03	.98	3.2	1.19	.59	1.77	.96	.40	.92	.9	.5	.0

Year	[Se] (**ng** m^{-3})			[V] (**ng** m^{-3})			[Cu] (**ng** m^{-3})			[Sr] (**ng** m^{-3})			[Rb] (**ng** m^{-3})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
2001	.99			1.0			.51			.58			.15		
2002	.68	.34	1.4	.64	.13	.8	.44	.25	.63	.47	.12	.55	.18	.06	.19
2003	.74	.28	.96	.49	.15	.36	.48	.22	.57	.48	.17	.47	.16	.06	.23
2004	.89	.42	1.7	.60	.21	.56	.56	.33	1.0	.43	.24	.38	.18	.13	.18
2005	.77	.35	1.4	.56	.3	.6	.53	.27	.7	.45	.28	.4	.15	.09	.17

2006	.52	.21	.8	.54	.20	.8	.55	.32	.8	.58	.36	.8	.15	.12	.23
2007	.63			.60			.46			.50			.15		
Baseline	.77	.35	1.33	.57	.16	.59	.49	.26	.73	.46	.18	.47	.173	.08	.20

Year	[As] (**ng** m^{-3})			[Ni] (**ng** m^{-3})			[Cr] (**ng** m^{-3})			[Zr] (**ng** m^{-3})					
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile			
2001	.12			.08			.5			.06					
2002	.09	.02	.17	.12	.01	.22	.09	.03	.16	.08	.03	.09			
2003	.14	.09	.24	.091	.02	.08	.05	.05	.05	.02	.00	.02			
2004	.12	.10	.18	.13	.05	.13	.053	.03	.06	.03	.00	.04			
2005	.10	.04	.2	.13	.05	.15	.06	.03	.08	.02	.01	.00			
2006	.11	.05	.19	.14	.05	.19	.07	.03	.08	.04	.01	.01			
2007	.08			.123			.08			.08					
Baseline	.12	.07	.20	.113	.03	.14	.062	.04	.09	.04	.01	.05			

The formulations $(NH_4)_2SO_4$ and NH_4NO_3 implicitly account for H, and NaCl already implicitly accounts for Na. The fine soil formulation considers K. IMPROVE monitor detects only negligible concentrations of other components of fine particulate matter; DEQ therefore finds that these trace components contribute only negligibly to regional haze.

F. Baseline Visibility at Wichita Mountains

Using the data heretofore provided, DEQ calculates the baseline visibility conditions in the mean, on the best quintile visibility days, and on the worst quintile visibility days.

Table II-10: Average Visibility Conditions at the Wichita Mountains

Year	β_{ext_S} (Mm^{-1})	$\beta_{ext_{NO_3^-}}$ (Mm^{-1})	$\beta_{ext_{organic}}$ (Mm^{-1})	$\beta_{ext_{elemental}}$ (Mm^{-1})	$\beta_{ext_{soil}}$ (Mm^{-1})	$\beta_{ext_{coarse}}$ (Mm^{-1})	$\beta_{ext_{Cl^-}}$ (Mm^{-1})	$\beta_{ext_{Rayleigh}}$ (Mm^{-1})	β_{ext} (Mm^{-1})	Haze index (deciview)
2001	24.	10.	8.0	2.7	.98	4.7	.06	11.	58.	16.4
2002	25.	8.9	7.2	2.3	.79	4.4	.006	11.	59.	16.5
2003	22.3	10.8	9.1	3.0	.85	4.5	.07	11.	62.	17.1
2004	21.4	11.9	9.9	2.6	.82	3.8	.37	11.	62.	16.8
2005	32.	9.	8.3	3.2	.64	4.5	.20	11.	69.	17.9
2006	21.	7.	6.7	2.6	.98	5.1	.24	11.	54.	15.9
2007	20.7	10.8	6.6	2.4	.87	4.0	.52	11.	57.	16.1
Baseline	22.7	10.5	8.7	2.6	.82	4.2	.15	11.	60.8	16.8

Fine particulate with sulfur and nitrate accounts for a majority of scattering of visible light in the atmosphere at the Wichita Mountains. Rayleigh scattering from air molecules also reduces visibility significantly.

Table II-11: Best Quintile Visibility Conditions at the Wichita Mountains

Year	β_{ext_S} (Mm^{-1})	$\beta_{ext_{NO_3^-}}$ (Mm^{-1})	$\beta_{ext_{organic}}$ (Mm^{-1})	$\beta_{ext_{elemental}}$ (Mm^{-1})	$\beta_{ext_{soil}}$ (Mm^{-1})	$\beta_{ext_{coarse}}$ (Mm^{-1})	$\beta_{ext_{Cl^-}}$ (Mm^{-1})	$\beta_{ext_{Rayleigh}}$ (Mm^{-1})	β_{ext} (Mm^{-1})	Haze index (deciview)
2001										
2002	5.4	3.2	3.2	1.2	.26	2.5	.000	11.	27.	9.8
2003	5.0	2.7	3.7	1.3	.38	3.3	.06	11.	27.	10.0
2004	5.0	2.5	3.9	1.3	.30	2.2	.23	11.	26.	9.6
2005	7.	2.	3.	1.5	.4	4.	.08	11.	30.	10.6
2006	6.	2.0	2.7	1.1	.5	4.	.09	11.	27.	9.8
2007										
Baseline	5.1	2.8	3.6	1.2	.31	2.7	.10	11.	26.9	9.8

On the clearest quintile of days at the Wichita Mountains, Rayleigh scattering off air molecules exceeds the combined effects of sulfureous and nitrate aerosols on visibility.

Table II-12: Worst Quintile Visibility Conditions at the Wichita Mountains

Year	β_{ext_S} (Mm^{-1})	$\beta_{ext_{NO_3^-}}$ (Mm^{-1})	$\beta_{ext_{organic}}$ (Mm^{-1})	$\beta_{ext_{elemental}}$ (Mm^{-1})	$\beta_{ext_{soil}}$ (Mm^{-1})	$\beta_{ext_{coarse}}$ (Mm^{-1})	$\beta_{ext_{Cl^-}}$ (Mm^{-1})	$\beta_{ext_{Rayleigh}}$ (Mm^{-1})	β_{ext} (Mm^{-1})	Haze index (deciview)
2001										
2002	62.	10.	15.	4.2	.8	5.	.000	11.	109.	23.6
2003	43.	29.	15.	4.5	.9	4.	.02	11.	107.	23.6
2004	42.	32.	22.	4.7	.7	4.	.44	11.	118.	24.2
2005	80	10.	17.	6.	.7	5.	.2	11.	135	26.
2006	43.	11.	13.	5.	1.5	7.	.5	11.	92	22.
2007										
Baseline	49.	24.	17.	4.5	.79	4.6	.15	11.	111.	23.8

On the worst quintile of days, fine sulfureous aerosols account for almost as much visibility impairment as all particles do on an average day. Fine particles of nitrate and organic carbon also degrade visibility on these days. Although anthropogenic sources contribute greatly to particulate matter in the atmosphere, some degradation of visibility results from natural sources and processes.

III. Natural Conditions

DEQ estimates the average natural background visibility conditions for the most and least impaired quintiles of days based upon available monitoring data and appropriate analysis techniques. DEQ follows the "revised" natural haze levels approach, most consistent with the algorithm for estimating baseline conditions. EPA and DEQ base this approach on estimates that John C. Trijonis developed and included in his contribution to a National Acid Precipitation Assessment Program report in 1990.This chapter explains sources and magnitude of error in the algorithm and presents alternative estimates of natural conditions. Natural sources of visibility impairment include windblown dust, fires, active volcanoes, and biogenic emissions. Natural conditions also change, sometimes dramatically, on various temporal and spatial scales. This chapter also compares observed visibility statistics with natural background estimates to obtain a uniform rate of progress toward the goal of achieving natural visibility conditions at the Wichita Mountains in 2064.

To summarize conclusions, DEQ data finds that visibility degradation at the Wichita Mountains is primarily caused by anthropogenic emissions of sulfur and nitrogen oxides but organic aerosols also contribute significantly in summer. Meeting the uniform rate of progress glidepath toward the statutory goal of no visibility impairment in 2064 necessitates an improvement of 34.18 Mm^{-1} in light extinction by 2018 and entails an average rate of improvement of 0.27 deciviews per year. This calculation assumes an ultimate goal to reach natural conditions at 7.53 deciviews by the year 2064. DEQ considers this analysis approach seriously flawed but lacks adequate understanding of the magnitude and location of natural sources of particulate matter. DEQ consequently chooses not to proceed with an alternative natural background estimate at the Wichita Mountains but may do so in later implementation plan revisions.

A. Contribution of Constituents to Natural Background

The algorithm bases its estimates of natural conditions on annual average estimates of Trijonis (1990) for the American West. This is consistent with EPA communications establishing 98°W longitude as the division between East and West but inconsistent with airflow patterns. In the work of Trijonis, the East extends one tier of states west beyond the Mississippi River. Desert or mountain arid areas of the Mountain and Pacific Time Zones define the West. A strong dichotomy in vegetation, humidity, and historic measured visibility between the two regions suggests different natural visibility conditions. Oklahoma observes Central Time but lies in the second tier of states west of the Mississippi River and therefore strictly belongs to neither region; Trijonis lacked sufficient data from the Great Plains states to place these states in any regional group.

The Trijonis estimates depend on an extensive literature review which concentrates on emissions inventories, measurements in remote areas, and tracer-based regression studies. Because of the extremely general character of the estimates and their inherent assumptions, they apply only as broad regional averages, not necessarily to specific points, and include large error, usually a factor of

two without any quantified confidence. His assessment recommends significant further research to refine these estimates. No such research yet has been published.

The algorithm for estimating natural conditions assumes that natural conditions display the same distribution as observed conditions, true only to the extent that natural and anthropogenic sources geographically and temporally coincide. The algorithm attributes a constant proportion of each constituent of observed particulate to natural conditions in any given calendar year. The identity of the days among the best and worst quintiles, however, may differ between natural and observed conditions because a different proportion applies to each particulate constituent.

In the tables in this chapter, the best and worst quintiles refer to observed daily data unless otherwise indicated. The identity of the best and worst quintile of days under natural conditions differs markedly. This document, however, focuses on improving visibility on the existing worst quintile of days while preventing deterioration on the existing best quintile of days; therefore, DEQ finds comparisons to these respective quintiles advantageous for clarity. Unless otherwise indicated, the values in the tables in this chapter do not reflect the error factor associated with natural conditions.

1. Sulfureous Particulate

Natural sulfur emissions include terrestrial and marine gaseous sulfur. Anthropogenic emissions clearly overwhelm their natural counterparts, especially in the East. Trijonis identified a denser network of natural sulfur emissions in the East than in the West. Table III-1~~Table III-1~~ assigns his regional averages to observations at the Wichita Mountains.

Table III-1: Estimated natural sulfureous particulate concentrations at the Wichita Mountains

Conditions	[S] (µg m^{-3})			β_{extS} (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	.75	.187	1.48	22.7	5.1	49.
Natural—East	.056	.014	.11	1.5	.4	3.0
Natural—West	.029	.007	.06	.76	.19	1.5

Sulfureous particulate clearly arises overwhelmingly from anthropogenic sources. Known natural sources of sulfur in Oklahoma include gypsum and other sulfureous minerals in the soils, sulfur springs, petroleum seeps, and biological decay, mostly in swamps and other wetlands. Distant marine sources and active volcanoes also contribute to natural background concentrations.

High sulfureous particulate concentrations at the Wichita Mountains generally occur on days when broad anticyclonic flow moves air from the Eastern states through Texas to the Wichita Mountains on prevailing southerly winds. Any natural sulfureous emissions in this broad region contribute to

decreased visibility at the Wichita Mountains. The natural sulfureous particulate concentration at the Wichita Mountains consequently fits better in the East than in the West.

2. Nitrate Particulate

Trijonis estimated the average annual natural conditions from available data. Table III-2~~Table III-2~~ applies his regional averages to observations at the Wichita Mountains.

Table III-2: Estimated natural nitrate particulate concentrations at the Wichita Mountains

Conditions	$[NO_3^-]$ (µg m^{-3})			$\beta_{ext_{NO_3^-}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	1.02	.30	2.1	10.5	2.8	24.
Natural—East	.08	.023	.16	.7	.21	1.5
Natural—West	.08	.023	.16	.7	.21	1.5

Nitrate particulate haze occurs primarily on cold, cloudy days during the winter but still frequently exceeds the target natural conditions of the algorithm on most hot summer days. A considerable proportion of the source region for nitrate aerosols and their precursors lie in the rural to remote regions of the Great Plains north of the Wichita Mountains. Grazing livestock and wild animals excrete significant amounts of ammonia and its precursors. Any urine readily decays into ammonia and carbon dioxide. In the uncommon event of snow cover and an associated low inversion, the concentration of ammonium nitrate arising from this natural process may exceed mean natural conditions greatly, particularly if the meteorological conditions persist over several days or weeks. Natural sources of ammonium nitrate precursors also include soils and vegetation.

3. Organic Carbonaceous Particulate

Organic carbonaceous particulate covers a broad selection of chemical constituents derived from various organisms. DEQ lacks the data to assign the observed organic particulate to any particular chemical species. Natural sources include plant waxes and terpenes, especially isoprene. Wetter and hotter areas support greater plant growth and related organic emissions; organic particulate concentrations often reach 10 µg m^{-3} in tropical rain forests.

In the atmosphere, organic compounds and particulates partake in a particularly complex web of chemical reactions involving thousands of chemical species as they degrade or deposit. Trijonis cited southwestern desert field studies with an ambient concentration around 3 µg m^{-3}, analyzed as largely petroleum-related organic carbon and significant wood smoke.

Table III-3

Formatte
Auto, Do r

Formatte
Custom Co
and gramm

~~Table III-3~~ presents estimates of natural conditions at the Wichita Mountains for both eastern and western divisions.

Table III-3: Estimated natural organic carbonaceous particulate concentrations at the Wichita Mountains

Conditions	$[O_1] + [O_2] + [O_3] + [O_4] + [O_P]$ (μg m^{-3})			$\beta_{ext\,organic}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	1.41	.66	2.5	8.7	3.6	17.
Natural—East	1.0	.5	1.8	5.4	2.5	11.
Natural—West	.33	.16	.6	1.8	.8	3.3

The error factor in the estimates of Trijonis describes a broad range of plausible natural conditions between 0.5 μg m^{-3} and 2.0 μg m^{-3} (carbon-only mass in fine organic particulate) averaged over the entire East. The baseline organic aerosol concentration at the Wichita Mountains falls within the margin of error of this estimate of natural conditions for the eastern states. This assessment does not preclude an anthropogenic contribution, but quantifying the relatively small anthropogenic influence requires a reevaluation of natural conditions and a detailed inventory of anthropogenic sources. A prudent evaluation also requires a better understanding of gaseous, aqueous, and particulate organic chemistry in the atmosphere. Only an extensive site-specific field study can provide the necessary data.

A significant proportion of organic aerosol at the Wichita Mountains originates from area sources, a category primarily containing fires. Estimates of natural visibility conditions include particulate emissions from naturally-occurring fires. The high correlation between organic and elemental carbon particulates suggests prevalent combustion-related emissions among organic carbon. Trijonis understandably attributed combustion to anthropogenic sources, but fire cessation would alter the ecosystem. Dendrochronology in the American Southwest suggests that fires occurred regularly in the mountains where rains fell and trees thrived during the first half of the second millennium. The species that now contribute to the "natural environment" of Oklahoma consequently now tolerate or even depend on fire. Fires effectively created and maintained Oklahoma prairies for millennia. The non-air-quality environmental effects of regulatory cessation of fire use in land management practices would cause the endangerment of numerous native species through loss of habitat. Consideration of fires as natural phenomena necessarily entails acceptance of slightly degraded visibility at the Wichita Mountains from organic and elemental carbonaceous particulate.

The other major component of natural organic carbonaceous particulate comes from vegetative emissions. The organic carbonaceous particulate concentrations show seasonal cycles with a pronounced hibernal minimum. This minimum again suggests a dominant non-anthropogenic contribution because anthropogenic sources tend to operate year-round, whereas most plants undergo dormancy during the winter. Biogenic production of organic aerosols varies according to species, life cycle, temperature, hydration, stressors, and other factors.

As subsequent chapters of this implementation plan revision demonstrate, DEQ cannot implicate any significant anthropogenic sources of organic carbonaceous particulate that impair visibility at the Wichita Mountains. Without a completed field study identifying and quantifying biogenic and anthropogenic sources, DEQ can only deduce that an overwhelming majority of organic aerosols originate from natural sources or fires.

4. Elemental Carbonaceous Particulate

Only combustion releases elemental carbonaceous particulate; therefore, wildfires constitute its only significant natural source. The natural conditions in Table III-4~~Table III-4~~ reflect information that Trijonis used in his estimates. Elemental carbonaceous particulate correlates strongly with sulfate particulate, suggesting a dominant anthropogenic component.

Table III-4: Estimated natural elemental carbonaceous particulate concentrations at the Wichita Mountains

Conditions	$[E_1] + [E_2] + [E_3] - [O_P]$ (µg m^{-3})			$\beta_{ext_{elemental}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	.26	.13	.45	2.6	1.3	4.5
Natural—East	.02	.010	.034	.20	.10	.34
Natural—West	.02	.010	.034	.20	.10	.34

Increasing incidence of fires, both as huge conflagrations in the American West and as a management tool on farmland and pastureland in the Great Plains, may render the concentrations that Trijonis specified far too low.

5. Fine Soil Particulate

Trijonis assumed that half of fine soil particulate originated from natural sources of wind-blown dust. Traffic, construction, agriculture, and anthropogenic land-use changes presumably raised the remainder. Fine soil concentrations did not vary between West and East. Fine soil aerosols over both the East and the West currently fit within the error factor of two.

Table III-5: Estimated natural fine soil particulate concentrations at the Wichita Mountains

Conditions	2.20[Al] + 2.49[Si] + 1.63[Ca] + 2.42[Fe] + 1.94[Ti] (µg m^{-3})			$\beta_{ext_{soil}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	.81	.32	.79	.81	.32	.79
Natural—East	.50	.19	.5	.50	.19	.5
Natural—West	.50	.19	.5	.50	.19	.5

High fine soil concentrations generally occur on days without high sulfureous particulate concentrations because the two regional haze components originate in different geographical regions. Days with high sulfureous particulate concentrations and relatively low fine soil concentrations currently dominate the worst quintile visibility days at the Wichita Mountains. Because reaching natural conditions entails dramatic reduction in sulfureous particulate concentrations, other days with relatively high fine soil concentrations will displace the current set of days among the worst quintile. This exchange means that approaching natural conditions should increase the fine soil concentration on the worst quintile of days, even assuming no climate change, and even if a considerable proportion of fine soil particulate currently results from anthropogenic sources. With increasing effective reductions in sulfate and nitrate particulate pollution, Oklahoma anticipates that more days with high fine soil concentrations will qualify for the worst quintile; the fine-soil particulate concentrations in that worst quintile consequently should increase.

Because larger particles tend to settle readily from windblown dust, overseas deserts contribute far more fine soil than they do coarse particulate matter, whereas nearby arid regions contribute mostly coarse particulates. Saharan dust reaches the Wichita Mountains primarily during the late spring and early summer. Fine soils traceable to African sources tend to occur in higher concentrations during years with inactive hurricane seasons. A switch to a negative phase of the Atlantic multi-decadal oscillation consequently may increase the incidence of fine soils dramatically.

Other natural sources of fine soils, usually accompanying considerable or disproportionate coarse particulate, include fierce gales sweeping over dry lands on this continent. Asian dust occasionally reaches the Wichita Mountains as both fine soils and coarse particulate. Absent any contrary reliable information, DEQ considers fine soil particulate observed in the Wichita Mountains to originate mostly from various natural and foreign sources.

6. Coarse Particulate

Trijonis assumed that natural organic coarse particulate concentrations in the Eastern states are similar to dust-dominated coarse concentrations in the Western states.

Table III-6: Estimated natural coarse particulate concentrations at the Wichita Mountains

Conditions	$[PM_{10}] - [PM_{2.5}]$ ($\mu g\ m^{-3}$)			$\beta_{ext\ coarse}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	7.	4.5	8.	4.2	2.7	4.6
Natural—East	3.0	1.9	3.	1.8	1.1	2.0
Natural—West	3.0	1.9	3.	1.8	1.1	2.0

Dust storms in arid regions of the High Plains and the American Southwest occur naturally, most frequently in early spring after the typically dry High Plains winter when fierce gales raise soil from barren spots on the landscape. Westerly winds around developing strong spring storms frequently carry dust from West Texas and New Mexico into southwestern Oklahoma behind the dryline. The Dust Bowl of the 1930s taught Oklahoma farmers and ranchers the critical value of soil conservation and dust suppression efforts; however, adequately dense xeric vegetation simply cannot develop on certain climatologically desiccated landscapes. Bison, cattle, wapiti, other large herbivores, burrowing mammals, and even smaller animals disturb such denuded surfaces and kick dust into the atmosphere. Turbulence accompanying high winds in the surface layer of the atmosphere also removes soil from denuded surfaces.

Biogenic coarse particulate includes pollen and mold spores. The species of grasses, shrubs, trees, and other natural vegetation in the Wichita Mountains and elsewhere downstream might produce especially large quantities of pollen or other organic coarse particulates. Absent more reliable information, DEQ contends that most coarse particulate matter currently observed in the Wichita Mountains likely originates from natural sources.

7. Chlorine or Chloride Particulate

The Trijonis excluded sea-spray particles because of their lack of importance in inland regions, but the algorithm attributes all saline particulate to natural sources. The IMPROVE system in the Wichita Mountains rarely measured detectable levels of chloride particulate.

Table III-7: Estimated natural chloride particulate concentrations at the Wichita Mountains

Conditions	[Cl] (µg m^{-3})			$\beta_{ext_{Cl}}$ (Mm^{-1})		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	.02	.00	0.	.15	.10	.15
Natural—East	.02	.00	0.	.15	.10	.15
Natural—West	.02	.00	0.	.15	.10	.15

All observed chloride particulate arises from natural sources.

B. Estimate of Natural Visibility at the Wichita Mountains

Table III-8~~Table III-8~~ presents the baseline visibility conditions for the Wichita Mountains and three estimates of natural conditions. The EPA default considers the Wichita Mountains as a Western site, but the table also considers the Wichita Mountains as an Eastern site. Pseudo-natural conditions consider all organic carbonaceous particulate, coarse matter, and fine soils currently observed at the Wichita Mountains as natural and all sulfureous, nitrate, and elemental carbon particulate as anthropogenic. This implementation plan revision includes these pseudo-natural conditions because the organic carbonaceous, fine soil, and coarse matter components lack clearly identifiable and readily controllable anthropogenic sources, and their current concentrations lie within the margin of error of the natural conditions estimates used in the EPA default. This implementation plan revision identifies copious anthropogenic sources of sulfureous and nitrate particulate, and these anthropogenic sources overwhelm their natural counterparts.

Table III-8: Natural Visibility Conditions at the Wichita Mountains

Conditions	β_{ext} (Mm^{-1})			Haze index (deciview)		
	Mean	Best quintile	Worst quintile	Mean	Best quintile	Worst quintile
Baseline observed	60.8	26.9	111.	16.8	9.8	23.8
Natural—East	21	15	29	5.1	3.0	11.
Natural—West	17	14	21	7.1	4.2	7.5
Pseudo-natural	25	16	39	8.5	4.8	13.

After significant further reductions in emissions in Oklahoma and Texas, DEQ can begin to identify natural sources of sulfureous and nitrate aerosols and their precursors to reevaluate natural

visibility conditions. As DEQ and other clean air agencies work to decrease the overwhelmingly anthropogenic components of regional haze, concentrations of those components already near natural conditions actually may increase among the worst quintile of days. These increases will occur because days with dense sulfureous or nitrate haze presently displace days with fires, dust storms, organic aerosols, and other natural impediments to visibility for placement among the worst quintile. The worst quintile days at the Wichita Mountains consequently increasingly will comprise of relatively minor dust and smoke events.

C. Uncertainty and Error

DEQ may update the estimates of natural particulate mass concentrations for each component based on recent peer-reviewed literature rather than using the default values. DEQ also may rely upon any other scientifically and technically supportable method to refine the default approach. Because Oklahoma lies near the boundary between East and West, EPA advises DEQ to choose and adopt values from the most appropriate regional estimate. Trijonis restricted his Western averages to arid mountain and desert regions of the Mountain and Pacific Time zones. Although the Wichita Mountains perhaps qualified as peripherally semi-arid during the Dust Bowl era, the Wichita Mountains now receives a climatological normal of 35 inches of rain per year, more than many Eastern Class I areas.

EPA guidance allows natural sources to contribute no more particulate in any category than the least observed five-year average. This constraint does not affect default natural-background concentrations at the Wichita Mountains. Unique events like wildfires and volcanic eruptions, however, may produce protracted periods of naturally reduced visibility, and entirely natural climate change can modulate the occurrence and intensity of natural fires, dust storms, and organic emissions on timescales of decades and longer. The Wichita Mountains lie astride a sharp and ever-shifting gradient in precipitation between the swampy humid forests of eastern Oklahoma and deep east Texas and the partially barren semiarid short grass prairies and chaparral of west Texas and New Mexico. The chemical composition of natural particulate at the Wichita Mountains changes constantly with the ever-shifting climate.

Most natural concentrations of Trijonis (1990) contained an error factor of 2; a natural nitrate particulate concentration of 0.1 µg m^{-3}, for example, indicates a broad regional mean that lies probably between 0.05 µg m^{-3} and 0.2 µg m^{-3}. The error inherent in these estimates allows for the possibility of natural background either much lower or much higher than the EPA estimates derived from his work. Current concentrations of all components of regional haze exceed the estimated regional natural background. The estimated natural concentrations with their error factors apply only as broad regional averages; actual natural conditions at the Wichita Mountains or at other points may exceed even the high end range of these estimates.

D. Uniform Rate of Improvement

A uniform rate of improvement (progress) under 40 C.F.R. § 51.308(d)(1)(i)(B) specifies a linear reduction in visibility impairment in deciviews on the worst quintile of days from baseline conditions to reach estimated natural visibility in 2064. Table III-9~~Table III-9~~ shows the uniform rate of progress at the Wichita Mountains for the worst quintile of days with the Western natural background assumptions.

Table III-9: Uniform rate of progress at Wichita Mountains (worst quintile, Western natural background)

Conditions	(Mm^{-1})	Haze index (deciviews)
Presently observed (2002-2004) conditions	108.15	23.81
Improvement needed by 2018 assuming uniform rate of progress	34.18	3.80
Progress (2004-2018) at uniform rate		.27 per year
Observed impairment above natural conditions	86.91	16.28
Ultimate goal of natural conditions (for 2064)	21.23	7.53

IV. Emissions Inventory

In fulfillment of 40 C.F.R. §51.308(d)(3)(iii), DEQ bases its long-term strategy on an identified baseline emissions inventory, Base G of the CENRAP inventory for 2002. In accordance with 40 C.F.R. §51.308(d)(3)(iv), DEQ identifies all anthropogenic sources of visibility impairment considered in developing the long-term strategy. To comply with 40 C.F.R. §51.308(d)(4)(v), DEQ submits an emissions inventory of pollutants from Oklahoma sources reasonably anticipated to cause or contribute to visibility impairment at the Wichita Mountains or any other mandatory Class I area. A table summarizing the 2002 Oklahoma Emissions Inventory values can be found in section A for this chapter, broken down into five main source categories. Further breakdown for each source category can be found in subsequent sections.

A. Summary

DEQ followed specific EPA guidance and inventoried emissions of sulfur dioxide (SO_2), ammonia (NH_3), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and particulate matter of aerodynamic diameters less than 10 µm (PM_{10}) and less than 2.5 µm ($PM_{2.5}$) from all anthropogenic and biogenic sources. DEQ and CENRAP developed an inventory for the baseline year of 2002. Table IV-1~~Table IV-1~~ summarizes this inventory. DEQ submits the complete Oklahoma statewide emissions inventory for 2002 as Appendix 4-1.

Table IV-1: Summary of emissions from Oklahoma sources in 2002 (tons per year)

	SO_2	NH_3	NO_x	VOCs	PM_{10}-$PM_{2.5}$	$PM_{2.5}$
Point	148,761	24,102	158,818	37,794	8,026	8,636
Area	11,779	114,363	115,407	201,758	304,560	109,279
Non-road mobile	4,773	280	49,396	47,863	433	4,580
On-road mobile	4,708	4,434	142,592	99,924	879	2,459
Biogenic	0	0	35,909	988,314	0	0
Total	170,021	143,179	502,122	1,375,653	313,898	124,954

Following convention, DEQ divides the emissions inventory into five primary categories: point, area, non-road mobile, on-road mobile, and biogenic. These divisions reflect differing inventory development methods, unifying attributes, and model processing needs.

State, tribal, and local agencies submitted information to the national emissions inventory for 2002 which formed the basis of the CENRAP emissions inventory. Sonoma Technology supplemented national emissions inventory data with non-point source inventories developed for CENRAP. These CENRAP-specific inventories addressed agricultural and prescribed burning, on-road and non-road

mobile sources, agricultural tilling and livestock dust, and agricultural ammonia. Appendix 4-2, *Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans*, fully documents the methods used in the development of the emissions inventory for 2002 and includes technical support documents.

B. Point Source Emissions in 2002

DEQ rule OAC 252:100-5 requires individually permitted point sources to submit an emissions inventory annually with well-defined location and release parameters; therefore, DEQ bases this point-source inventory for 2002 on this facility-reported information. DEQ followed internal quality assurance procedures and submitted the data to EPA for the 2002 national emissions inventory.

Following submission to the national emissions inventory, CENRAP provided additional quality assurance and revision opportunities for data improvement. E.H. Pechan & Associates, (Pechan) through a contract with CENRAP, obtained the Oklahoma point-source inventory and worked with DEQ to make necessary corrections. Revisions focused on updating and correcting facility coordinates and stack parameters. Pechan also prepared day- and hour-specific emissions for electric generating units based on continuous emissions monitoring data for 2002. Two documents referenced in Appendix 4-2—*The Consolidation of Emissions Inventories* (April 28, 2005) and *Refinement of CENRAP's 2002 Emissions Inventories* (August 31, 2005)—detail the work of Pechan on behalf of CENRAP.

C. Area Source Emissions in 2002

EPA treats each class of immobile area sources collectively by county. Neither EPA nor DEQ can collect data for each point of emission, and EPA consequently provides estimates of emissions over larger regions. Residential heating and architectural coatings exemplify stationary area sources. The area-source inventory for 2002 builds on EPA-provided estimates for area-source emissions. It includes emissions estimates that DEQ and CENRAP prepared and data from the national emissions inventory to fill gaps.

Sonoma Technology prepared the following reports. Referenced in Appendix 4-2, they contain the data and methods used to develop the prescribed burning, agricultural dust, and soil agricultural ammonia inventories for CENRAP.

- *Research and Development of Planned Burning Emission Inventories for the Central States Regional Air Planning Association* (July 30, 2004),
- *Emission Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States* (October 28, 2004), and
- *Research and Development of Ammonia Emission Inventories for the Central States Regional Air Planning Association* (October 30, 2003)

Departing from the primarily EPA-developed area source inventory, DEQ developed an oil and gas area-source emissions inventory. To produce this inventory, DEQ collected county-level oil and gas production data from the Oklahoma Corporation Commission and Oklahoma Tax Commission and combined these data with emissions calculation methods developed by the Texas Commission on

Environmental Quality. Appendix 4-2 contains the calculation methods, excerpted from the Texas emissions inventory documentation from 1996 entitled *Oil and Gas Production (East Texas, 1996 EI)*.

DEQ also developed area-source emissions estimates for gasoline distribution sources, dry cleaners, and wildfires, using the factors from emissions inventory improvement program and county-level activity data for Oklahoma.

In a contract with CENRAP, Pechan consolidated the area-source inventories from these various inventory sources, conducted additional quality assurance, and worked with DEQ to revise this consolidated inventory. Two documents referenced in Appendix 4-2 describe the work of Pechan in detail: *The Consolidation of Emissions Inventories* (April 28, 2005) and *Refinement of CENRAP's 2002 Emissions Inventories* (August 31, 2005).

University of California at Riverside (UCR), under contract with CENRAP, removed selected sources from the consolidated area inventories to process them as separate subcategories. UCR created these subcategories to allow specialized processing within the Sparse Matrix Operator Kernel Emissions (SMOKE) model in anticipation of particulate source apportionment within the Comprehensive Air Quality Model with extensions (CAMx). To enhance accuracy of transportable dust estimates, UCR also applied road and fugitive dust transport factors to appropriate area source emissions, following the *Methodology to Estimate the Transportable Fraction of Fugitive Dust Emissions for Regional and Urban Scale Air Quality Analyses* (Pace 2005). Table IV-2~~Table IV-2~~ summarizes area-source emissions from Oklahoma by subcategory.

Table IV-2: Inventory of area-source emissions from Oklahoma for 2002 by subcategory (tons per year)

	SO_2	NH_3	NO_x	VOCs	PM_{10}	$PM_{2.5}$
General area	4,634	6,146	96,166	173,250	526	10,332
Fire	7,145	5,819	19,623	28,507	11,167	41,764
Ammonia	0	102,245	0	0	0	0
Road dust	0	0	0	0	216,289	38,057
Fugitive dust	0	0	0	0	76,578	19,126
Total area sources	0	153	-381			

D. On-road Mobile Source Emissions in 2002

For vehicular sources which travel on roadways, DEQ can compute emissions either spread over a spatial extent or assigned to a line location called a link. Examples of these on-road mobile sources include light-duty gasoline vehicles and heavy-duty diesel vehicles.

DEQ and CENRAP developed the on-road mobile source emissions inventory for 2002 with contractor support. For all counties in Oklahoma and elsewhere throughout the CENRAP region, Sonoma Technology provided vehicle miles traveled data for all months of 2002 and MOBILE6 input files only for the months of January and July 2002, using the methods and data described in the report

Emissions Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States (October 28, 2004), referenced in Appendix 4-2. UCR prepared MOBILE6 input files for the remaining months of 2002 and processed the mobile emissions using the MOBILE6 model within the SMOKE framework.

E. Non-road Mobile Source Emissions

DEQ and EPA include a broad selection of equipment in the non-road mobile source category. EPA developed emissions estimates for all aircraft operations, commercial and recreational marine vessels, and railroad locomotives for the national emissions inventory for 2002.

Sonoma Technology, under contract to CENRAP, used the NONROAD model to prepare and develop broad emissions estimates for the non-road mobile source inventory. Sonoma Technology documented the methods and data used to generate this inventory in the report *Emissions Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States* (October 28, 2004) referenced in Appendix 4-2.

Pechan consolidated the estimates of Sonoma Technology with those of EPA to generate the full non-road emissions inventory. In the process of consolidating the emissions estimates, Pechan assured quality of the data and worked with DEQ to make necessary corrections before creating SMOKE model formatted files. Pechan made specific corrections to the fuel oxygenate content used in the NONROAD model. Two documents referenced in Appendix 4-2 describe the work of Pechan in detail: *The Consolidation of Emissions Inventories* (April 28, 2005) and *Refinement of CENRAP's 2002 Emissions Inventories* (August 31, 2005).

F. Biogenic Emissions

EPA calculates biogenic emissions based on land use data that characterize types of vegetation as county-total or grid-cell values.

As the emissions modeling contractor for CENRAP, UCR ran the Biogenic Emissions Inventory System 3 (BEIS3) model within the SMOKE framework to generate a biogenic emissions inventory. This system derives estimates of biogenic gas-phase emissions from land-use information, emissions factors for different plant species, and hourly meteorological data on a coordinate grid. The technical support document in Appendix 4-2 describes the development of the biogenic emissions inventory.

G. Discussion of Components

1. SO_2 Emissions

Four coal-fired electric power generators in or near the northeastern quarter of Oklahoma emitted half the total sulfur dioxide in this inventory. Other fossil fuel electric power generators and petroleum refiners also emitted sulfur compounds in 2002.

Table IV-3: Leading sources of SO_2 emissions in Oklahoma for 2002

Category	Source classification	Source name	County	Tons per year	Percent of total
point	fossil fuel electric power generation	Public Service Company of Oklahoma	Rogers	34,512	20.30%
		Oklahoma Gas and Electric	Muskogee	27,522	16.19%
		Oklahoma Gas and Electric	Noble	18,392	10.82%
		Grand River Dam Authority	Mayes	16,227	9.54%
		all other		14,180	8.34%
	petroleum refineries			12,350	7.26%
	all other			25,579	15.04%
area	fire			7,145	4.20%
	general			4,634	2.73%
non-road mobile				4,773	2.81%
on-road mobile				4,708	2.77%
biogenic				none	
Statewide total				170,021	100.00%

2. NH_3 Emissions

Animals contributed approximately three-fifths of ammonia emissions in Oklahoma in 2002, mostly through excreta. A further one-fifth of this inventory concerns emissions from crop fertilizers. These sources mostly lie beyond the currently active regulatory purview of DEQ.

Table IV-4: Leading sources of NH_3 emissions in Oklahoma for 2002

Category	Source classification	Source name	County	Tons per year	Percent of total
point	agricultural products—livestock and animal	Oklahoma City West Livestock Market	Canadian	2,002	1.40%
		all	Texas	9,698	6.77%
		all other		8,165	5.70%
	nitrogenous fertilizer manufacturing			2,850	1.99%
	all other			1,387	.97%
area	ammonia	agriculture production livestock—cattle and calves waste—beef cows		18,241	12.74%
		agriculture production livestock—cattle and calves waste—steers and bulls		16,096	11.24%
		agriculture production livestock—cattle and calves waste—heifers		10,678	7.46%
		agriculture production livestock—cattle and calves waste—milk cows		2,549	1.78%
		agriculture production livestock—poultry waste—broilers	LeFlore	2,270	1.59%
			McCurtain	1,980	1.38%
			all other	2,484	1.73%
		agriculture production livestock—poultry waste—all other		1,852	1.29%
		agriculture production livestock—swine production composite		2,742	1.92%
		agriculture production crops—fertilizer application—urea		18,470	12.90%
		agriculture production crops—fertilizer application—nitrogen solutions		3,754	2.62%
		agriculture production crops—fertilizer application—all other		3,931	2.75%
		domestic animal waste—dogs		2,465	1.72%
		natural sources—biogenic—agricultural land crop and pasture Anderson use code		3,499	2.44%
		natural sources—biogenic—forest land deciduous Anderson use code		3,106	2.17%
		natural sources—biogenic—all other		3,018	2.11%
		all other		5,112	3.57%
	general	industrial processes—not elsewhere classified	Rogers	6,044	4.22%
		all other		102	.07%
	fire	agriculture production crops—field burning whole set—grasses technique not important		3,890	2.72%
		all other		1,929	1.35%

Category	Source classification	Source name	County	Tons per year	Percent of total
	agriculture production crops—fertilizer application—all other (certain types and counties excluded from ammonia subcategory)			153	.11%
non-road mobile				280	.20%
on-road mobile (model output)				4,434	3.10%
biogenic (model output)				none	
Statewide total				143,179	100.00%

3. NO_x Emissions

On-road mobile sources emitted more than one-quarter of all oxides of nitrogen in this statewide inventory for 2002. Four large coal-fired electric power generators in or near the northeastern quarter of Oklahoma contributed almost one-eighth of these emissions. Other large contributors included small (area-source) industrial natural gas boilers, several large fossil fuel electric power generators, non-road mobile equipment emissions, considerable biogenic emissions, and agricultural and prairie fires.

Table IV-5: Leading sources of NO_x emissions in Oklahoma for 2002

Category	Subcategory	Source name	County	Tons per year	Percent of total
point	fossil fuel electric power generation	Oklahoma Gas and Electric	Muskogee	17,442	3.47%
		Public Service Company of Oklahoma	Rogers	16,827	3.35%
		Grand River Dam Authority	Mayes	14,160	2.82%
		Oklahoma Gas and Electric	Noble	12,184	2.42%
		all other		24,931	4.96%
	natural gas liquid extraction			16,547	3.29%
	pipeline transportation of natural gas			15,038	2.99%
	crude petroleum and natural gas extraction			12,001	2.39%
	all other			29,688	5.91%
area	general	industrial processes—oil and gas production		66,480	13.23%
		stationary source fuel combustion—industrial—natural gas—total boilers and internal engines		21,524	4.28%
		all other		8,161	1.62%
	fire	agriculture production crops—field burning whole set—grasses technique not important		16,885	3.36%
		all other		2,738	.54%
	wildfires (considered among fire area sources but not total area sources for NO_x purposes only)			-381	-.08%
non-road mobile	off-highway diesel	agricultural equipment—tractors		9,340	1.86%
		all other		12,159	2.42%
	railroad equipment	diesel—line haul locomotives class I operations		18,293	3.64%
	all other			9,605	1.91%
on-road mobile (model output)				142,592	28.38%
biogenic (model output)				35,909	7.15%
Statewide total				502,504	100.00%

Point and area sources related to extraction, production, and transportation of crude oil, natural gas, and related fuels accounted for more than one-fifth of this inventory, much of it in counties in relative proximity to the Wichita Mountains. The statewide inventory includes numerous small-scale petroleum and natural gas extraction and pipeline operations in locations throughout western Oklahoma. Despite efforts to improve accuracy of area-source inventories, DEQ cannot assess their reliability nor use them as a basis for regulation without a lengthy field study to quantify pollutants

released during petroleum and natural gas exploration, extraction, transport, delivery, and storage under various conditions often encountered.

4. Volatile organic compound emissions

Common anthropogenic emissions sources of organic carbon largely relate to small oil and gas producers. For forests, prairies, and other biogenic sources DEQ resorts to estimates from biogenic models. Estimates of natural biogenic emissions comprise a majority of this statewide inventory.

Table IV-6: Leading sources of volatile organic compound emissions in Oklahoma for 2002

Category	Subcategory	Source name	Tons per year	Percent of total
point			37,794	2.75%
area	general	industrial processes—oil and gas production	104,193	7.57%
		all others	69,057	5.02%
	fire		28,507	2.07%
non-road mobile			47,863	3.48%
on-road mobile (model output)			99,924	7.26%
biogenic (model output)			988,314	71.84%
Statewide total			1,375,652	100.00%

DEQ lacks the financial capacity to conduct an in-depth field study to assess the performance of biogenic models within Oklahoma. Biogenic sources emit most VOCs in Oklahoma and lie beyond the regulatory purview of DEQ. Because of enormous uncertainty in biogenic volatile organic emissions, however, DEQ recommends a detailed field study of such components, focusing on all poorly resolved sources and covering the entire warm season and possibly the remainder of the year. A biogenic study can focus on actual organic emissions from biota that live near the Wichita Mountains and in upstream ecosystems during actual meteorological conditions. DEQ also requires further study to identify anthropogenic emissions of VOCs and to determine which such compounds most efficaciously contribute to visibility impairment and ozone production.

5. Coarse particulate direct emissions

An overwhelming majority of direct emissions of coarse particulate matter came from road and fugitive dust. These sources of direct emissions of coarse particulate do not differ chemically from natural sources. Although the inventory excludes biogenic sources, an unknown quantity of mold spores, pollen, and other poorly understood emissions fits into this category.

Table IV-7: Leading sources of direct PM_{10} - $PM_{2.5}$ emissions in Oklahoma for 2002

Category	Subcategory	Source name	Tons per year	Percent of total
point			8,026	2.56%
area	road dust	mobile—unpaved—fugitives	200,479	63.87%
		mobile—paved—fugitives	15,810	5.04%
	fugitive dust	agriculture production crops—tilling	53,762	17.13%
		industrial processes—construction	13,062	4.16%
		all other	9,754	3.11%
	fire		11,167	3.56%
	general		526	.17%
non-road mobile			433	.14%
on-road mobile (model output)			879	.28%
biogenic (model output)			none	
Statewide total			313,898	100.00%

6. Fine particulate direct emissions

Direct emissions of fine particulate matter in the Oklahoma statewide inventory for 2002 originate from more varied sources than those for coarse particulate matter. Fires and dust nonetheless constitute a considerable majority of this inventory. Despite their inclusion among area sources in this inventory, one can argue for the inclusion of these fires and dust among natural conditions. The algorithm for computation of visibility impairment apportions directly emitted fine particulate matter among all categories except coarse particulate matter.

Table IV-8: Leading sources of direct $PM_{2.5}$ emissions in Oklahoma for 2002

Category	Subcategory	Source name	Tons per year	Percent of total
point			8,636	6.99%
area	fire	agriculture production crops—field burning whole set—grasses technique not important	28,443	23.04%
		all other	11,840	9.59%
	road dust	mobile—unpaved—fugitives	35,257	28.55%
		mobile—paved—fugitives	2,800	2.27%
	fugitive dust	agriculture production crops—tilling	13,441	10.89%
		all other	5,685	4.60%
	general		10,332	8.37%
non-road mobile			4,580	3.71%
on-road mobile (model output)			2,459	1.99%
biogenic (model output)			none	
Statewide total			123,473	100.00%

V. Modeling Assessment

Sections A, B, C, D, and E of this chapter discuss in detail modeling methods and protocol used by DEQ in developing the assessment. Results primarily attribute sulfureous aerosol, nitrate aerosol, and elemental carbonaceous particulate to anthropogenic sources; organic carbonaceous particulate, fine soil particulate, and coarse particulate concentrations are attributed to natural and/or area sources. For most pollutants, the majority of visibility-impairing pollutants originate outside Oklahoma; prevailing winds transport a considerable proportion of visibility impairing aerosols from Texas, and more than one-tenth of visibility impairment at the Wichita Mountains results from international transport. In comparison, the data in section G depicts Oklahoma as only a very minor contributor to visibility impairment for any Class I area outside of the state. Inside of Oklahoma, Texas alone contributes more to visibility impairment at the Wichita Mountains than Oklahoma does. Considering these results, any effective strategy for managing visibility impairment at the Wichita Mountains must address outside sources including regional and international transport.

Numerical modeling of regional haze comprises three steps: numerical weather simulation (meteorological modeling), mapping emissions inventories to the model grid (emissions modeling), and air-chemistry simulation. In the 1 July 1999 publication of the regional haze rule in the Federal Register, EPA endorsed the use of such regional modeling in analyses:

- To calculate the degree of visibility improvement that emissions reductions will achieve at the Wichita Mountains and at other Class I areas;
- To determine emissions reductions needed to meet the progress goal at the Wichita Mountains and at other Class I areas;
- To determine the extent of emissions reductions needed from sources in Oklahoma, Texas, and other individual states;
- To support a conclusion a long-term strategy provides for reasonable progress; and
- To compare visibility improvement between proposed control strategies.

CENRAP conducted regional air-quality modeling to provide these analyses, to support DEQ in the development of this implementation plan revision, and to support clean air agencies of other member states in the development of their respective regional haze plans. CENRAP in 2003 began modeling projects to obtain a better understanding of the causes of visibility impairment. The CENRAP emissions and air-quality modeling team comprised of Environ, UCR, and other consulting firms under contract to CENRAP; the CENRAP modeling workgroup supervised these contracts and comprised personnel from clean-air agencies and stakeholders unconnected to modeling team members. The CENRAP modeling team in 2004 began to perform:

- Emissions processing and modeling;
- Air-quality and visibility modeling simulations;
- Analysis, display, and reporting of modeling results; and
- Storage and quality assurance of the modeling input and output files.

The modeling team developed *Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze SIP*, included as Appendix 4-2, to provide further detail on the modeling analyses.

This modeling attributes visibility impairment at the Wichita Mountains mainly to anthropogenic emissions of sulfureous and nitrate pollutants. Sources in Oklahoma contribute less than one-seventh of visibility impairment at the Wichita Mountains; emissions from Texas alone account for almost twice the impairment as those from all of Oklahoma.

A. Modeling Protocol

At the outset of the study, the modeling team prepared a protocol, following EPA guidance, to serve as an outline for performing CENRAP emissions and air quality modeling and to communicate the modeling plans to CENRAP members. The modeling protocol took the long-range plan of CENRAP and the modeling needs of this implementation plan revision into account. Appendix 4-2 includes *Modeling Protocol for the CENRAP 2002 Annual Emissions and Air Quality Modeling*.

1. Quality Assurance Project Plan

The modeling team prepared a quality-assurance project plan for the CENRAP emissions and air quality modeling study (Appendix 5-1: *Quality Assurance Project Plan for Central Regional Air Planning Association Emissions and Air Quality Modeling*). That project plan describes the quality management functions performed by the modeling team. The team based its quality-assurance project plan on the national consensus standards for quality assurance. The project plan follows EPA's general and modeling guidelines for quality-assurance and takes into account recommendations from the North American Research Strategy for Tropospheric Ozone *Quality Handbook*. EPA and North American Research Strategy for Tropospheric Ozone developed their guidance documents specifically for modeling projects with quality assurance concerns different from those of environmental monitoring data collection projects. This project involved modeling work both at the basic research level and also for regulatory and planning applications. To use model outputs for these applications, the team

followed a project-planning process described in EPA modeling guidance documents. The systematic planning process incorporates:

- Identification of assessments and related performance criteria;
- Peer-reviewed theory and equations;
- Carefully designed life-cycle development process that minimizes errors;
- Documentation of any changes from original plans;
- Clear documentation of assumptions, theory, and parameterization;
- Input data and parameters accurate and appropriate for the analysis; and
- Output data.

2. Selection of Episodes

CENRAP selected the entire calendar year of 2002 for regional haze modeling, as described in the *CENRAP Modeling Protocol*. Applicable EPA guidance on $PM_{2.5}$ and regional haze modeling identified specific goals to consider when selecting modeling periods for use in demonstrating reasonable progress in attaining the regional haze goal. During the modeling period selection process, EPA also published an updated summary of $PM_{2.5}$ and regional haze modeling guidance which served in as an interim placeholder. The goals for ozone attainment, annual and episodic $PM_{2.5}$ attainment, and regional haze progress demonstrations generally share common modeling strategy. EPA ultimately issued final modeling guidance for the $PM_{2.5}$ and ozone national ambient air quality standards and regional haze. This final common guidance document addresses selecting episodes for all three objectives, consistent for regional haze with interim EPA modeling guidance.

EPA guidance recommends that the selection of a modeling period derive from the following three principal criteria.

- The modeled period should cover a variety of meteorological conditions, including those on the worst quintile and best quintile visibility days at the Wichita Mountains and at other Class I areas in the CENRAP region.
- The modeled period should represent the baseline period of 2000-2004. Monitoring data at the Wichita Mountains did not commence until March 2001, making 2002 the first year with complete data.
- The modeling periods should include sufficient available days to average relative response factors over more than 15 days among the worst quintile (and 15 days among the best quintile), but guidance suggests the preferred approach to model a full representative year for regional haze.

EPA also lists several other considerations for choosing potential regional haze episodes, including choosing:

- Periods already modeled,
- Days with available enhanced data beyond routine aerometric and emissions monitoring to the extent possible,
- Weekend days among those chosen, and
- Periods that meet as many episode selection criteria as possible at the Wichita Mountains and at other Class I areas.

Available resources allowed CENRAP to model a single calendar year. DEQ and CNERAP selected the modeling year from the five-year baseline of 2000-2004. CENRAP selected the calendar year 2002, the middle of the baseline period, for the following reasons:

- The complete IMPROVE monitoring site at the Wichita Mountains entered operation before 2002 with partial data available from 2001 and none from 2000;
- CENRAP initiated modeling before IMPROVE data for 2003 and 2004 came available;
- The other regional planning organizations used the year 2002; and
- The year 2002 apparently typifies weather conditions for the five-year baseline period of 2000-2004.

B. Meteorological Modeling

1. Model Selection

CENRAP based its selection of the meteorological model on a review of previous regional haze modeling studies performed in the region and elsewhere in the United States. CENRAP selected The Pennsylvania State University (PSU)/National Center for Atmospheric Research (NCAR) Mesoscale Model 5 (MM5 3.6 MPP), a non-hydrostatic, prognostic meteorological model routinely used for urban-scale and regional haze, and other regulatory modeling studies.

40 C.F.R. Part 51 Appendix W provides regional-scale modeling guidelines for particulate matter and visibility. The one-atmosphere photochemical grid approach of Models-3/CMAQ modeling system of EPA includes MM5 and can address particulate matter and visibility at a regional scale for extended periods.

2. MM5 Meteorological Model Configuration

MM5 originated from a mesoscale model developed at PSU in the early 1970s which thereafter underwent many changes designed to broaden its usage. These changes include:

- multiple-nest capability,
- non-hydrostatic dynamics that allows the use of the model at a few-kilometer scale,
- multitasking capability on shared- and distributed-memory machines,
- four-dimensional data assimilation capability, and
- additional physics options

This implementation plan revision and its appended technical support document refer to several auxiliary programs that support MM5 collectively as the MM5 system. As a regional model, MM5 requires initial and lateral boundary conditions to run. A lateral boundary condition for a model run requires gridded data to cover the entire integration period of the model. CENRAP ran MM5 using 34 vertical layers from the surface to a top pressure level of 100 mb (approximately 15 km above ground level).

3. Model Inputs

The Iowa Department of Natural Resources conducted the 36-km MM5 simulation for 2002 and performed a preliminary model performance evaluation. EPA Region VII and Texas Commission on Environmental Quality performed application of MM5 on a 12-km grid covering the central states for portions of 2002. CENRAP performed an additional MM5 evaluation of the 36-km MM5 simulation which included a comparative evaluation against the final VISTAS 36-km MM5 simulation and an interim WRAP 36-km simulation for 2002.

Appendix 4-2 provides details of a conducted comparative evaluation of the CENRAP, WRAP, and VISTAS 36-km MM5 simulations for 2002. This study concluded that the VISTAS simulation performed best; the moderate CENRAP MM5 performance resembled that of VISTAS more than that of WRAP.

C. Emissions Modeling

1. Model Selection, Configuration, and Domain

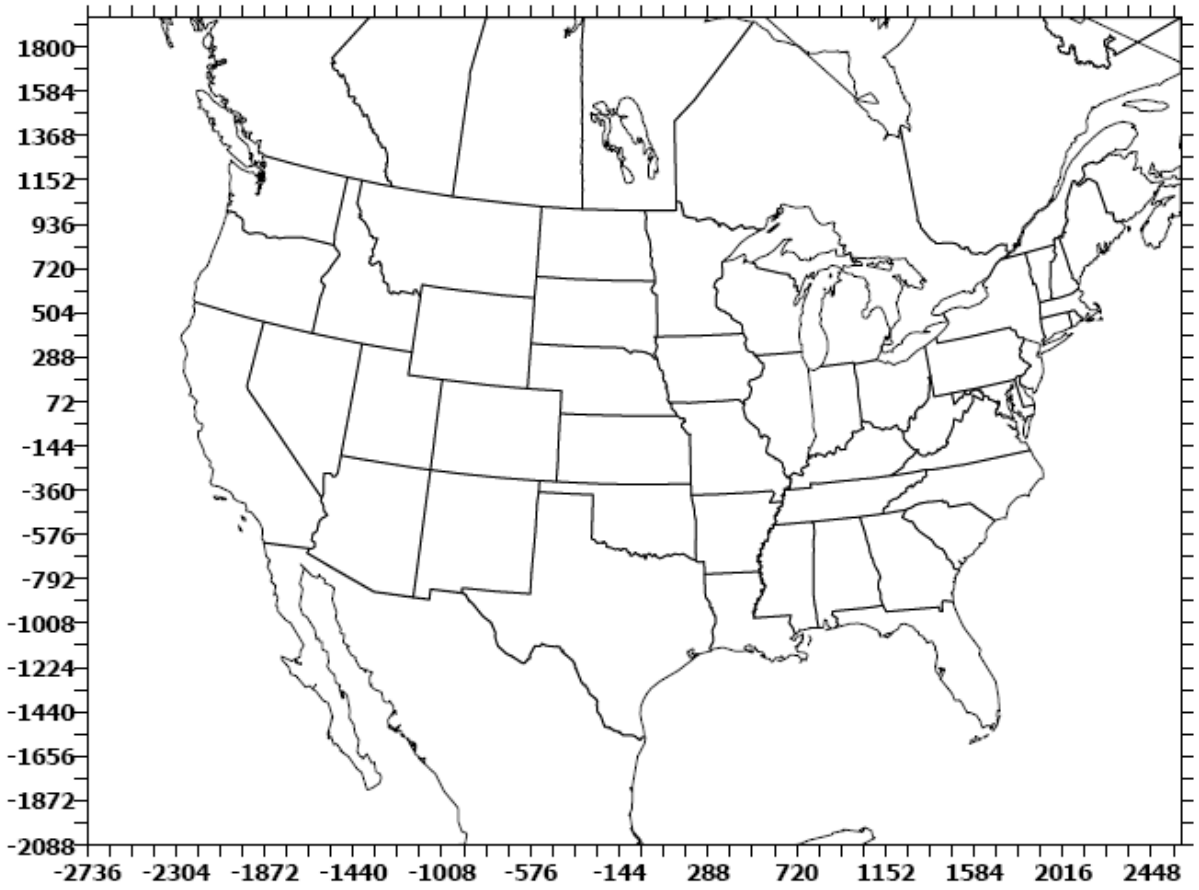
CENRAP based its selection of the emissions model on a review of previous modeling studies in the United States of America. CENRAP emissions modeling protocol provides details on the justification for model selection and the formulation of different models.

CENRAP selected the SMOKE modeling system to generate hourly-gridded, speciated emissions inputs for point, area, non-road mobile, on-road mobile, and biogenic source categories for photochemical grid models. SMOKE system and similar emissions models generally do not simulate emissions from first principles and lack the science configuration options found in meteorological and air chemistry models. SMOKE only provides an efficient tool for converting base emissions inventories for each source category into the hourly, gridded, speciated, formatted emissions files that an air chemistry model requires. SMOKE system nevertheless uses meteorological and other inputs to estimate on-road

mobile and biogenic emissions. Appendix 4-2 summarizes the SMOKE system version and sources of data used in constructing the required modeling inventories.

CENRAP conducted emissions and air quality modeling on the 36-km national regional planning organization domain. This domain consists of a 148 × 112 array of 36-km × 36-km grid cells and covers the continental United States. The technical support document, included as Appendix 4-2, provides additional information on the modeling domain.

Figure V-1: National regional planning organization 36-km modeling domain used in the CAMx and CMAQ modeling for CENRAP



2. Emission Inventories

UCR prepared emissions inputs for the air-chemistry model using the SMOKE system. The CENRAP modeling emissions inventory for 2002 consists of a base case dataset for model performance evaluation and a distinct typical-scenario dataset. These datasets differ only in emissions from electric generating units (EGUs). Carolina Environmental Program under contract to CENRAP obtained continuous emission monitoring data for 2001, 2002, and 2003; generated temporal profiles; and then applied them to annual emissions inventories for EGUs. CENRAP used these temporal profiles in the modeling for 2002 to reflect typical operations of these critical sources, rather than using specific

operations in 2002 that might contain anomalous events. The inventory extends spatially throughout the regional planning organization 36-km modeling domain which covers the continental United States and portions of Canada and Mexico. Several rounds of CENRAP workgroup review and revision refined the initial Base A version of the inventory, culminating in the Base G inventory. The technical support document, found as Appendix 4-2, provides the methods for the SMOKE processing. Chapter 5 of the technical support document summarizes the development of the emissions inventory.

3. Quality Assurance Project Plan

Key components of the CENRAP modeling quality-assurance project plan include the graphical display of model inputs and outputs and multiple peer reviews for each step of the modeling process. UCR displayed emissions plots, model outputs, and other work products on the CENRAP modeling website for the modeling team, modeling workgroup, and others.

D. Air Chemistry Modeling

1. Model Selection

CENRAP based its selection of the air-chemistry models on a review of previous studies. CENRAP air-chemistry modeling protocol provides details on the justification for model selection and the formulation of the different models. 40 C.F.R. Part 51 Appendix W provides guidelines for conducting regional-scale modeling for particulate matter and visibility.

EPA recommends the use of Community Multi-scale Air Quality (CMAQ) model or Comprehensive Air-quality Model with Extensions (CAMx) to simulate aerosols impairing visibility. CENRAP modeling team used both CMAQ system as the primary air quality model and CAMx as the secondary corroborative model. The one-atmosphere photochemical grid approach of Models-3/CMAQ system of EPA can address particulate matter, visibility, and other applications at a regional scale for extended periods.

2. Air Chemistry Model Configuration

CENRAP used CMAQ 4.5 with the secondary organic aerosol modules (SOAmods) enhancement described hereinafter and the configuration shown in Appendix 4-2. The modeling team set up and exercised the model on the same regional planning organization national 36-km grid that WRAP and VISTAS used. VISTAS performed CMAQ simulations for 2002 and found that the model greatly underestimated organic carbon concentrations, especially in the summer. A review of the CMAQ formulation found that it failed to treat secondary organic aerosol formation from sesquiterpenes and isoprene and failed to account for the polymerization of secondary organic aerosol; although no longer volatile, polymerized aerosols stay in the particle form. VISTAS thus updated CMAQ secondary organic aerosol module to include these missing processes and found much-improved performance regarding organic carbonaceous aerosols. CENRAP tested CMAQ 4.5 with this secondary organic aerosol modules enhancement and found that it performed much better for organic carbon than the standard versions of CMAQ 4.5. CENRAP therefore adopted CMAQ 4.5 model with the secondary organic aerosol modules enhancement. The standard CAMx and CMAQ runs typically use the PPM advection solver.

3. Selection of Modeling Domain

CENRAP conducted air-chemistry modeling on the same 36-km domain used for emissions modeling. CENRAP performed a cost-benefit analysis of nesting a 12-km grid, covering the entire CENRAP region, within the bounds of the national 36-km domain. Smaller grid resolutions substantially increase processing time but offer the possibility of improved accuracy. CENRAP modeling team modeled three episodes in 2002 with the 36-km and 12-km domains. The episodes represented spring, summer, and winter periods of poor visibility at Class I areas in the CENRAP region. The modeling team found CMAQ results to be insensitive to these grid resolutions, but 12-km resolution reduced the sulfate under-prediction bias in the summertime with CAMx. With this possible exception, CENRAP noted little benefit in model performance with use of the 12-km grid. CENRAP also considered in its decision that VISTAS also found similar visibility projections for 2018 using 36-km and 12-km grids, supporting the conclusion that costs outweighed benefits of the smaller grid resolution. The technical support document, found at Appendix 4-2, provides additional information on the modeling domain.

4. Vertical Structure of the Modeling Domain

CAMx and CMAQ model configurations can collapse vertical layers from MM5 into thicker air-chemistry model layers to improve computational efficiency. WRAP and VISTAS evaluated the sensitivity of CMAQ model estimates to the number of vertical layers. The modeling team performed CMAQ simulations without layer collapsing (*i.e.*, with the same 34 layers that MM5 used) and with various layer collapsing schemes. These studies found that using 19 vertical layers upward to 100 mb (the same model top as MM5) and matching the eight lowest MM5 vertical layers near the surface produced results nearly identical to those without layer collapsing. They also found that very aggressive layer collapsing (*e.g.*, 34 layers to 12 layers) produced results with substantial differences compared to those without layer collapsing. Based on WRAP and VISTAS sensitivity analyses, CENRAP adopted the 19-vertical-layer configuration.

5. Initial Concentrations and Boundary Conditions

CENRAP modeling team operated CAMx and CMAQ model separately for each quarter of 2002 using an approximate 15-day spin-up period to limit the influence of the assumed initial concentrations (*e.g.*, start 15 June 2002 for the third quarter that began on 1 July). Sensitivity simulations with this 15-day spin-up period demonstrated the minimal influence of initial concentrations using the 36-km regional planning organization national domain. CMAQ and CAMx modeling consequently specified clean initial concentrations using a 15-day spin-up period.

Boundary conditions result from the assumed concentrations along the lateral edges of the 36-km modeling domain (see Figure V-1~~Figure V-1~~). CENRAP used the results for 2002 from GEOS-CHEM, a three-dimensional global circulation and chemistry simulation driven by assimilated meteorological observations from the Goddard Earth Observing System (GEOS) of National Aeronautics and Space Administration (NASA) Global Modeling and Assimilation Office. Research groups around the world use this general circulation model for a wide range of atmospheric composition problems. The atmospheric-chemistry modeling group at Harvard University provides central management and support of the model and applied it in a joint regional planning organization study for 2002 that VISTAS

coordinated. This study retained the University of Houston to process the GEOS-CHEM output for 2002 into boundary conditions for the CMAQ model.

Boundary conditions include visibility-impairing emissions from Mexico City, the Yucatán Peninsula, much of central and southern Mexico, and further south into Mesoamerica.

Initial conditions represent the assumed three-dimensional concentrations throughout the modeling domain at the beginning of the simulation.

6. Quality and Performance Evaluation

CENRAP air-quality modeling quality-assurance project plan includes the graphical display of model inputs and outputs as well as multiple peer reviews of each step of the modeling process. UCR displayed emissions plots, model outputs, and other work products on their CENRAP modeling website for the modeling team, modeling workgroup, and others. Other model valuations for CENRAP compared concentrations of various pollutants that CAMx and CMAQ model simulated with observations from:

- IMPROVE,
- Clean Air Status and Trends Network (CASTNet),
- Speciated Trends Network (STN),
- Aerometric Information Retrieval Systems (AIRS), and
- South Eastern Aerosol Research and Characterization (SEARCH).

The modeling team of UCR and Environ evaluated CMAQ model and CAMx against ambient measurements of particulate constituents, gas-phase species, and wet deposition. The team conducted numerous base- and typical-case CMAQ model and CAMx simulations for 2002 and several performance evaluations during the course of the CENRAP modeling study. CENRAP shared the results of these evaluations on its modeling website, in presentations made to the public, and in previous reports. CAMx and CMAQ model generally performed well for sulfate and elemental carbonaceous aerosols. For nitrate aerosols, the model performance varied from underestimation in summer to overestimation in winter. Performance for organic carbonaceous aerosols also varied, but the inclusion of the secondary organic aerosol modules enhancement greatly improves this performance in summer. The model performed poorly for fine soil and coarse matter. The IMPROVE measurements partially result from local fugitive dust sources not captured in the emissions inventories or not well resolved in the 36-km model grid; this measurement/model incommensurability perhaps partially explains the poor performance for fine soil and especially for coarse mass. The technical support document in Appendix 4-2 details information on the model performance evaluations.

7. Model Simulations

The modeling team conducted numerous runs on the successive versions of the base inventory. Modeling began in autumn of 2004 and concluded in summer of 2007 with the final Base G control strategy runs; during this process, the modeling team adopted many corrections and refinements of the inventory and enhancements of emissions and air-chemistry models. CENRAP workgroup chairs and the modeling team documented these changes through reports and presentations made publicly available

on the CENRAP website, CENRAP modeling website, and listserv. Appendix 4-2 includes some of these documents. The technical support document discusses the evolution of the modeling analyses.

Because of the similarity between Base F and Base G for 2002 and resource constraints, CENRAP did not re-conduct the model evaluation for Base G; therefore, only the typical modeling run for 2002 and the base and control strategy modeling runs for 2018 reflect the Base G inventory. Chapter 3 and Appendix C of the technical support document provide specific details on the performance evaluation of the final Base F 36-km CMAQ base-case model for 2002.

E. Particulate Source Apportionment

1. Model Selection and Configuration

A state-of-science one-atmosphere photochemical grid model from Environ, CAMx can address particulate matter and visibility impairment at a regional scale for extended periods. The CENRAP modeling team used CAMx, and CENRAP selected the system as the secondary corroborative air-quality model. EPA recommends its use to simulate pollutants impairing visibility.

The modeling team applied CAMx 4.40 using options similar to those used for CMAQ system. CAMx contains particulate-matter source apportionment technology widely used in CENRAP modeling. Appendix 4-2 lists the main CAMx configuration used for CENRAP annual modeling, selected in part for consistency with the CMAQ model configuration.

A 12-km resolution reduced the sulfate under-prediction bias in the summertime with the CAMx model. CENRAP nevertheless decided that use of the 12-km grid for regional haze modeling provided inadequate benefits to justify the computational expense. CAMx simulations consequently used the same modeling domain as the CMAQ simulations.

CAMx and CMAQ model configurations can collapse vertical layers from MM5 into thicker air-chemistry model layers to improve computational efficiency. CAMx simulations used the same vertical structure as CMAQ simulations.

2. Input, Simulation, and Performance Evaluation

CENRAP modeling team operated CAMx and CMAQ model separately for each quarter of 2002 using the same 15-day spin-up period. CAMx and CMAQ modeling specified clean initial concentrations.

The modeling team initially used CAMx in side-by-side comparisons with CMAQ. Environ presented comparative model performance results and other factors for CAMx 4 and CMAQ 4.4 with secondary organic aerosol modules enhancement at the 7 February 2006 CENRAP modeling workgroup meetings and concluded:

- Neither model outperformed the other consistently over all chemical constituents and averaging times.
- Both models performed well for sulfate aerosol.
- CAMx tended to over-predict winter nitrate aerosol more than CMAQ model did.
- CAMx performed slightly better than CMAQ model for elemental carbonaceous aerosol.
- CMAQ performed much better than CAMx for organic carbonaceous aerosol.
- Both models over-predicted fine soil dust and under-predicted coarse matter.
- CMAQ ran faster than CAMx due to multiple-processor capability.
- CAMx required much less disk space than CMAQ.

Based on these factors, CENRAP selected CMAQ as the primary air-chemistry model for the CENRAP regional haze modeling and CAMx as the secondary corroborative model; however, CAMx also features particulate source apportionment technology capability that the CENRAP modeling used widely. The team used consistent model configuration where possible to support the corroborative use of both models. Environ nevertheless used the Bott advection solver in the CAMx but the PPM advection solver in CMAQ. The high computational requirements of the CAMx particulate source apportionment technique runs dictated this choice of the highly computationally efficient Bott scheme.

Because of the similarity between Base F and Base G for 2002 and resource constraints, CENRAP did not re-conduct the model evaluation for Base G; therefore, only the typical modeling run for 2002 and the base and control strategy modeling runs for 2018 reflect the Base G inventory. Particulate source apportionment technique modeling reflects the Base F inventory. The technical support document, Appendix 4-2, details information on the model performance evaluations.

F. Discussion of Components

The tables in this chapter show the modeled contributions of various areas and pollutants to visibility impairment at the Wichita Mountains on the worst quintile of monitored days in 2002. The projections shown in these tables use the modeling results scaled to measured pollutant concentrations according to the modeling guidelines of EPA.

1. Sulfureous Aerosol

CENRAP modeling apportioned most sulfureous particulate to point sources in the United States, particularly Texas and several Eastern states. Anthropogenic sources in Oklahoma, however, contribute less than five percent of sulfureous particulate that reaches the Wichita Mountains. The modeling nevertheless missed one-third of the observed sulfureous particulate, revealing a lack of understanding of atmospheric gaseous and aqueous sulfur chemistry, inadequacies in emissions inventories, discrepancies between the modeled concentrations and the sampling method, or some other problems.

Table V-1: Projected sulfureous sources of light extinction at Wichita Mountains (worst quintile days in 2002)

All values in Mm^{-1}	Total	Point	Area	Non-road Mobile	On-road Mobile	Biogenic
Texas	13.98	11.56	1.85	.28	.29	.00
East	7.49	6.90	.40	.09	.10	.00
boundary conditions	3.93					
Louisiana	2.60	1.93	.56	.08	.03	.00
Indiana	2.41	2.29	.09	.02	.02	.00
Mexico	1.79	1.67	.09	.01	.01	.00
Oklahoma	**1.77**	**1.28**	**.33**	**.06**	**.09**	**.01**
Canada	1.62	1.50	.08	.02	.01	.00
Ohio	1.61	1.54	.02	.02	.02	.00
Illinois	1.55	1.47	.03	.03	.02	.00
Kentucky	1.35	1.23	.08	.02	.01	.00
Alabama	1.30	1.16	.11	.02	.02	.00
Tennessee	1.29	1.15	.08	.03	.02	.00
Missouri	1.13	.95	.14	.03	.02	.00
Arkansas	1.03	.73	.21	.04	.03	.01
Kansas	.92	.71	.16	.04	.02	.00
Iowa	.46	.42	.01	.02	.01	.00
Michigan	.42	.37	.02	.02	.01	.00
West	.37	.28	.03	.03	.01	.02
Mississippi	.32	.25	.01	.04	.01	.00
Nebraska	.32	.25	.03	.03	.01	.00
Minnesota	.30	.24	.03	.02	.01	.01
Wisconsin	.25	.23	.01	.01	.01	.00
North Dakota	.23	.21	.01	.01	.00	.00
Wyoming	.18	.15	.02	.01	.00	.00
all other	.49	.28	.17	.03	.01	.00
total	**49.12**	**38.76**	**4.59**	**1.00**	**.79**	**.05**

Source: Particulate source apportionment technique—2002 base year

Formatte

Formatte
Auto

Formatte

Table V-1

~~Table V-1~~ indicates that point sources contribute overwhelmingly to sulfureous particulate that impairs visibility at the Wichita Mountains. The high sulfureous particulate concentrations generally reflect transport from Texas and the eastern two-thirds of the United States.

2. Nitrate Aerosol

The overwhelming majority of nitrate aerosol at the Wichita Mountains comes from anthropogenic sources in the United States, three-tenths from Oklahoma. CENRAP model projection

implicates on-road mobile sources for a plurality of emissions that impair visibility at the Wichita Mountains, significantly implicates point sources, and assigns some culpability to area sources in Oklahoma. This model projection nevertheless considerably overestimates nitrate particulate concentrations on the worst quintile of days.

Table V-2: Projected nitrate sources of light extinction at Wichita Mountains (worst quintile days in 2002)

All values in Mm^{-1}	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	7.89	1.97	.96	.98	2.74	1.24
Oklahoma	**6.43**	**1.80**	**1.54**	**.61**	**1.69**	**.78**
Kansas	1.94	.66	.24	.41	.47	.15
Missouri	1.06	.39	.08	.16	.36	.07
boundary conditions	.87					
Nebraska	.63	.16	.04	.20	.19	.04
Canada	.58	.14	.14	.13	.15	.02
Iowa	.57	.22	.01	.10	.20	.04
Arkansas	.49	.13	.06	.08	.20	.02
Illinois	.42	.20	.02	.09	.10	.01
Mexico	.37	.24	.02	.01	.04	.07
Minnesota	.31	.12	.03	.05	.10	.01
Louisiana	.30	.12	.06	.03	.08	.01
West	.29	.08	.02	.06	.11	.02
New Mexico	.28	.09	.06	.05	.06	.03
Colorado	.25	.08	.02	.03	.10	.02
Wyoming	.16	.08	.02	.04	.02	.00
East	.15	.05	.01	.02	.06	.01
North Dakota	.14	.06	.01	.03	.03	.01
South Dakota	.12	.01	.01	.03	.05	.03
all other	.48	.20	.05	.08	.13	.01
total	**23.72**	**6.80**	**3.41**	**3.16**	**6.87**	**2.61**

Source: Particulate source apportionment technique—2002 base year

Nitrates from on-road mobile and point sources throughout the domain each contribute 7% of the visual impairment at the Wichita Mountains.

3. Organic Carbonaceous Particulate

In the atmosphere, organic aerosols and compounds partake in a complex web of chemical reactions involving thousands of chemical species as they usually degrade or deposit. Available modeling algorithms greatly simplify these processes and may not represent them adequately to assign culpability with sufficient confidence to justify pursuing reductions in the already small concentrations

of organic carbonaceous particulate. CENRAP modeling classifies organic aerosols as primary or secondary. The term “primary” refers to particles emitted directly into the atmosphere. The term “secondary” refers to particles formed in the atmosphere, usually through chemical reactions, some within condensed water droplets.

CENRAP particulate source apportionment modeling for 2002 traces less than 5% of baseline concentrations to point, on-road mobile, or non-road mobile sources in the United States. Trijonis cited a considerable petroleum-based component to organic aerosols in a desert field study during the 1980s, presumably near major cities of Los Angeles, Riverside, and San Diego. A lack of cities of such population in Oklahoma, decades of federally mandated improvement in motor vehicle emissions, the increasing prevalence of catalytic converters and fuel-injection systems, and other efforts to decrease emissions from petroleum combustion, however, lend credibility to our modeling suggesting only a trivial contribution from mobile sources.

CENRAP model projection captures organic aerosol largely from wildfires. The model projects that more than four-fifths of primary organic aerosol at the Wichita Mountains originates outside Oklahoma. Major source regions include Texas and areas outside the boundary of the domain. These boundary conditions include extensive agricultural burning and occasional wildfire emissions throughout Mesoamerica and the Caribbean that occur each spring. Questionable accuracy of fire emission inventories nevertheless yields uncertainty regarding the modeled effect of fire emissions on primary organic aerosol concentrations.

CENRAP modeling attributes a significant proportion of organic aerosols at the Wichita Mountains to the anthropogenic area category, including fires. It attributes a further one-third of organic particulate to “secondary” aerosol production.

Table V-3: Projected organic carbonaceous sources of light extinction at Wichita Mountains (worst quintile days in 2002)

All values in Mm^{-1}	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
boundary conditions	3.61					
Texas	3.05	.34	2.37	.19	.12	.03
secondary biogenic	2.91					
secondary anthropogenic	2.57					
Oklahoma	**2.26**	**.13**	**1.75**	**.19**	**.08**	**.12**
Kansas	.57	.05	.49	.02	.01	.01
Louisiana	.42	.17	.18	.04	.01	.03
East	.34	.04	.25	.03	.01	.01
Arkansas	.31	.03	.11	.03	.01	.13
West	.20	.00	.04	.01	.01	.14
Missouri	.19	.00	.13	.05	.00	.00
Minnesota	.11	.00	.04	.01	.00	.05
Mississippi	.10	.01	.06	.01	.00	.01
Canada	.09	.01	.04	.01	.00	.03
Nebraska	.08	.02	.04	.01	.00	.00
all other	.48	.06	.28	.07	.03	.03
total	**17.28**	**.86**	**5.79**	**.66**	**.30**	**.60**

Source: Particulate source apportionment technique—2002 base year
Primary aerosols only except where "secondary" explicitly indicated

A detailed field study may identify the species of gaseous and particulate organic compounds in the atmosphere near the Wichita Mountains, locate their sources and sinks, and improve understanding of their chemistry; however, DEQ presently lacks the financial and other resources to undertake such study.

4. Elemental Carbonaceous Particulate

Modeling apportions more than three-quarters of elemental carbon particulate to United States anthropogenic sources, largely to area sources, a category that includes fires.

Table V-4: Projected elemental carbonaceous sources of light extinction at Wichita Mountains (worst quintile days in 2002)

All values in Mm^{-1}	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	1.42	.03	.83	.36	.20	.01
Oklahoma	**1.08**	**.03**	**.56**	**.32**	**.14**	**.03**
boundary conditions	.69					
Kansas	.30	.00	.23	.06	.01	.00
Louisiana	.14	.01	.08	.03	.02	.01
East	.13	.01	.05	.05	.02	.00
Arkansas	.13	.01	.03	.03	.02	.03
West	.07	.00	.01	.02	.01	.03
Missouri	.07	.00	.03	.03	.01	.00
all other	.44	.01	.08	.25	.08	.03
total	**4.47**	**.10**	**1.89**	**1.14**	**.51**	**.14**

Source: Particulate source apportionment technique—2002 base year

5. Fine Soil Particulate

Available atmospheric chemistry modeling systems generally do not capture natural wind erosion. CENRAP modeling attributes the overwhelming majority of fine soils to grossly overestimated area sources.

Table V-5: Projected fine soil sources of light extinction at Wichita Mountains (worst quintile days in 2002)

All values in Mm^{-1}	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	.29	.02	.22	.00	.00	.05
Oklahoma	**.26**	**.00**	**.24**	**.00**	**.00**	**.01**
all other	.24	.02	.18	.00	.00	.02
total	**.79**	**.05**	**.65**	**.00**	**.00**	**.07**

Source: Particulate source apportionment technique—2002 base year

6. Coarse Particulate

CENRAP modeling attributes practically all coarse particulate matter to natural and area sources. The coarse matter in the atmosphere at the Wichita Mountains comes primarily from natural dust storms that modeling simulates poorly.

Table V-6: Projected coarse particulate sources of light extinction at the Wichita Mountains (worst quintile days in 2002)

All values in Mm^{-1}	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Oklahoma	**2.91**	**.01**	**2.73**	**.00**	**.00**	**.17**
Texas	1.51	.02	1.15	.00	.00	.34
all other	.17	.01	.13	.00	.00	.03
total	**4.60**	**.04**	**4.01**	**.00**	**.01**	**.53**

Source: Particulate source apportionment technique—2002 base year

G. Other Class I Areas

Table V-7~~Table V-7~~ illustrates that emissions from Oklahoma sources only insignificantly impair visibility at all Class I areas in other states. DEQ consequently need not undertake any emission reduction action to protect Class I areas in other states.

Table V-7: Projected contribution of Oklahoma emissions to visibility impairment in Class I areas (worst quintile days in 2002)

Class I Area	State	Contribution to light extinction (Mm^{-1})	Total light extinction from all sources (Mm^{-1})	Oklahoma contribution (%)	Deciview contribution
Wichita Mountains	**Oklahoma**	**14.72**	**111.03**	**13.25%**	**1.42**
Hercules-Glades	Missouri	4.84	151.05	3.20%	.33
Salt Creek	New Mexico	1.71	63.50	2.69%	.27
Guadalupe Mountains	Texas	1.18	58.80	2.01%	.20
Seney	Michigan	2.10	116.35	1.80%	.18
Caney Creek	Arkansas	2.61	144.93	1.80%	.18
White Mountain	New Mexico	.76	43.91	1.72%	.17
Upper Buffalo	Arkansas	2.43	142.79	1.70%	.17
Isle Royale	Michigan	1.17	81.92	1.43%	.14
Badlands	South Dakota	.72	55.87	1.28%	.13
Wind Cave	South Dakota	.65	51.71	1.26%	.13
Big Bend	Texas	.68	58.79	1.16%	.12
Wheeler Peak	New Mexico	.33	32.96	.99%	.10
Breton	Louisiana	1.34	134.99	.99%	.10
Mingo	Missouri	1.62	170.83	.95%	.10
Bosque del Apache	New Mexico	.36	41.71	.86%	.09
Great Sand Dunes	Colorado	.32	38.88	.82%	.08
San Pedro Parks	New Mexico	.23	31.82	.74%	.07
Rocky Mountain	Colorado	.29	43.13	.68%	.07
Boundary Waters Canoe Area	Minnesota	.48	72.33	.66%	.07
Voyageurs	Minnesota	.34	70.50	.48%	.05
Bandelier	New Mexico	.18	40.97	.44%	.04
Everglades	Florida	.38	115.24	.33%	.03
Galiuro	Arizona	.13	40.51	.32%	.03
Chassahowitzka	Florida	.39	125.17	.31%	.03
Wolf Island	Georgia	.45	149.00	.30%	.03
Theodore Roosevelt	North Dakota	.18	61.33	.29%	.03
UL Bend	Montana	.12	48.42	.24%	.02
Mammoth Cave	Kentucky	.52	218.58	.24%	.02
Lye Brook	Vermont	.29	123.08	.24%	.02
Presidential Range-Dry River	New Hampshire	.22	112.46	.20%	.02
Saint Marks	Florida	.27	140.35	.19%	.02
Roosevelt Campobello	Maine	.17	90.67	.19%	.02
Rawah	Colorado	.06	34.23	.17%	.02
Cape Romain	South Carolina	.22	134.64	.16%	.02
Cohutta	Georgia	.32	218.72	.15%	.01
Acadia	Maine	.15	100.97	.15%	.01
Swanquarter	North Carolina	.17	120.86	.14%	.01

Class I Area	State	Contribution to light extinction (Mm^{-1})	Total light extinction from all sources (Mm^{-1})	Oklahoma contribution (%)	Deciview contribution
Brigantine	New Jersey	.22	178.06	.12%	.01
Pine Mountain	Arizona	.05	39.84	.12%	.01
Sipsey	Alabama	.22	187.03	.12%	.01
Saguaro	Arizona	.05	47.10	.11%	.01
Lostwood	North Dakota	.08	72.91	.11%	.01
Shining Rock	North Carolina	.18	182.63	.10%	.01
Medicine Lake	Montana	.06	60.56	.10%	.01
James River Face	Virginia	.17	189.25	.09%	.01
West Elk	Colorado	.03	30.67	.09%	.01
Joyce Kilmer-Slickrock	North Carolina	.17	193.84	.09%	.01
Linville Gorge	North Carolina	.13	183.46	.07%	.01
Shenandoah	Virginia	.13	197.41	.07%	.01
Otter Creek	West Virginia	.11	177.35	.06%	.01
Petrified Forest	Arizona	.03	42.36	.06%	.01
Weminuche	Colorado	.02	31.72	.06%	.01
Gila	New Mexico	.02	42.24	.05%	.01
Washakie	Wyoming	.02	34.73	.05%	.01

Source: Particulate source apportionment technique—2002 base year
Oklahoma contribution is less than .10 Mm^{-1} and less than .1% at every unlisted Class I area.

H. Strategy for Wichita Mountains

As Table V-8~~Table V-8~~ indicates, sulfureous emissions clearly most importantly impair visibility at the Wichita Mountains. Nitrate particulate matter forms from NO_x emissions but occurs predominantly during the winter months; sulfureous aerosol comprises a plurality during the rest of the year. Organic carbonaceous aerosols also contribute significantly to visibility impairment at the Wichita Mountains. Texas sources bear culpability for the largest proportion of visibility impairment. In every category except coarse particulate matter, sources in Texas (and other states) notably contribute more than those within Oklahoma do. Several other states each emit sulfureous aerosols which impair visibility at the Wichita Mountains more than emissions from all Oklahoma sources do.

Table V-8: Projected sources of light extinction at Wichita Mountains (worst quintile days in 2002)

All values in Mm^{-1}	Sum	Sulfureous	Nitrate	Organic carbonaceous	Elemental carbonaceous	Soils	Coarse
Texas	28.15	13.98	7.89	3.05	1.42	.29	1.51
Oklahoma	**14.72**	**1.77**	**6.43**	**2.26**	**1.08**	**.26**	**2.91**
Rayleigh scattering	11.00						
boundary conditions	9.17	3.93	.87	3.61	.69	.02	.05
East	8.12	7.49	.15	.34	.13	.01	.00
Kansas	3.82	.92	1.94	.57	.30	.05	.05
Louisiana	3.47	2.60	.30	.42	.14	.01	.00
secondary biogenic	2.91			2.91			
secondary anthropogenic	2.57			2.57			
Indiana	2.53	2.41	.07	.02	.02	.00	.00
Missouri	2.47	1.13	1.06	.19	.07	.02	.01
Canada	2.35	1.62	.58	.09	.05	.01	.00
Mexico	2.25	1.79	.37	.04	.02	.01	.02
Illinois	2.05	1.55	.42	.04	.03	.00	.00
Arkansas	1.97	1.03	.49	.31	.13	.01	.01
Ohio	1.68	1.61	.02	.02	.02	.00	.00
Tennessee	1.51	1.29	.11	.07	.03	.00	.00
Kentucky	1.47	1.35	.05	.04	.02	.00	.00
Alabama	1.41	1.30	.03	.06	.02	.00	.00
Iowa	1.16	.46	.57	.06	.03	.03	.01
Nebraska	1.11	.32	.63	.08	.04	.02	.02
West	.93	.37	.29	.20	.07	.01	.01
Minnesota	.78	.30	.31	.11	.04	.01	.00
Mississippi	.52	.32	.06	.10	.03	.00	.00
Michigan	.47	.42	.02	.01	.01	.00	.00
New Mexico	.46	.14	.28	.02	.01	.00	.01
Colorado	.45	.16	.25	.02	.01	.00	.00
North Dakota	.41	.23	.14	.02	.01	.00	.00
Wyoming	.36	.18	.16	.01	.00	.00	.00
Wisconsin	.33	.25	.05	.02	.01	.00	.00
South Dakota	.23	.05	.12	.02	.02	.01	.01
Gulf of Mexico	.22	.15	.06	.01	.00	.00	.00
initial conditions	.00	.00	.00	.00	.00	.00	.00
total	**111.03**	**49.12**	**23.72**	**17.28**	**4.47**	**.79**	**4.64**

Source: Particulate source apportionment technique—2002 base year

I. International Transport

Table V-8~~Table V-8~~ shows some contribution from sources in southern Canada, northern México, and especially the boundary conditions outside the CENRAP modeling domain. The boundary conditions include particulate from much of central and all of southern México, including Ciudad México

(Distrito Federal), the Mexican Yucatán Peninsula, Mesoamerica, the Caribbean region, Africa, the People's Republic of China, and other Asian and international sources. International transport contributes more than one-tenth of the regional haze on the worst quintile of days at the Wichita Mountains.

The contribution of international transport of anthropogenic regional haze into Oklahoma, Texas, and other states makes reaching natural conditions at the Wichita Mountains difficult without reductions in this transport. Approaching natural conditions ultimately may necessitate reductions in international transport of particulate matter and its precursors to parallel the reductions in American anthropogenic regional haze.

VI. Best Available Retrofit Technology

The federal regional haze rule requires certain older emission sources, largely unregulated under other provisions of the CAA, to apply additional controls. On 6 July 2005, EPA published final amendments to its regional haze rule, which requires emission sources that fit specific criteria, including reasonably anticipated contribution to visibility impairment in any Class I area, to install best available retrofit technology (BART). The final rule provides direction on determining which sources must install BART, and on determining what such sources must do to meet the BART requirement. The rule also includes Appendix Y to 40 C.F.R. Part 51, "Guidelines for BART Determinations under the Regional Haze Rule." Oklahoma's BART rule, OAC 252:100-8, Part 11, became effective as an emergency rule on 8 October 2006 and as a permanent rule on 15 June 2007. This rule implements the BART requirements of EPA's regional haze rule and incorporates by reference 40 C.F.R. Part 51, Appendix Y. The rule also provides that the resulting source-specific requirements be incorporated into that source's air quality permit. A copy of Oklahoma's BART rule, along with administrative materials required under 40 C.F.R. Part 51, Appendix V, Section 2.1(b) through (h), are included in Appendix 6-1.

A. BART-eligible Sources in Oklahoma

The Oklahoma BART rule sets out the criteria for identifying BART-eligible sources and incorporates by reference the guidelines contained in Appendix Y to 40 C.F.R. Part 51. The Oklahoma rule affects sources that:

- Belong to one of twenty-six industry source categories;
- Did not operate before 7 August 1962 but were in existence on 7 August 1977; and
- Have the potential to emit 250 tons per year or more of any regulated air pollutant. (The Appendix Y guidance narrows this to any visibility-impairing pollutant.)

DEQ determined that the visibility-impairing pollutants in Oklahoma include sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM_{10} and $PM_{2.5}$). CENRAP modeling shows that anthropogenic VOCs do not significantly impair visibility at the Wichita Mountains. Because of the limiting role of NO_X and SO_2 on $PM_{2.5}$ formation and the uncertainties in assessing the effect of ammonia emissions reductions on visibility, Oklahoma does not consider ammonia among visibility-impairing pollutants.

DEQ reviewed its emissions inventory and followed the steps listed in Subsection II.A of Appendix Y to 40 C.F.R. Part 51 to derive a list of BART-eligible sources.

Table VI-1 ~~Table VI-1~~ lists these sources.

Formatte
Auto, Do

Table VI-1: Facilities with BART-eligible Units in Oklahoma

BART source category	Facility name	County	Number of units
kraft pulp mills	Georgia Pacific Consumer Products (formerly Fort James Operating) Muskogee Mill	Muskogee	2
	International Paper (formerly Weyerhaeuser) Valliant Paper Mill	McCurtain	5
hydrogen, sulfuric, and nitric acid plants	Koch Nitrogen Enid Plant	Garfield	7
	Terra International Oklahoma Woodward Complex	Woodward	11
	Terra Nitrogen Partnership Verdigris Plant	Rogers	12
petroleum refineries	Sinclair Oil Tulsa Refinery	Tulsa	7
	Holly Refining and Marketing (formerly Sunoco) Tulsa Refinery	Tulsa	25
	Wynnewood Refining	Garvin	14
	Valero Refinery (formerly TPI Petroleum Inc) Ardmore Refinery	Carter	24
Portland cement plant	Lafarge Building Materials Tulsa Rogers City Line	Rogers	10
fossil fuel-fired steam electric plants	OG&E Horseshoe Lake Generating Station	Oklahoma	2
	OG&E Muskogee Generating Station	Muskogee	2
	OG&E Seminole Generating Station	Seminole	3
	OG&E Sooner Generating Station	Noble	2
	AEP/PSO Comanche Power Station	Comanche	2
	AEP/PSO Northeastern Power Station	Rogers	2
	AEP/PSO Riverside Jenks Power Station	Tulsa	2
	AEP/PSO Southwestern Power Station	Caddo	1
	Western Farmers Electric Coop Anadarko Plant	Caddo	3
	Western Farmers Electric Coop Mooreland Station	Woodward	3

B. Determination of Sources Required to Install BART

Federal guidelines (Section III of Appendix Y to 40 CFR Part 51) give DEQ two options regarding BART-eligible sources:

- Make BART determinations for all sources, or
- Consider exempting some sources from BART because they do not cause or contribute to visibility impairment at the Wichita Mountains or any other Class I area.

DEQ chose to exempt some sources from BART. The regulatory guidelines suggest three options for exempting an eligible source from BART:

- Individual source attribution approach (dispersion modeling),
- Use of model plants to exempt sources with common characteristics, and
- Cumulative modeling to exclude every source in Oklahoma from BART.

DEQ chose the first option and required the owner or operator of each BART-eligible source to perform a source-specific analysis, using the CALPUFF model to determine whether it causes or contributes to visibility impairment. DEQ will require any BART-eligible source determined to cause or contribute to visibility impairment at the Wichita Mountains or any other Class I area to install BART.

Appendix 6-2 includes the CALPUFF modeling protocol used for determining facilities subject to BART. Subsection III.A of the regulatory guidelines in Appendix Y to 40 C.F.R. Part 51 provide DEQ the discretion to set a maximum contribution threshold below 0.5 deciview if "the location of a large number of BART-eligible sources within the State and in proximity to a Class I area justifies this approach." With only three Oklahoma BART-eligible sources within close proximity of the Wichita Mountains, DEQ allowed sources to use the 0.5-deciview threshold; therefore, BART-eligible sources that always contribute less than 0.5 deciview of visibility impairment need not install BART. Some sources used dispersion modeling to determine that they fell below the 0.5 deciview threshold, and DEQ granted waivers to the facilities listed in Table VI-2~~Table VI-2~~. These waivers are in Appendix 6-3. Each application includes a modeling analysis.

Table VI-2: BART-eligible Sources in Oklahoma Granted Waivers from BART Based on Dispersion Modeling

Company	Facility	Greatest Impact
Koch Nitrogen	Enid Plant	0.489 dv
Terra International Oklahoma Inc.	Woodward Complex	0.405 dv
Terra Nitrogen Ltd Partnership	Verdigris Plant	0.427 dv
Sinclair Oil Corporation	Tulsa Refinery	0.119 dv
Holly Refining and Marketing	Tulsa Refinery	0.335 dv
Wynnewood Refining Company	Wynnewood Refinery	0.267 dv
Valero Refinery Company	Ardmore Refinery	0.22 dv
Oklahoma Gas & Electric	Horseshoe Lake Generating Station	0.359 dv*
American Electric Power	PSO Riverside Jenks Power Station	0.239 dv*
Western Farmers Electric Coop	Mooreland Station	0.18 dv*
Lafarge Building Materials	Tulsa Rogers City Line	0.121 dv*
*98th Percentile		

The facilities listed in Table VI-3~~Table VI-3~~ have applied for permit modifications to include enforceable limits on potential emissions that will lower each facility's modeled visibility impairment contribution below the 0.5-deciview threshold and allow them to qualify for similar waivers from installing BART. These waivers are also in Appendix 6-3.

Table VI-3: BART-eligible Sources in Oklahoma Granted Waivers from BART with New Proposed Permitted Emission Limits

Facility name	Emission reductions (tons per year)		
	SO_2	NO_x	PM_{10}
Georgia Pacific Consumer Products LP Muskogee Mill	0	143	0
International Paper Valliant Paper Mill	4,128	2,104	110
Western Farmers Electric Coop Anadarko Plant	861	4,971	454

Table VI-4~~Table VI-4~~ lists the facilities with BART-eligible units that must install BART. The negligible SO_2 and PM emissions from natural gas-fired steam electric plants do not significantly

contribute to visibility impairment and were therefore not further evaluated. Sources required to install BART must complete a BART analysis.

Table VI-4: Sources in Oklahoma Required to Install BART

Facility Name	BART Emission Units	Source Category	Pollutants Evaluated	98th Percentile Contribution (deciview)
OG&E Seminole Generating Station	Units 1, 2, and 3	fossil fuel-fired steam electric plants	NO_x	1.300
OG&E Sooner Generating Station	Units 1 and 2	fossil fuel-fired steam electric plants	SO_2	1.795
			NO_x	1.244
			PM_{10}	0.281
OG&E Muskogee Generating Station	Units 4 and 5	fossil fuel-fired steam electric plants	SO_2	1.724
			NO_x	0.210
			PM_{10}	1.469
AEP PSO Comanche Power Station	Units 1 and 2	fossil fuel-fired steam electric plants	NO_x	1.830
AEP PSO Northeastern Power Station	Unit 2	fossil fuel-fired steam electric plants	NO_x	0.809
AEP PSO Northeastern Power Station	Units 2, 3, and 4	fossil fuel-fired steam electric plants	SO_2	1.836
			NO_x	1.029
			PM_{10}	0.230
AEP PSO Southwestern Power Station	Unit 3	fossil fuel-fired steam electric plants	NO_x	3.863

C. Determination of BART Requirements for Subject Sources

Table VI-5 shows BART for each visibility-impairing pollutant for each source required to install it. BART is an emission limit for each pollutant based on the degree of reduction achievable through the application of the best system of continuous emission reduction. These limits consider the technology available, the costs of compliance, the energy required for compliance, the non-air-quality environmental effects of compliance, any pollution control equipment in use or in existence at the source, the remaining useful life of the source, and the resultant improvement in visibility reasonably anticipated from the use of such technology. If a BART-eligible source lacks the potential to emit at least 40 tons of SO_2 or NO_x per year or at least 15 tons of PM_{10} per year, then the regulation does not require DEQ to make a determination of BART for such pollutants.

Table VI-5: BART Levels for Sources Subject to BART

Facility	Unit number	Fuel	BART emissions factor (lb/mmBtu)		
			NO_x	SO_2	PM_{10}
OG&E Muskogee Generating Station	4	coal	0.15	0.1	0.015
	5		0.15	0.1	0.015
OG&E Sooner Generating Station	1		0.15	0.1	0.015
	2		0.15	0.1	0.015
AEP/PSO Northeastern Power Station	3		0.15	0.15	0.1
	4		0.15	0.15	0.1
	2	natural gas	0.28	--	--
AEP/PSO Southwestern Power Station	3		0.45	--	--
AEP/PSO Comanche Power Station	1		0.15	--	--
	2		0.15	--	--
OG&E Seminole Generating Station	1		0.203	--	--
	2		0.212	--	--
	3		0.164	--	--

Appendix 6-4 includes DEQ's BART analyses for each facility required to install BART. Oklahoma's BART rule requires each source subject to BART to install and operate BART no later than 5 years after EPA approves this implementation plan revision. *See* OAC 252-100-8-75(e). Table VI-5 summarizes the BART emission standards. DEQ will issue enforceable Part 70 air quality permits requiring BART-eligible sources subject to BART to: (1) install BART and achieve the associated BART emission standards; or (2) "achieve greater reasonable progress toward natural visibility conditions" through an approvable alternative as provided for in 40 CFR § 51.308(e). Subject sources must achieve the BART emission standards referenced above or achieve the "greater reasonable progress" referenced above within seven (7) years from the date of submission of the Oklahoma Regional Haze SIP or within five (5) years of EPA's approval of the SIP, whichever is longer. Each permit modification will also include a requirement, schedule, and procedures to ensure that the source properly installs, operates, and maintains any required control equipment. If necessary, DEQ may issue an Administrative Order as an enforceable mechanism to ensure compliance pending the issuance of an operating permit modification and/or any necessary construction permit(s). The Oklahoma BART rule contains the BART compliance schedule and enforceable mechanism for each source. Table VI-6 lists controls used to comply with BART emissions limitations.

Table VI-6: Controls Used to Comply with BART

Facility	Fuel	Unit No.	Controls		
			SO_2	NO_X	PM
OG&E Muskogee	Coal	4 & 5	DFGD	LNB/OFA	Fabric Filter Baghouse
OG&E Seminole	Gas	1, 2, & 3	Natural Gas Fuel Exclusively-	LNB/OFA FGR	Natural Gas Fuel Exclusively
OG&E Sooner	Coal	1 & 2	DFGD	LNB/OFA	Fabric Filter Baghouse
PSO Northeastern	Gas	2	Natural Gas Fuel Exclusively	LNB/OFA	Natural Gas Fuel Exclusively
PSO Northeastern	Coal	3 & 4	DFGD	LNB/OFA	Existing ESP
PSO Southwestern	Gas	3	Natural Gas Fuel Exclusively	LNB/OFA	Natural Gas Fuel Exclusively
PSO Comanche	Gas	1 & 2	Natural Gas Fuel Exclusively	LNB	Natural Gas Fuel Exclusively

DFGD – Dry Flue Gas Desulfurization (Dry Scrubber)

LNB/OFA - Low NO_X Burner with Over-fire Air

FGR - Flue Gas Recirculation

The application of BART to all sources required to install it provides an estimated emission reduction of 88,577 tons of SO_2 per year, 55,736 tons of NO_x per year, and 1361 tons of PM_{10} per year from the baseline year of 2002. Tables VI-7, VI-8, and VI-9 show these reductions for each source.

Table VI-7: BART-Level Emissions Reductions from the 2002 Baseline, Sulfur Dioxide

Facility	Unit	Baseline Emissions lb/MMBTU	Emission Reductions TPY
OG&E Muskogee Generating Station	4 (coal fired)	0.8	31,324
OG&E Muskogee Generating Station	5 (coal fired)	0.85	
OG&E Sooner Generating Station	1 (coal fired)	0.86	30,654
OG&E Sooner Generating Station	2 (coal fired)	0.86	
PSO Northeast Generating Station	3 (coal fired)	0.9	26,599
PSO Northeast Generating Station	4 (coal fired)	0.9	

Table VI-8: BART-Level Emissions Reductions from the 2002 Baseline, Nitrogen Oxides

Facility	Unit	Baseline Emissions lb/MMBTU	Emissions Reduction TPY
OG&E Muskogee Generating Station	4 (coal fired)	0.495	15,489
OG&E Muskogee Generating Station	5 (coal fired)	0.522	
OG&E Seminole Generating Station	1 (gas fired)	0.339	3,998
OG&E Seminole Generating Station	2 (gas fired)	0.354	
OG&E Seminole Generating Station	3 (gas fired)	0.219	
OG&E Sooner Generating Station	1 (coal fired)	0.601	17,849
OG&E Sooner Generating Station	2 (coal fired)	0.584	
PSO Northeastern Generating Station	2 (gas fired)	0.71	854
PSO Northeastern Generating Station	3 (coal fired)	0.536	15,205
PSO Northeastern Generating Station	4 (coal fired)	0.491	
PSO Southwestern Generating Station	3 (gas-fired)	0.57	450
PSO Comanche Generating Station	1 (gas-fired)	0.696	1,891
PSO Comanche Generating Station	2 (gas-fired)	0.613	

Table VI-9: BART-Level Emissions Reductions from the Baseline, Particulate Matter (PM_{10})

Facility	Unit	Baseline Emissions* lb/MMBTU	Emissions Reduction TPY
OG&E Muskogee Generating Station	4 (coal fired)	0.0184	308
OG&E Muskogee Generating Station	5 (coal fired)	0.0244	
OG&E Sooner Generating Station	1 (coal fired)	0.038	1053
OG&E Sooner Generating Station	2 (coal fired)	0.039	
*Maximum 24-hour Average Baseline Emissions			

Tables VI-10 and VI-11 list the anticipated improvement in visibility at mandatory federal Class I areas due to the installation of BART NO_X and SO_2 controls. Modeling for existing ESP controls and proposed fabric filter baghouses indicate both technologies control visibility impairment well below 0.5dv at all Class I areas.

Table VI-10: Visibility Improvement in the 98th Percentile with BART NO_x Controls

Facility	Wichita Mountains Δ-dv	Caney Creek Δ-dv	Upper Buffalo Δ-dv	Hercules Glades Δ-dv
OG&E Muskogee (coal -fired)	0.44	0.77	0.55	0.33
OG&E Seminole (gas fired)	0.37	0.25	0.14	0.12
OG&E Sooner (coal fired)	0.83	0.38	0.31	0.28
PSO Northeastern ((gas fired)	0.40	0.21	0.21	0.22
PSO Northeastern coal fired)	0.39	0.64	0.41	0.302
PSO Southwestern (gas fired)	1.93	0.14	0.11	0.08
PSO Comanche (gas fired)	1.28	0.07	0.06	0.05

Table VI-11: Visibility Improvement in the 98th Percentile with BART SO_2 Controls

Facility	Wichita Mountains Δ-dv	Caney Creek Δ-dv	Upper Buffalo Δ-dv	Hercules Glades Δ-dv
OG&E Muskogee (coal -fired)	0.98	1.18	1.05	0.85
OG&E Sooner (coal fired)	1.19	0.53	0.39	0.30
PSO Northeastern (coal fired)	1.07	1.05	0.84	0.84

D. Further Evaluation of Revised Cost Effectiveness Calculations for SO_2 BART Determinations.

OG&E and AEP PSO submitted amended BART proposals on September 22nd and 23rd, 2009, respectively. The proposals covered the three coal-fired Oklahoma sources that are required to install and operate BART. *See* Appendix 6-5 (OG&E Regional Haze Proposal and AEP PSO CAVR Compliance Strategy). Previously, on September 18, 2009, OG&E also submitted to DEQ revised cost effectiveness calculations concerning SO_2 retrofit technologies for the BART evaluations for the Sooner and Muskogee Generating Stations. *See* Appendix 6-5 (Letter and attached Cost Effectiveness Report from OG&E Air Quality Supervisor Ford Benham to DEQ Air Quality Division Director Eddie Terrill dated September 18, 2009). The revised calculations are based on a recent EPA notice of proposed rulemaking. *See* "Assessment of Anticipated Visibility Improvements at Surrounding Class I Areas and Cost Effectiveness of Best Available Retrofit Technology for Four Corners Power Plant and Navajo Generating Station: Advanced Notice of Proposed Rulemaking," 74 Fed. Reg. 44313, 44321 (Aug. 28, 2009). Using the actual annual baseline emissions as described in EPA's Advanced Notice of Proposed Rulemaking, OG&E increased its cost effectiveness calculations for Dry FGD-SDA to a range of $9,625 to $10,843 per ton of

SO_2 removed and to a range of $10,271 to $11,490 per ton of SO2 removed for Wet FGD. DEQ is continuing to evaluate these revised cost effectiveness calculations. In the event that the evaluation demonstrates that the costs associated with the current SO_2 BART determinations (i.e., Dry FGD-SDA) are unreasonable, the SO_2 BART determinations for these sources could potentially be changed to only include the continued use of low-sulfur coal and a corresponding sulfur limit of 0.9 lbs/MMBTU.

VII. Long-term Strategy with Emission Reduction

The long-term strategy for this implementation plan revision addresses regional haze visibility impairment at the Wichita Mountains and covers the period through 2018 in fulfillment of 40 C.F.R. §51.308(d)(3). DEQ considered several regulatory factors in 40 C.F.R. §51.308(d)(3)(v) when developing this long-term strategy, which includes enforceable emissions limitations, compliance schedules, and other measures necessary to achieve the reasonable progress goal for the Wichita Mountains. This strategy includes issuance and enforcement of permits limiting emissions from all known major sources in Oklahoma, state rules which specifically limit targeted emissions sources and categories, and several other ongoing air pollution control programs. In order to administer this strategy, DEQ already has rules in place; citations for those rules are throughout the chapter in appropriate sections. These citations refer to DEQ's current permitting process, prevention of significant deterioration (PSD) provisions, BACT and BART requirements. These rules have corresponding compliance schedules and enforcement protocol which are also discussed in section A. Section B discusses emissions limitations set forth for various pollutants of sources within the state of Oklahoma; these emissions limitations are based upon the National Ambient Air Quality Standards. Section C contains details regarding other ongoing air pollution control programs. Such programs include federal mobile emissions programs, the Clean Air Interstate Rule, Maximum Achievable Control Technology, and Refinery Consent Decrees. This strategy should enable the achievement of a reasonable progress goal for 2018 toward the elimination of visibility impairment at the Wichita Mountains. Because emissions from Oklahoma only insignificantly impair visibility at all other Class I areas, this long-term strategy for achievement of reasonable progress goals in other Class I areas requires no further rules or action from DEQ.

A. Permits, Compliance, and Enforcement

This implementation plan revision includes a state regulatory strategy to minimize emissions that cause or contribute to visibility impairment. DEQ will continue to apply rules that already afford protection to visibility at the Wichita Mountains and at other Class I areas.

1. Permits and Emissions Limitations

Various state rules limit opacity and particulate matter emissions from point and area sources. Oklahoma Administrative Code (OAC) 252:100-7, Permits for Minor Facilities, applies to permitted and unpermitted minor sources. OAC 252:100-8, Permits for Part 70 Sources, contains provisions for the prevention of significant deterioration and the BART requirements directly applicable for the Wichita Mountains and other Class I areas.

DEQ's PSD new source review rules in OAC 252:100-8, Parts 7 and 9, require application of best available control technology (BACT) or Lowest Achievable Emission Rate (LAER) to major new and modified point sources of SO_2, NO_x, VOCs, and particulate matter. BACT minimizes emissions of all

pollutants impacting attainment of the national ambient air quality standards, hence minimizing their contribution to regional haze.

2. Compliance Schedules

DEQ issues permits to all known major point sources in Oklahoma, and each permit contains enforceable limitations on emissions of various pollutants, some of which may cause or contribute to regional haze at the Wichita Mountains. Unless permits specify a different schedule for compliance, DEQ requires permitted sources to comply with their permits immediately upon issuance. DEQ also enforces compliance schedules of relevant administrative and judicial orders, including consent decrees.

3. Enforceability

40 CFR § 51.308(d)(3)(v)(F) requires Oklahoma to ensure the enforceability of emissions limitations and control measures used to meet reasonable progress goals. As previously stated in Chapter VI(B) of the State Implementation Plan, DEQ will issue enforceable Part 70 air quality permits requiring BART-eligible sources subject to BART to: (1) install BART and achieve the associated BART emission limits; or (2) "achieve greater reasonable progress toward natural visibility conditions" through an approvable alternative as provided for in 40 CFR § 51.308(e). Subject sources must achieve the BART emission limits referenced above or achieve the "greater reasonable progress" referenced above within seven (7) years from the date of submission of the Oklahoma Regional Haze SIP or within five (5) years of EPA's approval the SIP, whichever is longer.

In general, DEQ has the statutory authority to carry out all "duties, requirements and responsibilities necessary and proper for the implementation of the Oklahoma Clean Air Act and fulfilling the requirements of the Federal Clean Air Act." 27A O.S. § 2-5-105(22). This authority includes "sole environmental jurisdiction to regulate air emissions from all facilities and sources subject to operating permit requirements under Title V of the Federal Clean Air Act as amended." 27A O.S. § 1-3-101(E)(8). The DEQ also has authority to issue and renew air quality permits, see 27A O.S. §§ 2-5-112(B), 2-5-105(22), and 2-14-202, as well as to reopen and revise existing air quality permits, see 27A O.S. § 2-5-112(B)(3). It is unlawful for any entity to "operate any new or existing source of air contaminants except in compliance with a permit issued by the [DEQ]." 27A O.S. § 2-5-112(A); see also OAC 252:100-8-1.3.

DEQ has the authority to administratively and judicially enforce any provision of a DEQ issued air quality permits. See 27A O.S. §§ 2-5-110, 2-3-502, and 2-3-504. In addition to these enforceable permit provisions, the Oklahoma Administrative Code requires that "each BART-eligible source subject to BART shall install and operate BART no later than five years after EPA approves the Oklahoma Regional Haze SIP." OAC 252:100-8-75(e).

B. Oklahoma Emissions Limitations and Visibility Impairment

Various state rules limit emissions of pollutants which may contribute to regional haze at the Wichita Mountains and elsewhere.

1. Sulfureous Emissions

OAC 252:100-31 limits sulfur dioxide, hydrogen sulfide, total reduced sulfur compounds, and sulfuric acid from various sources, including:

- Petroleum and natural gas related operation processes,
- Pulp mills,
- Electric generating units,
- Limekilns,
- Sulfuric acid plants,
- Smelters, and
- Sulfur recovery units at petroleum refineries and all other sources.

Together with many lower emissions limitations in permits for new and modified sources, these rules limit the contribution of Oklahoma sources to sulfureous particulate at the Wichita Mountains.

2. Nitrate Precursor Emissions

OAC 252:100-33 controls emissions of nitrogen oxides from fuel-burning equipment.

3. Carbonaceous Emissions

OAC 252:100-13 prohibits most open burning of refuse and other combustible materials. The regulation 40 C.F.R. §51.308 (d)(3)(v)(E) requires DEQ to consider smoke management techniques for the purposes of agricultural and forestry management in developing a reasonable progress goal. OAC 252:100-13-7(4) includes provisions for the burning of forestland, cropland, and rangeland. In addition, the DEQ is developing an Oklahoma Smoke Management Plan in cooperation with the Oklahoma Department of Agriculture, Food & Forestry intended to minimize the impacts from wildland and prescribed fires.

4. Direct Emissions of Particulate Matter

OAC 252:100-17 limits particulate matter and opacity of emissions from incinerators. OAC 252:100-19 controls emission of particulate matter from fuel-burning units and industrial processes. OAC 252:100-23 controls opacity of emissions from cotton gins. OAC 252:100-24 limits emissions opacity and fugitive dust from grain, feed, and seed operations. OAC 252:100-25 limits opacity of smoke, visible emissions, and particulates.

5. Fugitive Dust from Construction Activities

40 C.F.R. §51.308(d)(3)(v)(B) requires Oklahoma to consider measures to mitigate the impacts of construction activities. DEQ relies on fugitive dust control rules in OAC 252:100-29 to control and minimize the air quality effects of blowing dust from construction activities.

C. Ongoing Air Pollution Control Programs

40 C.F.R. §51.308(d)(3)(v)(A) requires DEQ to consider emissions reductions from ongoing pollution-control programs. Because Oklahoma attains all national ambient air quality standards, DEQ has not implemented many ongoing pollution-control programs beyond those required under federal regulations. If circumstances warranted, however, DEQ may consider such programs. Federal rules

include motor vehicle emissions control programs, CAIR, and EPA requirements for cleaner non-road diesel and gasoline-powered engines.

1. Federal Mobile Emissions Reduction Programs

The federal motor vehicle emissions control program sets stringent limits on emissions of NO_x, particulate matter, and VOCs from new on-road motor vehicles. The lower federal limits on sulfur content for gasoline and diesel fuel continue to reduce the sulfur input to internal combustion engines and therefore reduce their total sulfureous emissions. The lower-sulfur fuels also contribute to lower emissions of NO_x, particulate matter, and VOCs for diesel and gasoline on-road motor vehicles and non-road engines. The regulations 40 C.F.R. Parts 80, 81, 86, 89, 90, 92, 94, 1039, and 1048 contain several significant federal programs intended to reduce air pollution emissions.

2. Clean Air Interstate Rule Reductions

On 10 March 2005, EPA issued the Clean Air Interstate Rule (CAIR), requiring reductions in SO_2 and NO_x emissions from electric generating units in 28 states and the District of Columbia (70 FR 25162-25405), including Texas and most states east of Oklahoma. CAIR applies to SO_2 in all covered areas except Arkansas, Delaware, New Jersey, and New England. CAIR will reduce SO_2 emission allowances from applicable states by more than 60 percent below federal acid-rain cap levels for 2003. CAIR states may participate in an EPA-administered cap-and-trade program for electric generating units to meet regulatory requirements. Reductions of SO_2 and NO_x will occur in two phases under a cap-and-trade system that EPA established. Emissions caps for SO_2 will drop in 2010 and again in 2015. Allowable NO_x emission will decrease in 2009 and again in 2015. Oklahoma is not a CAIR state; Electric generating unit allowances that cap annual NO_x emissions do not apply in Oklahoma under CAIR but apply to most emissions affecting the Wichita Mountains.

On 11 July 2008, the United States Court of Appeals for the District of Columbia Circuit issued a decree vacating and remanding the CAIR as a violation of the CAA. After petitions for rehearing, however, the Court on 23 December 2008 conceded per curiam a stay of its decree in lieu of vacatur. The Court did not impose a deadline for EPA to promulgate a replacement rule that addresses the fundamental flaws of the CAIR but emphasized that it did not grant an indefinite stay; EPA pronounced intent to attempt to initiate progress toward preliminary compliance within two years. Expected emissions reductions and limitations from other states depend critically upon CAIR, and DEQ cannot submit this implementation plan revision without relying on these reductions. DEQ anticipates—and any long-term strategy depends upon the assumption—that any replacement rule requires electric generators or other emissions facilities in other states sufficiently to achieve at least as much visibility improvement as CAIR otherwise might achieve. In the time interval between the submittal of this plan revision and promulgation of the replacement rule, any conclusions and strategies involving CAIR will be accurate and effective because CAIR remains in effect until replaced.

3. Consent Decrees

Joint EPA and DEQ refinery consent decrees cover both SO_2 and NO_x. The NO_x reductions generally apply as company-wide requirements. EPA and DEQ provided specific SO_2 and NO_x reductions for each refinery emissions point subject to these consent decrees. Final CENRAP modeling in support of this implementation plan revision accounted for and included these EPA-estimated reductions. These enforceable consent decrees include compliance schedules.

Table VII-1: Consent decree emissions reductions

Facility	County	NO_x (ton/year)	SO2 (ton/year)	PM (ton/year)	Consent decree
Sinclair Oil Corp	Tulsa	760	2,100	0	06-2002-3744
Valero Refining Company	Carter	0	156	412	06-2000-1220
Sunoco Refinery	Tulsa	517	2,242	0	06-2002-3747
Conoco Inc	Kay	1,400	1,124	0	06-2002-3717

4. Maximum Achievable Control Technology

EPA promulgated the reciprocating internal combustion engines regulation in 40 C.F.R. §63.6580 *et seq.* and the turbine maximum achievable control technology (MACT) regulation in 40 C.F.R. §63.6080 *et seq.* Rule changes in July 2006 affected both standards. For subject natural gas-powered turbines, these MACT regulations apply only to new sources. The rule changes did not affect four-cycle rich burn engines. The revised rule applies only to new four- and two-cycle lean burn engines and new compression-ignition engines.

5. Area Sources

On 26 February 1988, EPA promulgated new source performance standard for residential wood combustion in 40 C.F.R. Part 60, Subpart AAA, which contributes to minimizing emissions from residential woodburning. Other new source performance standards may apply to Oklahoma area sources; however, their identity and applicability cannot be ascertained. OAC 252:100-13-7(4), which addresses the burning of forestland, cropland, and rangeland will continue to remain in effect. When finalized, the Oklahoma Smoke Management Plan (currently in draft) will further address area sources resulting from fire.

VIII. Modeling of Regional Haze in 2018

40 C.F.R. § 51.308(d)(3)(v)(G) requires DEQ to consider and address the anticipated net effect on visibility resulting from changes projected in point, area, and mobile source emissions by 2018. These changes will result from population growth, land management evolution, air pollution control, and development of industry, energy and natural resources. In order to assess the effect of these changes, CENRAP developed an estimated emissions inventory for the year 2018. While a full estimated emissions inventory is included as Appendix 8-1, a summary of this inventory is included below in Section A of this chapter. Assumptions made which reflect future control technology for point source emissions are included in section B. For 2018 modeling, 2002 meteorological observations were utilized. Section C contains numerical values for the components of 2018 modeling. Similar to modeling for 2002, modeling for 2018 continues to predict that emissions from Oklahoma do not significantly impact Class I Areas in other states. Table VIII-9~~Table VIII-9~~ supports this conclusion. Table VIII-10~~Table VIII-10~~ attributes anticipated regional haze at the Wichita Mountains to sources in several states and other regions in 2018.

Formatte
Bold, Font

Formatte
Bold, Font

A. Emissions Inventory

CENRAP developed an estimated emissions inventory for 2018. Appendix 4-2 fully documents the methods for this development and includes technical support documents.

To estimate emissions in 2018 from the inventory for 2002, CENRAP used a combination of EPA Economic Growth Analysis System (EGAS 5), EPA mobile emissions factor model (MOBILE 6), EPA off-road emissions factor model (Nonroad), and Integrated Planning Model (IPM) of ICF International for electric generating units. Control strategies expected to take effect before 2018 may offset growth in each emissions category. Table VIII-1~~Table VIII-1~~ summarizes the estimated inventory for 2018. DEQ submits complete emissions estimates for 2018 as Appendix 8-1.

Table VIII-1: Estimate of emissions from Oklahoma sources in 2018 (tons per year)

	SO_2	NH_3	NO_x	Volatile organic compounds	PM_{10}-$PM_{2.5}$	$PM_{2.5}$
Point	106,701	35,215	140,298	125,648	8,935	13,989
Area	12,374	141,532	128,257	400,056	275,844	127,018
Non-road mobile	156	40	25,387	28,489	2,914	292
On-road mobile	545	5,818	39,397	39,281	0	953
Biogenic	0	0	35,909	988,314	0	0
Total	119,776	182,605	369,248	1,581,788	287,693	142,252

CENRAP generated a distinct base-case scenario emissions dataset for 2018. Carolina Environmental Program generated "typical" temporal profiles for 2002 under contract to CENRAP, which used these profiles in all modeling for 2018.

Table VIII-2: Comparison of Oklahoma emissions inventory for 2002 and estimates for 2018 (tons per year)

Year	SO_2	NH_3	NO_x	Volatile organic compounds	PM_{10}-$PM_{2.5}$	$PM_{2.5}$
Inventory for 2002	171,707	137,435	502,656	1,603,591	308,921	148,279
Estimate for 2018	119,776	182,605	369,248	1,581,788	287,693	142,252
Net change	-51,931	+45,170	-133,408	-21,803	-21,228	-6,027
Percent change	-30.2440%	+32.8664%	-26.541%	-1.35964%	-6.8717%	-4.0646%

Table VIII-2~~Table VIII-2~~ illustrates the substantial emissions reductions anticipated from Oklahoma sources.

B. Point Source Emissions for 2018

Under contract to CENRAP, Pechan compiled the growth and control assumptions and factors used to estimate point-source emissions in 2018 from the inventory for 2002. A report in Appendix 4-2, entitled *Development of Growth and Control Inputs for CENRAP 2018 Emissions Draft Technical Support Document* (May 2005), documents this estimation. The control factors for point sources other than EGUs account for MACT standards.

EPA provided control assumptions which CENRAP then applied to the inventory for 2018. Using SMOKE model, CENRAP modeling team applied the agreed growth-and-control factors to the inventory for 2002 to estimate emissions from point sources other than EGUs in 2018. CENRAP modeling did not incorporate the effect of the refinery global settlements until the Base G simulations. These efforts will reduce SO_2 emissions; however, the modeling also anticipates NO_x reductions in Oklahoma, Louisiana, and Minnesota. The technical support document in Appendix 4-2 describes modeling contractor work on the point source inventory for 2018.

1. Maximum Achievable Control Technology

Pechan developed control factors for engines in 2005 based on the reciprocating internal combustion engines regulation in 40 C.F.R. § 63.6580 *et seq.*, applicable to new four- and two-cycle lean-burn engines and to new compression-ignition engines. Subsequent regulatory changes in July 2006 affected this standard. This regulation does not apply to four-cycle rich burn engines, so relevant estimates for 2018 reflect control factors based on the original Pechan estimates. Because the revised regulation applies only to certain classes of new engines, the CENRAP modeling workgroup chose to apply control parameters only to relevant grown emissions.

Pechan also developed control factors for turbines in 2005 based on the MACT regulation in 40 C.F.R. § 63.6080 *et seq.* Subsequent regulatory changes in July 2006 also affected this standard. For natural gas-powered turbines subject to this regulation, the CENRAP modeling workgroup modified assumptions to apply controls to only the grown portion of the emissions estimates, reflecting the applicability of the regulation to new sources only.

2. Electric Generating Unit Projections

ICF International developed the proprietary Integrated Planning Model (IPM 2.1.9) to examine various issues facing the electric power sector. EPA used this model to simulate electric power generation and distribution scenarios based upon least-cost assumptions for future years and to generate estimates of NO_x and SO_2 emissions associated with these scenarios. ICF International conducted a run under contract to the regional planning organizations which specifically addressed emissions reductions through implementation of the acid rain program (Title IV–Phases I and II), NO_x state implementation plan call (63 FR 207 (27 October 98) p. 57356), and numerous state and local regulations. This run also incorporated unit-level updates that electric power company stakeholders provided.

CENRAP used the output from this Integrated Planning Model run to estimate EGU emissions for 2018. Pechan prepared SMOKE inventory data analyzer-formatted version of the file for 2018 for CENRAP. The Pechan report in Appendix 4-2, *Refinement of CENRAP's 2002 Emissions Inventories* (August 31, 2005), gives more information.

3. Presumptive BART

DEQ modified the projected emissions from the Integrated Planning Model for OG&E Sooner and Muskogee electric power plants and AEP/PSO Northeast and Comanche electric power plants to reflect the application of presumptive BART controls.

C. Other Emission Sources

1. Area Source Inventory for 2018

CENRAP member state clean-air agencies provided data which formed the basis for the area source emissions inventory for 2018. Pechan prepared area-source growth-and-control factors, documented in the report in Appendix 4-2 entitled *Development of Growth and Control Inputs for CENRAP 2018 Emissions Draft Technical Support Document* (May 2005). The control factors reflect new source performance standards for residential wood combustion. The modeling team applied the growth-and-control factors for area sources within SMOKE model. The technical support document in Appendix 4-2 describes work on the area-source inventory for 2018. CENRAP held windblown dust from nonagricultural land-use categories and fire emissions constant from 2002 to 2018.

Pechan developed the original growth-and-control factors and applied them to residential wood-stove categories; CENRAP modeling workgroup agreed to modify these factors following guidance from the Office of Air Quality, Planning, and Standards (OAQPS) of EPA.

2. Non-road Mobile Emissions for 2018

CENRAP based the non-road mobile emissions inventory for 2018 on inputs from DEQ and member state clean-air agencies. Pechan prepared factors for growth and control of emissions from locomotives, aircraft, and commercial marine vessels. The control factors accounted for federal standards for commercial marine vessels and locomotives. For the remaining non-road mobile categories, Pechan ran EPA's NONROAD2004 model for 2018. This model accounts for estimated growth in equipment populations and incorporates anticipated effects of most final federal standards, including the Tier 4 compression-ignition engine standards and the exhaust emissions standards for large spark-ignition engines, compression-ignition marine engines, and land-based recreational engines. The following report referenced in Appendix 4-2 describes methods of Pechan in detail: *Development of Growth and Control Inputs for CENRAP 2018 Emissions Draft Technical Support Document* (May 2005).

3. On-road Mobile Source Emissions for 2018

DEQ and CENRAP developed the on-road mobile source emissions inventory for 2018 with contractor support. Pechan prepared and provided the vehicle-miles-traveled growth factors and MOBILE6 input files in SMOKE format for the on-road mobile-source emissions inventory for 2018. For each county or group of counties modeled, Pechan prepared one MOBILE6 file representing July conditions and another such file representing January conditions. The following report referenced in Appendix 4-2 describes methods of Pechan in detail: *Development of Growth and Control Inputs for CENRAP 2018 Emissions Draft Technical Support Document* (May 2005). Modeling contractors ran the MOBILE6 model within SMOKE framework to prepare input files for the remaining months of 2018 and to process the on-road mobile emissions for the entire year. SMOKE applies the vehicle-miles-traveled growth factors. MOBILE6 accounts for federal motor vehicle controls, including light-duty spark-ignition engine standards, low-sulfur gasoline and diesel fuel, heavy-duty compression-ignition engine standards, and other components of the programs. The technical support document in Appendix 4-2 describes the on-road mobile emissions inventory processing conducted by CENRAP contractors.

4. Biogenic Emissions

CENRAP held biogenic emissions constant from 2002 to 2018.

D. Meteorological and Air-quality Simulations for 2018

CENRAP modeling uses the same meteorological fields for 2002 and 2018. The future-year modeling for 2018 employs the same options as that for 2002 with only the inventories changed.

E. Discussion of Components

The tables in this chapter show model-projected contributions of various areas and pollutants to visibility impairment at the Wichita Mountains on the worst quintile days in 2018. The projections shown in the tables use modeling results scaled to measured pollutant concentrations according to EPA guidelines. These tables present modeled estimates of the relative response of concentrations of components of particulate matter to anticipated changes in emissions.

1. Sulfureous Particulate

CENRAP modeling suggests that CAIR and other promulgated efforts to reduce sulfur emissions from other states will reduce visibility impairment from sulfureous particulate at the Wichita Mountains. These programs should reduce contributions from distant eastern states drastically.

Table VIII-3: Sulfureous Sources of Light Extinction at Wichita Mountains (Worst Quintile Days)

All values in Mm^{-1}	Model Projection (2018)						Projected reduction (2002 to 2018) (negative reduction indicates an increase)					
	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	9.68	7.83	1.73	.08	.04	.00	4.30	3.73	.12	.20	.25	.00
East	2.67	2.27	.37	.01	.01	.00	4.82	4.63	.03	.08	.09	.00
boundary conditions	3.77						.16					
Louisiana	2.77	2.16	.56	.05	.00	.00	-.17	-.23	-.01	.04	.03	.00
Indiana	.86	.78	.07	.00	.00	.00	1.55	1.51	.02	.01	.01	.00
Mexico	1.72	1.61	.09	.01	.00	.00	.07	.06	.00	.00	.01	.00
Oklahoma	**1.58**	**1.23**	**.33**	**.01**	**.01**	**.00**	**.19**	**.05**	**.00**	**.06**	**.08**	**.00**
Canada	1.39	1.28	.08	.02	.00	.00	.23	.21	.00	.00	.01	.00
Ohio	.45	.41	.03	.01	.00	.00	1.17	1.13	.00	.02	.02	.00
Illinois	.78	.74	.03	.00	.00	.00	.77	.73	.00	.03	.01	.00
Kentucky	.63	.54	.07	.01	.00	.00	.73	.69	.01	.01	.01	.00
Alabama	.47	.37	.09	.01	.00	.00	.83	.79	.02	.01	.01	.00
Tennessee	.65	.56	.07	.01	.00	.00	.64	.60	.01	.02	.02	.00
Missouri	1.15	1.00	.14	.00	.00	.00	-.02	-.05	.00	.02	.02	.00
Arkansas	1.04	.82	.21	.01	.00	.01	-.01	-.08	.00	.04	.03	.00
Kansas	.63	.46	.17	.00	.00	.00	.29	.25	-.01	.04	.02	.00
Iowa	.49	.48	.01	.00	.00	.00	-.03	-.06	.00	.02	.01	.00
Michigan	.38	.35	.02	.01	.00	.00	.05	.02	.00	.01	.01	.00
West	.33	.28	.03	.00	.00	.02	.04	.00	.00	.02	.01	.00
Mississippi	.19	.16	.01	.02	.00	.00	.13	.10	.00	.02	.01	.00
Nebraska	.25	.21	.04	.00	.00	.00	.06	.04	-.01	.03	.01	.00
Minnesota	.31	.27	.04	.00	.00	.00	-.01	-.03	.00	.01	.00	.00
Wisconsin	.21	.20	.01	.00	.00	.00	.05	.04	.00	.01	.00	.00
North Dakota	.23	.22	.01	.00	.00	.00	.00	-.01	.00	.01	.00	.00
Wyoming	.21	.18	.02	.00	.00	.00	-.02	-.03	-.01	.01	.00	.00
all other	.50	.23	.27	.00	.00	.00	-.01	.05	-.09	.02	.00	.00
total	**33.33**	**24.64**	**4.51**	**.28**	**.10**	**.04**	**15.79**	**14.12**	**.08**	**.72**	**.69**	**.02**

A large majority of sulfureous particulate will still come from point sources. Federal motor vehicle and gasoline regulations should drastically reduce the contribution to sulfureous particulate from on- and non-road mobile sources.

2. Nitrate Particulate

Planned programs should reduce visibility impairment attributable to American anthropogenic nitrate emissions by two-sevenths. These programs also should reduce emissions from Oklahoma sources. These programs aim to reduce nitrate particulate primarily from on- and non-road mobile sources.

Table VIII-4: Projected nitrate sources of light extinction at Wichita Mountains (worst quintile days)

All values in Mm^{-1}	Model Projection (2018)						Projected reduction (2002 to 2018) (negative reduction indicates an increase)					
	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	6.08	2.17	1.02	.85	.71	1.33	1.81	-.19	-.06	.12	2.03	-.09
Oklahoma	**4.99**	**1.52**	**1.82**	**.34**	**.49**	**.83**	**1.44**	**.28**	**-.27**	**.27**	**1.20**	**-.05**
Kansas	1.36	.56	.27	.20	.16	.16	.58	.10	-.03	.21	.30	-.01
Missouri	.71	.30	.09	.10	.14	.07	.35	.08	-.01	.05	.22	.00
boundary conditions	1.03						-.16					
Nebraska	.42	.17	.06	.10	.05	.04	.21	-.01	-.01	.09	.13	.00
Canada	.46	.17	.14	.12	.00	.02	.12	-.03	.00	.00	.15	.00
Iowa	.39	.20	.02	.06	.07	.04	.18	.02	.00	.04	.13	.00
Arkansas	.30	.12	.06	.04	.06	.02	.19	.02	.00	.04	.13	.00
Illinois	.22	.10	.02	.06	.03	.01	.20	.10	.00	.03	.08	.00
Mexico	.30	.21	.02	.01	.00	.07	.07	.03	.00	.00	.03	.00
Minnesota	.22	.11	.03	.03	.03	.01	.09	.01	-.01	.02	.07	.00
Louisiana	.30	.14	.08	.04	.03	.01	.00	-.02	-.03	-.01	.05	.00
West	.22	.08	.04	.04	.04	.02	.07	-.01	-.02	.02	.07	.00
New Mexico	.23	.06	.09	.03	.02	.03	.06	.02	-.03	.02	.04	.00
Colorado	.16	.07	.03	.02	.03	.01	.09	.01	-.01	.01	.07	.00
Wyoming	.14	.07	.04	.03	.00	.00	.02	.02	-.02	.01	.01	.00
East	.07	.03	.01	.01	.01	.01	.08	.03	.00	.01	.04	.00
North Dakota	.12	.07	.02	.02	.01	.01	.02	.00	.00	.01	.02	.00
South Dakota	.08	.01	.01	.02	.01	.03	.04	-.01	.00	.01	.04	.00
all other	.30	.09	.08	.06	.02	.00	.19	.11	-.04	.01	.10	.00
total	18.10	6.25	3.96	2.18	1.92	2.76	5.62	.54	-.55	.98	4.95	-.15

Beyond the nitrate emissions reductions modeled, additional controls at point and area sources may result from ozone-reduction programs not yet conceived.

3. Organic Carbonaceous Particulate

Modeling for 2018 suggests a slight reduction in organic carbonaceous particulate at the Wichita Mountains; however, much of the particulate probably results from such natural sources as trees and fires.

Table VIII-5: Organic carbonaceous sources of light extinction at Wichita Mountains (worst quintile days)

All values in Mm^{-1}	Model projection (2018)						Projected reduction (2002 to 2018)					
	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	2.57	.49	1.74	.26	.05	.02	.48	-.15	.63	-.07	.07	.01
boundary conditions	3.55						.06					
secondary biogenic	2.84						.06					
secondary anthropogenic	2.22						.35					
Oklahoma	**2.10**	**.18**	**1.64**	**.14**	**.02**	**.11**	**.17**	**-.05**	**.11**	**.05**	**.06**	**.01**
Missouri	.17	.01	.12	.04	.00	.00	.02	.00	.01	.01	.00	.00
Kansas	.56	.06	.48	.01	.00	.01	.01	-.01	.01	.01	.00	.00
Louisiana	.45	.21	.17	.03	.00	.03	-.03	-.04	.00	.00	.01	.00
East	.31	.05	.23	.02	.00	.01	.03	-.01	.02	.01	.01	.00
Arkansas	.27	.04	.12	.02	.00	.09	.04	-.01	.00	.01	.01	.04
West	.18	.00	.04	.01	.01	.13	.01	.00	.00	.00	.00	.01
Minnesota	.07	.01	.04	.00	.00	.02	.04	.00	.00	.00	.00	.03
Mississippi	.10	.02	.06	.01	.00	.01	.00	-.01	.00	.00	.00	.00
Canada	.09	.01	.04	.01	.00	.03	.00	.00	.00	.00	.00	.00
Nebraska	.07	.02	.04	.01	.00	.00	.01	-.01	.00	.01	.00	.00
all other	.43	.08	.26	.01	.00	.00	.03	.00	.00	.00	.00	.01
total	**15.98**	**1.19**	**4.99**	**.61**	**.11**	**.47**	**1.30**	**-.33**	**.79**	**.04**	**.19**	**.13**

A detailed field study may identify the particular chemical mixture of gaseous and particulate organic compounds in the atmosphere near the Wichita Mountains, locate their sources and sinks, and improve understanding of their chemistry. Such study would provide data necessary before Texas Commission on Environmental Quality or DEQ could devise an effective strategy to reduce anthropogenic emissions.

4. Elemental Carbonaceous Particulate

Modeling indicates a sizable reduction in elemental carbonaceous particulate reaching the Wichita Mountains by 2018.

Table VIII-6: Elemental carbonaceous sources of light extinction at Wichita Mountains (worst quintile days)

All values in Mm^{-1}	Model projection (2018)						Projected reduction (2002 to 2018)					
	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	.68	.03	.44	.15	.05	.00	.74	-.01	.39	.21	.15	.00
Oklahoma	**.72**	**.01**	**.52**	**.14**	**.02**	**.03**	**.36**	**.03**	**.04**	**.18**	**.11**	**.00**
boundary conditions	.69						.00					
Kansas	.26	.00	.22	.02	.00	.00	.04	.00	.00	.03	.01	.00
Louisiana	.12	.01	.08	.02	.00	.01	.02	.00	.00	.01	.01	.00
East	.08	.01	.04	.03	.00	.00	.05	.00	.01	.02	.02	.00
Arkansas	.08	.01	.03	.02	.00	.02	.04	.00	.00	.02	.02	.01
West	.05	.00	.01	.01	.01	.03	.02	.00	.00	.01	.01	.00
Missouri	.04	.00	.03	.01	.00	.00	.02	.00	.00	.01	.01	.00
all other	.27	.00	.07	.17	.00	.02	.16	.00	.00	.12	.02	.01
total	**3.00**	**.09**	**1.45**	**.55**	**.11**	**.11**	**1.47**	**.01**	**.44**	**.59**	**.40**	**.03**

5. Fine Soil Particulate

Because fine soil particulate originates mostly from natural sources and blowing dust, DEQ cannot predict its prevalence in 2018; however, Table VIII-7~~Table VIII-7~~ presents the modeling results.

Table VIII-7: Fine soil sources of light extinction at Wichita Mountains (worst quintile days)

All values in Mm^{-1}	Model projection (2018)						Projected reduction (2002 to 2018)					
	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Texas	.30	.03	.21	.00	.00	.05	.00	-.01	.01	.00	.00	.00
Oklahoma	**.24**	**.01**	**.23**	**.00**	**.00**	**.01**	**.01**	**.00**	**.02**	**.00**	**.00**	**.00**
all other	.22	.01	.17	.00	.00	.00	-.01	-.02	.00	.00	.00	.00
total	**.79**	**.08**	**.62**	**.00**	**.00**	**.07**	**.00**	**-.03**	**.03**	**.00**	**.00**	**.00**

6. Coarse Particulate

Most coarse particulate matter observed at the Wichita Mountains originates from natural sources and blowing sand, so DEQ anticipates little change in light extinction from coarse matter in the future.

Table VIII-8: Coarse particulate sources of light extinction at the Wichita Mountains (worst quintile days)

All values in Mm^{-1}	Model projection (2018)						Projected reduction (2002 to 2018)					
	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic	Sum	Point	Area	Non-road mobile	On-road mobile	Biogenic
Oklahoma	**.72**	**.02**	**2.45**	**.00**	**.00**	**.17**	**.27**	**.00**	**.27**	**.00**	**.00**	**.00**
Texas	.68	.03	1.12	.00	.00	.34	.02	.00	.03	.00	.00	.00
all other	1.60	.01	.33	.00	.00	.03	.00	.00	.00	.00	.00	.00
total	**4.30**	**.05**	**3.70**	**.00**	**.01**	**.53**	**.29**	**-.01**	**.30**	**.00**	**.00**	**.00**

7. Chlorine Particulate and Rayleigh Scatter

CENRAP modeling assumed no change in chlorine particulate concentration between 2002 and 2018. Because DEQ does not anticipate significant changes in atmospheric structure or density, this implementation plan revision assumes constant Rayleigh scattering, reducing visibility with an additive extinction coefficient around 11 Mm^{-1}.

F. Long-term Strategy for Other Class I Areas

The analysis of model output presented in Table VIII-9~~Table VIII-9~~ demonstrates that Oklahoma emissions will impair visibility only insignificantly at all Class I areas in other states. DEQ consequently need not undertake any emission reduction action to protect other Class I areas.

Table VIII-9: Projected influence of emissions from Oklahoma on Class I areas (worst quintile days, 2018)

Class I area	State	Contribution to light extinction (Mm^{-1})	Total light extinction (Mm^{-1})	Oklahoma contribution (%)	Deciview contribution	Reduction in Oklahoma contribution from 2002 (Mm^{-1})
Wichita Mountains	**Oklahoma**	**12.28**	**86.56**	**14.19%**	**1.53**	**2.43**
Hercules-Glades	Missouri	3.74	103.49	3.61%	.37	1.10
Salt Creek	New Mexico	1.46	57.67	2.53%	.26	.25
Guadalupe Mountains	Texas	1.11	55.43	2.00%	.20	.07
Seney	Michigan	1.74	95.27	1.83%	.18	.36
Caney Creek	Arkansas	2.23	96.84	2.30%	.23	.38
White Mountain	New Mexico	.69	40.80	1.70%	.17	.06
Upper Buffalo	Arkansas	1.97	97.16	2.03%	.21	.45
Isle Royale	Michigan	1.08	73.71	1.46%	.15	.09
Badlands	South Dakota	.60	52.20	1.14%	.11	.12
Wind Cave	South Dakota	.52	48.16	1.08%	.11	.13
Big Bend	Texas	.60	55.23	1.08%	.11	.08
Wheeler Peak	New Mexico	.29	31.80	.92%	.09	.04
Breton	Louisiana	.99	105.06	.94%	.09	.35
Mingo	Missouri	1.22	110.24	1.11%	.11	.40
Bosque del Apache	New Mexico	.33	40.13	.82%	.08	.03
Great Sand Dunes	Colorado	.27	37.77	.71%	.07	.05
San Pedro Parks	New Mexico	.22	31.21	.70%	.07	.02
Rocky Mountain	Colorado	.25	40.41	.63%	.06	.04
Boundary Waters Canoe Area	Minnesota	.38	64.32	.59%	.06	.10
Voyageurs	Minnesota	.26	63.10	.41%	.04	.08
Bandelier	New Mexico	.17	40.25	.41%	.04	.01
Everglades	Florida	.32	87.23	.36%	.04	.06
Galiuro	Arizona	.12	39.75	.30%	.03	.01
Chassahowitzka	Florida	.39	91.00	.43%	.04	.01
Wolf Island	Georgia	.45	112.84	.40%	.04	-.00
Theodore Roosevelt	North Dakota	.15	57.80	.25%	.03	.03
UL Bend	Montana	.09	45.16	.21%	.02	.02
Mammoth Cave	Kentucky	.41	134.80	.30%	.03	.11
Lye Brook	Vermont	.24	86.33	.28%	.03	.05
Presidential Range-Dry River	New Hampshire	.17	76.10	.23%	.02	.05
Saint Marks	Florida	.21	94.24	.23%	.02	.06
Roosevelt Campobello	Maine	.15	67.68	.22%	.02	.02
Rawah	Colorado	.05	32.71	.14%	.01	.01
Cape Romain	South Carolina	.20	101.82	.19%	.02	.03
Cohutta	Georgia	.22	112.69	.20%	.02	.10

Class I area	State	Contribution to light extinction (Mm^{-1})	Total light extinction (Mm^{-1})	Oklahoma contribution (%)	Deciview contribution	Reduction in Oklahoma contribution from 2002 (Mm^{-1})
Acadia	Maine	.12	70.17	.17%	.02	.03
Swanquarter	North Carolina	.13	77.53	.16%	.02	.04
Brigantine	New Jersey	.20	122.69	.16%	.02	.02
Pine Mountain	Arizona	.04	39.96	.10%	.01	.01
Sipsey	Alabama	.16	114.75	.14%	.01	.06
Saguaro	Arizona	.05	42.92	.11%	.01	.01
Lostwood	North Dakota	.07	69.15	.10%	.01	.01
Shining Rock	North Carolina	.15	96.10	.16%	.02	.03
Medicine Lake	Montana	.05	57.81	.08%	.01	.01
James River Face	Virginia	.12	100.27	.12%	.01	.05
West Elk	Colorado	.02	29.75	.08%	.01	.00
Joyce Kilmer-Slickrock	North Carolina	.13	104.67	.12%	.01	.04
Linville Gorge	North Carolina	.09	90.25	.10%	.01	.04
Shenandoah	Virginia	.09	95.58	.09%	.01	.04
Otter Creek	West Virginia	.09	99.34	.09%	.01	.02
Petrified Forest	Arizona	.02	41.56	.05%	.01	.00
Weminuche	Colorado	.02	30.59	.05%	.01	.00
Gila	New Mexico	.02	39.79	.05%	.00	.00
Washakie	Wyoming	.02	33.76	.05%	.00	.00

G. Long-term Strategy Interpretation for Wichita Mountains

Table VIII-10~~Table VIII-10~~ illustrates modeled results of the combined long-term regional haze strategies of several states. At the Wichita Mountains, visibility impairment should decrease significantly.

Table VIII-10: Projected sources of light extinction at Wichita Mountains (worst quintile days)

	Model projection, 2018							Projected reduction, 2002 to 2018						
All values in Mm^{-1}	**Sum**	**Sulfureous**	**Nitrate**	**Organic carbonaceous**	**Elemental carbonaceous**	**Soils**	**Coarse**	**Sum**	**Sulfureous**	**Nitrate**	**Organic carbonaceous**	**Elemental carbonaceous**	**Soils**	**Coarse**
Texas	20.79	9.68	6.08	2.57	.68	.30	1.49	7.36	4.30	1.81	.48	.74	.00	.02
Oklahoma	**12.28**	**1.58**	**4.99**	**2.10**	**.72**	**.24**	**2.65**	**2.43**	**.19**	**1.44**	**.17**	**.36**	**.01**	**.27**
Rayleigh scattering	11.00							.00						
boundary conditions	9.11	3.77	1.03	3.55	.69	.02	.05	.06	.16	-.16	.06	.00	.00	.00
East	3.15	2.67	.07	.31	.08	.01	.00	4.97	4.82	.08	.03	.05	.00	.00
Kansas	2.90	.63	1.36	.56	.26	.05	.05	.92	.29	.58	.01	.04	.00	.00
Louisiana	3.65	2.77	.30	.45	.12	.01	.00	-.18	-.17	.00	-.03	.02	.00	.00
secondary biogenic	2.84			2.84				.06			.06			
secondary anthropogenic	2.22			2.22				.35			.35			
Indiana	.92	.86	.02	.02	.01	.00	.00	1.61	1.55	.05	.00	.01	.00	.00
Missouri	2.10	1.15	.71	.17	.04	.02	.01	.37	-.02	.35	.02	.02	.00	.00
Canada	2.00	1.39	.46	.09	.05	.01	.00	.36	.23	.12	.00	.00	.00	.00
Mexico	2.10	1.72	.30	.04	.02	.01	.02	.15	.07	.07	.00	.00	.00	.00
Illinois	1.06	.78	.22	.04	.02	.00	.00	.99	.77	.20	.00	.02	.00	.00
Arkansas	1.71	1.04	.30	.27	.08	.01	.01	.26	-.01	.19	.04	.04	.00	.00
Ohio	.49	.45	.01	.02	.01	.00	.00	1.19	1.17	.01	.00	.01	.00	.00
Tennessee	.79	.65	.05	.07	.02	.00	.00	.72	.64	.07	.00	.01	.00	.00
Kentucky	.70	.63	.03	.03	.01	.00	.00	.76	.73	.03	.00	.01	.00	.00
Alabama	.55	.47	.01	.05	.01	.00	.00	.86	.83	.01	.01	.01	.00	.00
Iowa	.99	.49	.39	.05	.02	.03	.01	.17	-.03	.18	.01	.01	.00	.00
Nebraska	.81	.25	.42	.07	.02	.02	.02	.30	.06	.21	.01	.02	.00	.00
West	.80	.33	.22	.18	.05	.01	.01	.13	.04	.07	.01	.02	.00	.00
Minnesota	.64	.31	.22	.07	.02	.01	.00	.14	-.01	.09	.04	.02	.00	.00
Mississippi	.36	.19	.04	.10	.02	.00	.00	.16	.13	.02	.00	.01	.00	.00
Michigan	.40	.38	.01	.01	.00	.00	.00	.06	.05	.01	.00	.00	.00	.00
New Mexico	.39	.13	.23	.01	.00	.00	.01	.07	.00	.06	.01	.00	.00	.00
Colorado	.31	.11	.16	.02	.01	.00	.00	.14	.05	.09	.00	.01	.00	.00
North Dakota	.38	.23	.12	.01	.01	.00	.00	.03	.00	.02	.00	.01	.00	.00
Wyoming	.80	.33	.22	.18	.05	.01	.01	-.44	-.15	-.06	-.18	-.04	-.01	.00
Wisconsin	.80	.33	.22	.18	.05	.01	.01	-.47	-.08	-.17	-.16	-.04	-.01	-.01
South Dakota	.16	.04	.08	.02	.01	.01	.01	.06	.01	.04	.00	.01	.00	.00
Gulf of Mexico	.33	.22	.10	.00	.00	.00	.00	-.11	-.07	-.04	.00	.00	.00	.00
initial conditions	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
total	**87.54**	**33.58**	**18.38**	**16.33**	**3.09**	**.80**	**4.36**	**23.49**	**15.54**	**5.34**	**.96**	**1.38**	**-.01**	**.28**

IX. Reasonable Progress Goal

The federal regional haze regulation aims to achieve the national goal of natural visibility at the Wichita Mountains and other Class I areas by 2064. This regulation requires DEQ to show reasonable progress toward this goal by 2018 and to set a specific goal for visibility improvement at the Wichita Mountains. Unfortunately, this goal falls short of the uniform rate of progress toward achieving natural visibility in 2064. Section A of this chapter depicts the reasonable progress goal in table and graph form, comparing it to the uniform rate of progress. The reasonable progress goal for 2018 is calculated at 9.23 deciviews for the best quintile days. Linear extrapolation of the deciview glide path for the reasonable progress goal suggests natural conditions will be met circa 2102. Section B discusses CAIR and associated uncertainties. Reductions required to meet the uniform rate of progress are shown in section C; here it is important to note that even the elimination of all anthropogenic sources within Oklahoma is not sufficient to comply with uniform rate of progress. Section D details control simulations; sources eligible for additional emission controls are identified and visibility projections are given for 2018 taking into consideration these expected emissions reductions. These simulations further confirm that the uniform rate of progress cannot be met for the Wichita Mountains. Additional factors taken under consideration in reaching this conclusion are discussed in section E; such factors include source retirement and replacement schedules, basis for emissions reductions obligations, and other statutory factors. The reasonableness of controls and weight of evidence are discussed in sections F and G, respectively.

A. Reasonable Progress Goal for the Wichita Mountains

DEQ considers the visibility improvement by 2018 at the Wichita Mountains shown in Tables IX-1 and Figure IX-1 reasonable and intends to achieve this goal. This reasonable progress goal derives from the CENRAP modeling with estimated emissions for 2018. It reflects visibility improvement resulting from emissions reduction programs associated with the federal CAA and Oklahoma CAA, including long-term strategies of Oklahoma, Texas, and other states and presumptive emissions reductions from the Oklahoma BART rule. The emissions reductions included in this implementation plan revision demonstrably will reduce emissions from Oklahoma sources sufficiently to attain the reasonable progress goal at the Wichita Mountains in conformity with 40 C.F.R. § 51.308(d)(3)(ii).

1. Worst Quintile Days

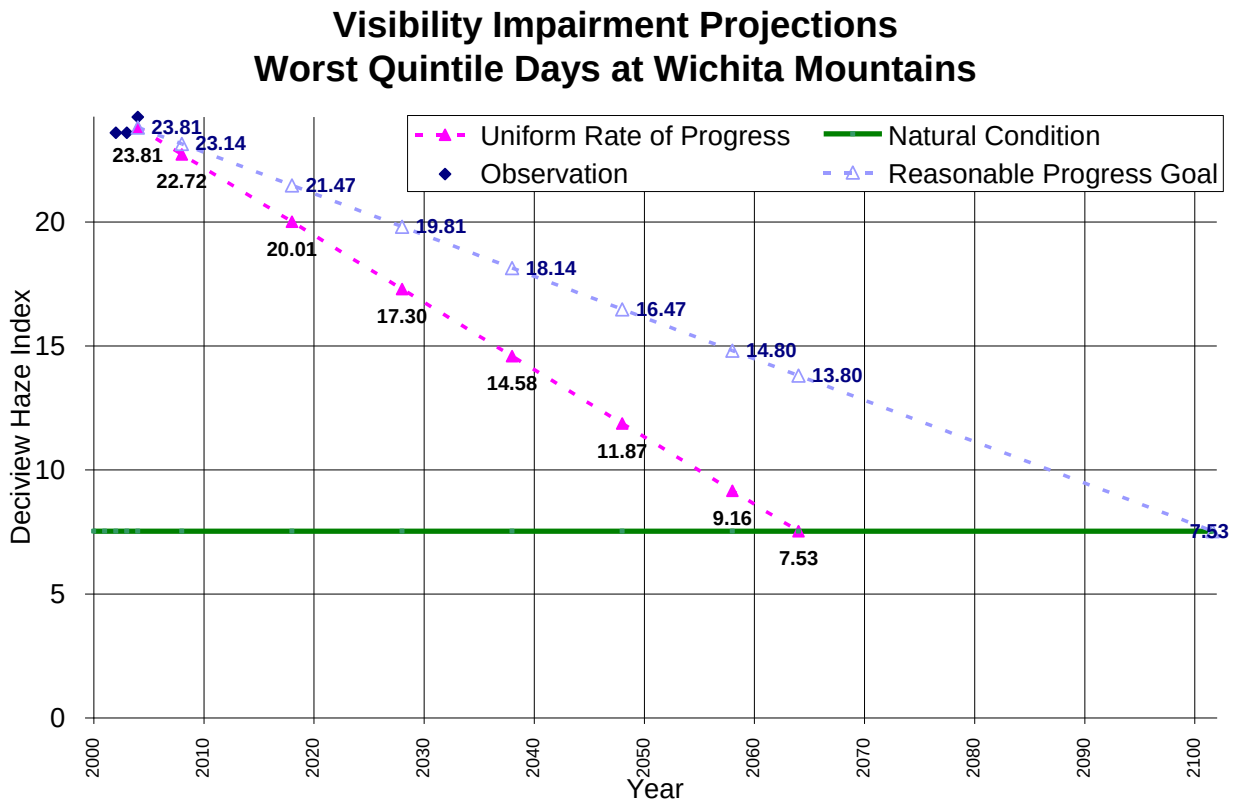
Table IX-1 compares the reasonable progress goal for the worst quintile days at the Wichita Mountains to the corresponding uniform rate of progress.

Table IX-1: Reasonable progress goal for visibility at the Wichita Mountains (worst quintile days)

Change by 2018 (reasonable progress goal)	-22.52 Mm^{-1}	- 2.33 deciviews
Change by 2018 at uniform rate of progress	-34.18 Mm^{-1}	- 3.80 deciviews
Projected rate of change (2004-2018)		- .17 deciviews/year
Change needed to reach natural conditions	-86.91 Mm^{-1}	-16.28 deciviews
Change by 2064 extrapolated from reasonable progress goal	-68.38 Mm^{-1}	-10.01 deciviews
Visibility in 2064 from extrapolated reasonable progress goal	+39.76 Mm^{-1}	+13.80 deciviews
Extrapolated from reasonable progress goal for 2102 (natural conditions)	+21.23 Mm^{-1}	+ 7.53 deciviews

Figure IX-1 graphically compares the reasonable progress goal to the uniform rate of progress glide path for the worst quintile days at the Wichita Mountains. It uses the default (western) natural conditions estimate. Natural conditions did not factor into setting the reasonable progress goal; however, extrapolation thereof suggests attaining natural conditions circa 2102. If natural conditions account for a greater proportion of presently observed visibility impairment, then extrapolation of this reasonable progress goal suggests achieving natural visibility conditions circa 2064. *See* Chapter III.

Figure IX-1: Glide path and Reasonable Progress Goal at the Wichita Mountains (worst quintile days)



The reasonable progress goal excludes the substantial anticipated effects of the installation of BART at three natural-gas-fired electric power generation facilities in Caddo, Comanche, and Seminole Counties. CENRAP modeling of regional haze for 2018 did not include or quantify these emissions reductions.

2. Best Quintile Days

Table IX-2 provides the reasonable progress goal for the best quintile of days at the Wichita Mountains.

Table IX-2: Reasonable progress at the Wichita Mountains (best quintile days)

Baseline visibility	26.58 Mm^{-1}	9.78 deciviews
Projected 2018 visibility (reasonable progress goal)	25.17 Mm^{-1}	9.23 deciviews
Improvement by 2018 (reasonable progress goal)	1.41 Mm^{-1}	.54 deciviews

CENRAP modeling for 2018 suggests compliance with the regulatory requirement in 40 C.F.R. § 51.308(d)(1) ensuring no degradation in visibility on the best quintile days at the Wichita Mountains.

3. Uncertainty Related to Clean Air Interstate Rule

CAIR presumably provides the majority of the emissions reductions underlying the predicted visibility improvements. CAIR allows trading of SO_2 and NO_x emissions allowances among electric generating units, leaving uncertainty regarding improvement in visibility at the Wichita Mountains. The program is expected to reduce visibility-impairing emissions across Texas and most eastern states. Because of its relatively low emissions compared to those from most industrial eastern states, EPA exempted Oklahoma from participation in the reductions. Texas contributes more to visibility impairment at the Wichita Mountains than Oklahoma or any other state does. Uncertainty in the geographical location of emissions reductions within the CAIR region contributes to uncertainty in estimated visibility in 2018. The temporary legal status of and likely replacement regulation for CAIR further compound this uncertainty; however, any substantial improvement in visibility at the Wichita Mountains depends critically upon large emissions reductions in the affected region.

B. Reductions Required to Meet the Uniform Rate of Progress

Ongoing programs alone cannot suffice to meet the uniform rate of progress at the Wichita Mountains. The model-extracted data in Table IX-3 suggest that even complete elimination of all anthropogenic emissions in Oklahoma likely would fail to meet this uniform rate of progress.

Table IX-3: Emissions reductions required to meet uniform rate of progress at the Wichita Mountains (worst quintile days)

Improvement projected by 2018 using reasonable progress goal	22.52 Mm^{-1}	2.33 deciviews
Improvement by 2018 at uniform rate of progress	34.18 Mm^{-1}	3.80 deciviews
Unreasonable improvement needed to meet uniform rate	11.66 Mm^{-1}	1.46 deciviews
Contribution from non-biogenic source categories in Oklahoma (modeled for 2018)	11.13 Mm^{-1}	
Contribution from biogenic sources in Oklahoma (modeled for 2018)	1.15 Mm^{-1}	

Unreasonable reductions imply severe control of Oklahoma sources to compensate for the influence of pollution from other states. The vast majority of visibility impairment at the Wichita Mountains comes from sources beyond the borders of the State of Oklahoma. The federal regional haze rule in 40 C.F.R. § 51.308(d)(3)(ii) does not require DEQ to compensate for the lack of control of emissions in Texas, other states, and foreign countries. Table IX-3 also reinforces that progress at the Wichita Mountains depends on reducing emissions from Texas and elsewhere. Given the significant contribution of emissions from Texas and other areas outside DEQ jurisdiction, the uncertainty in the effect of CAIR, and the economic and energy cost of additional point-source controls, DEQ finds additional controls for regional haze inappropriate and unreasonable.

C. Control Simulations

CENRAP conducted a control-sensitivity evaluation of the effect of reducing point-source emissions of NO_x and SO_2 only with existing emissions-control technology. CENRAP limited this evaluation to control technologies estimated to cost less than $5,000 per ton of emissions reduced.

CENRAP thereby intended to generate information on the effect of possible strategies in support of the consultation process. CENRAP did not design this modeling to prescribe control strategies but only to inform possible discussions that certainly would require much greater refinement of control options. CENRAP grouped the strategies together under a common set of criteria; DEQ and other members did not identify specific strategies.

1. Identification of Point Sources for Control Evaluation

CENRAP contracted with Alpine Geophysics to provide an evaluation of possible additional controls for the point-source inventory from member states for 2018. These controls would add to the long-term strategy of emissions reductions assumed in the scenario already modeled for 2018 and used to set the reasonable progress goal for the Wichita Mountains. The study overlaid a detailed EPA control-measure database on CENRAP emissions inventories to compute source- and pollutant-specific emissions reductions and associated costs at various geographic levels.

This CENRAP study used the latest revised version of AirControlNet, a database tool which EPA released in 2006 to enable cost-benefit analyses of potential emissions-control measures and strategies. AirControlNet estimates the cost per ton of emissions of NO_x and SO_2 reduced, based on new construction. The contractor enhanced Base F inventory files for 2018 with additional information on base-level controls and then linked these enhanced files with potential strategies from AirControlNet. CENRAP used AirControlNet to estimate cost per ton of emissions of the relevant pollutants reduced with potential add-on devices to control appropriate emissions generating units.

Alpine extrapolated cost estimates for NO_x and SO_2 emissions reductions in 2005 dollars for point sources. CENRAP evaluated various control levels in terms of cost per mass of emissions reductions and chose to base its sensitivity analysis on a maximum estimated cost of $5,000 per ton of emissions of NO_x or SO_2 reduced. CENRAP made this threshold with the understanding that this process underestimates the true cost of retrofit controls and does not consider recent market fluctuations in cost of control equipment and construction.

This control strategy analysis also excluded every source predicted to emit less than 100 tons of SO_2 and less than 100 tons of NO_x in the year 2018. The imperceptibly minute visibility benefit does not justify the regulatory and logistical overhead associated with more aggressively controlling these small sources.

Iowa Department of Natural Resources and Kansas Department of Health and Environment staff added area-of-influence data and distance calculations to each Class I area in every CENRAP member state. CENRAP refined the selection further, considering controls only to those sources with emissions of NO_x or SO_2 greater than or equal to five tons per year per kilometer of distance to the Wichita Mountains or the nearest other Class I area. This distance-weighting criterion limited the sensitivity evaluation to sources with the greatest likely influence on visibility. CENRAP did not consider additional controls outside the borders of its member states in this evaluation.

2. Control Sensitivity Results

Table IX-4 presents visibility projections for 2018 based on the CMAQ control-sensitivity simulations for Base G. This control scenario would reduce mainly SO_2 and NO_x emissions from point sources in the CENRAP member states, consequently limiting visibility improvements mainly to reductions in sulfureous and nitrate aerosols.

Table IX-4: Visibility at Wichita Mountains under control scenario (worst quintile days)

Observed visibility in 2002-2004	108.15 Mm^{-1}	23.81 deciviews
Visibility projected by 2018 using reasonable progress goal	85.63 Mm^{-1}	21.47 deciviews
Visibility by 2018 at uniform rate of progress	73.97 Mm^{-1}	20.01 deciviews
Visibility projected by 2018 under control scenario	**81.40 Mm^{-1}**	**20.97 deciviews**

The modeling projects that this control scenario would reduce visibility impairment only slightly on the worst quintile days compared to the reasonable progress goal. Even if all CENRAP member states compelled sources to install and use controls as effectively as this scenario envisions, then the Wichita Mountains still would fall significantly short of meeting the uniform rate of progress glide path for the worst quintile days in 2018. This preliminary scenario moreover includes at least some already implemented, prohibitively costly, technically unfeasible, or otherwise unreasonable controls. Most sources under consideration for control in this scenario lie in Texas or other states outside the territorial jurisdiction of DEQ.

3. Further Refinement of Sources to Control

DEQ used this CENRAP control model to start its own analysis of additional controls. DEQ reviewed cost information from CENRAP and made changes based on knowledge of the particular facilities and experience with implementing ozone limitation strategies. This additional analysis focused on moderate-cost controls for sources likely to contribute to visibility impairment at the Wichita Mountains. DEQ already considered most of these sources under the BART review process, refinery consent decrees, or other controls included in the reasonable progress goal. DEQ considers further emissions reductions from such sources currently unreasonable.

Eliminating exorbitantly costly controls and sources already subject to reasonable controls left very few existing sources in Oklahoma among the set still under consideration. The cost of retrofit controls at these few sources likely would prove unreasonably high.

Table IX-5: Sources considered for (additional) controls under Reasonable Progress Goals

Company	County	Industrial classification	Possible Control Equipment	Disposition for this implementation plan revision
Public Service Company of Oklahoma	Caddo	electric services utility 2 oil or gas-fired boilers	selective catalytic reduction	subject to BART; additional emissions reductions planned
Western Farmers Electric Cooperative	Choctaw	electric services utility coal-fired boiler	selective catalytic reduction and flue gas desulfurization wet scrubber	Not subject to BART; no additional emissions reductions planned
Public Service Company of Oklahoma	Comanche	electric services utility 2 natural gas-fired combustion turbines	selective catalytic reduction plus water injection	shall install BART
Great Lakes Carbon Corporation	Garfield	products of petroleum and coal not elsewhere classified industry 2 process units	flue gas desulfurization twice	Not subject to BART; no additional emissions reductions planned
Weyerhaeuser Valliant	McCurtain	paperboard mills iwood bark, residual oil and natural gas-fired boilers	selective non-catalytic reduction urea based, selective catalytic reduction, low NO_x burners, and wet flue gas desulfurization	kraft pulp mill at this facility granted BART waiver and agreed to reduce emissions
Grand River Dam Authority	Mayes	electric services utility coal-fired boilers	selective catalytic reduction, low NO_x burner with over-fire air, and flue gas desulfurization wet scrubber	Not subject to BART
Associated Electric Cooperative Incorporated	Mayes	electric services utility natural gas-fired combustion turbines	selective catalytic reduction plus water injection	Not subject to BART; no additional emissions reductions planned
Oklahoma Gas Electric	Muskogee	electric services utility 3 coal-fired boilers	low NO_x coal-and-air nozzles with close-coupled and separated over-fire air and flue gas desulfurization wet scrubber	shall install BART

Company	County	Industrial classification	Possible Control Equipment	Disposition for this implementation plan revision
Oklahoma Gas Electric	Noble	electric services utility 2 coal-fired boilers	low NO_x coal-and-air nozzles with close-coupled and separated over-fire air	shall install BART
Holcim United States Incorporated	Pontotoc	cement manufacturing coal-fired kilns	selective catalytic reduction and flue gas desulfurization	Not subject to BART; no emissions reductions planned
LaFarge Building Materials	Rogers	cement manufacturing coal-fired kilns	both selective non-catalytic reduction urea based and selective catalytic reduction	Portland cement plant at this location granted waiver from BART
Public Service Company of Oklahoma	Rogers	electric services utility 2 coal-fired boilers	selective catalytic reduction	shall install BART
Sinclair Oil Corporation	Tulsa	petroleum refining industry	flue gas desulfurization	granted waiver from BART but emission reductions under refinery consent decrees

D. Factors for Consideration

1. Source Retirement and Replacement Schedules

Pursuant to 40 C.F.R. § 51.308(d)(3)(v)(D), DEQ considered source retirement and replacement schedules in developing its long-term strategy of emissions reductions. DEQ cannot reliably predict the retirement or replacement of sources and consequently does not rely on source retirement to achieve any reasonable progress goal. DEQ will manage replacement of sources in conformance with applicable rules and regulations, including prevention of significant deterioration and new source review.

2. Statutory Factors

The federal CAA in § 169A(g)(1), 42 U.S.C. § 7491(g)(1), requires DEQ to consider these factors in determining a reasonable progress goal:

- Costs of compliance,
- Time necessary for compliance,
- Energy effects of compliance,
- Non-air quality environmental effects of compliance, and
- Remaining useful life of existing sources.

Compliance costs: Including cost estimates for each source adds weight against the finding of reasonableness in applying additional controls. Compelling facilities to expend large amounts of capital

on pollution reduction technology likely would cause some facilities to cease operations and further compound unemployment and other economic problems in the communities. Emissions controls that increase production costs may impair economic competitiveness or viability of facilities or lead to drastic increases in consumer prices. In consideration of these concerns, DEQ relied on the control basis developed by CENRAP in its initial control strategy simulations for an initial list of sources for further review.

Time for Compliance: In the reasonable progress goal for the Wichita Mountains, DEQ cannot rely on reductions that facilities cannot realize before 2018.

Energy effects of compliance and cost of energy: The cost estimates include energy necessary for additional controls to the extent quantifiable.

Non-air quality effects of compliance: Potential additional controls cannot be determined to have detrimental non-air-quality environmental impacts.

Remaining source life: CENRAP modeling for mobile sources considers this factor as it assumes reduced emissions per vehicle mile traveled due to the turnover of the on-road mobile source fleet. This consideration weighs more heavily against a determination of reasonableness in controlling sources with relatively short useful life remaining. Inclusion of sources with planned unit shutdowns raises cost estimates. None of the considered sources for additional reductions have indicated plans to shutdown.

E. Reasonableness of Controls

1. Emissions of sulfur compounds

The three largest point sources of sulfureous emissions in 2002 fall under the BART rule. Controls for Grand River Dam Authority, an electric power generator, would produce little visibility benefit at enormous monetary and energy cost, especially considering the vast distance between Mayes County and the Wichita Mountains; moreover, the facility already uses flue gas desulfurization. Consent decrees promise considerable emissions reductions from petroleum refineries. Other point sources emit sulfur and fall under existing rules limiting emissions. Retrofitting smaller facilities would impose prohibitively unreasonable costs with imperceptible visibility improvement.

2. Emissions of ammonia

EPA currently does not consider ammonia for regulation as a precursor of fine particulate matter. DEQ follows the lead of EPA on this matter. The IMPROVE monitor at the Wichita Mountains measures neither ammonia nor ammonium, and DEQ cannot restrict emissions reasonably without such monitoring data.

3. Emissions of nitrogen oxides

Three of the four largest point sources of emissions of nitrogen oxides in 2002 are to install BART. Controls for Grand River Dam Authority would entail considerable cost for too little benefit. Some smaller electric power generators closer to the Wichita Mountains also are to install BART.

At other point sources, the overwhelming majority of NO_x emissions originate from stationary combustion engines, including those used to extract and transport natural gas, petroleum, and natural gas liquids. Federal regulations of reciprocating internal combustion engines include new source performance standards and national emissions standards for hazardous air pollutants. These regulations generally apply only to new engines, but increasingly comprehensive or stringent limits likely will result in lower future emissions than those assumed in the reasonable progress goal. EPA may continue to promulgate increasingly stringent limits on various engines at point and area sources. These restrictions likely will result in the application of technology which reduces NO_x emissions beyond those estimated for the reasonable progress goal. Macroeconomic and geopolitical trends will modulate natural gas and petroleum extraction and production, so DEQ offers no further prediction of net emissions reductions from the hydrocarbon fuels sector.

Numerous other point sources emit nitrogen oxides and fall under various existing rules and regulations limiting emissions. Retrofitting these facilities would impose prohibitively unreasonable costs for negligible visibility improvement. See Emission Inventory Section.

Despite the considerable contribution of area sources, especially oil and gas industrial processes, to the Oklahoma NO_x emissions inventory presented in this implementation plan revision, DEQ lacks confidence in these estimates. Before targeting area sources for state rules requiring emissions limitations, DEQ desires a quality-assured enhanced inventory with confidence in its comprehensiveness and accuracy. Although DEQ possesses authority to conduct such inventory, time and resources do not suffice to complete such effort before the submission deadline of this implementation plan revision. Emissions controls on existing area sources also entail enormous cost to detect and enforce. As an initial attempt at refining this inventory, CENRAP conducted an oil and gas inventory project in 2008. Future control assessments will build on this information; however, this assessment lacks sufficient information on current levels of control to support a need for additional controls under this implementation plan revision.

DEQ lacks jurisdiction over non-road and on-road mobile sources. Because many of these sources often move to and from other states, DEQ relies on the federal motor vehicle emissions control programs and other EPA regulations to limit emissions from these sectors. DEQ also does not control fuel prices or other inhibitors to mobile source usage. DEQ considers biogenic and fire sources as natural conditions or otherwise uncontrollable.

4. Volatile organic emissions

The emissions inventory associated with this implementation plan revision assigns most emissions of VOCs to biogenic sources. DEQ considers these sources as natural and therefore uncontrollable.

A minority of VOC emissions in Oklahoma originate from area, industrial, point, and mobile sources. These sources largely already employ controls under various federal mandates. Considering the small and uncertain contribution of anthropogenic sources of VOC to visibility impairment at the Wichita Mountains, DEQ does not find further controls reasonable.

5. Coarse particulate emissions

DEQ believes that most coarse particulate matter observed at the Wichita Mountains originates from natural conditions and recognizes that dust storms occasionally occur naturally in dry environments, especially those west of the Wichita Mountains. DEQ lacks confidence in the inventory which assigns most coarse particulate emissions to road dust. Unpaved roads typically lack the traffic necessary to justify the expense of pavement.

6. Fine particulate emissions and smoke management

Fires cause most directly emitted fine particulate matter in the Oklahoma emissions inventory. DEQ recognizes many fires as natural, uncontrollable, or essential to ecosystem management or agricultural production. Pursuant to 40 C.F.R. § 51.308(d)(3)(v)(E), DEQ considered smoke management techniques for the purposes of agricultural and forestry management in developing this reasonable progress goal. Despite their prominence in the emissions inventory, agricultural burning and wildfires in Oklahoma do not contribute significantly to regional haze at the Wichita Mountains nor at any other Class I area. OAC 252:100-13-7(4) includes provisions for the burning of forestland, cropland, and rangeland. Additionally, DEQ and the Oklahoma Department of Agriculture, Food, and Forestry intend to create a basic, voluntary smoke management program based on *EPA's Interim Air Quality Policy on Wildland and Prescribed Fires*.

Most emissions of fine soil particulate matter also originate from natural sources (including the Sahara Desert), and even those in Oklahoma lie beyond the regulatory purview of DEQ. Other direct emissions of fine particulate contribute miniscule visibility impairment at the Wichita Mountains.

F. Conclusion

The reasonable progress goal for the Wichita Mountains provides for a slower rate of improvement in visibility than the uniform rate of progress; but the preceding discourse clearly demonstrates the reasonableness of this goal.

Given the lack of data from the south central US in the formulation of natural visibility estimates, DEQ believes that the default western target does not represent the actual conditions at the Wichita Mountains. Further, the uniform rate of progress for implementation by 2064 is not reasonable because the vast majority of anthropogenic contributors to the visibility impairment at the Wichita Mountains lie outside the territorial jurisdiction of DEQ. Additional controls at the remaining sources in Oklahoma are not reasonable given associated costs of controls and the resultant minimal visibility improvement.

X. Consultation and Comments

This chapter describes how this state implementation plan revision met consultation requirements in 40 C.F.R. § 51.308(d)(3)(i) and 40 C.F.R. § 51.308(i)(2). DEQ consulted with other state clean air agencies and tribal entities to develop coordinated emissions-reduction strategies as provided in 40 C.F.R. § 51.308(d)(3)(i). This requirement is particularly important in regard to emissions from Texas and other states which contribute to visibility impairment at the Wichita Mountains. It also provided for consultation on emissions from Oklahoma reasonably anticipated to contribute to visibility impairment in other Class I areas. To facilitate coordination with other agencies and tribes, DEQ joined CENRAP. DEQ participated in CENRAP to consult with members to develop technical information necessary for coordinated strategies. DEQ also coordinated with CENRAP and other regional planning organizations on a weight-of-evidence analysis used to develop its long-term strategy. DEQ also coordinated with federal land manager (FLM) staff on long-term strategy development. Details are provided for applicable correspondence, notifications and public hearings as well as for DEQ participation in regional planning organizations. Consultation with FLMs is specifically addressed in sections C, D, and G. Public comments on this plan revision are included in section F. DEQ sets forth intentions of updating emission inventories and submitting periodic reports in sections H and J.

A. Long-term Strategy and Reasonable Progress Goals Consultation

DEQ participated in consultations for Class I areas located in Arkansas, Missouri, and Texas. Missouri Department of Natural Resources and Arkansas Department of Environmental Quality held consultations in concert for Mingo (Missouri), Hercules Glades (Missouri), Upper Buffalo (Arkansas), and Caney Creek (Arkansas) as telephone conferences on 3 April, 11 May, and 7 June 2007. Texas Commission on Environmental Quality held consultations for Big Bend and Guadalupe Mountains National Parks on 11, 18, and 31 July 2007.

DEQ conducted four consultations in compliance with 40 C.F.R. § 51.308(d) and 40 C.F.R. § 51.308(i). DEQ held its first consultation, specifically directed to the tribal leaders in Oklahoma and their environmental managers, on 14 August 2007. Only the Delaware Nation of Oklahoma participated. Oklahoma held the next three consultations as conference calls on 16 August, 30 August, and 25 September 2007. In these consultations, DEQ invited CENRAP member clean air agencies, EPA, and the tribes to participate. DEQ invited personnel from clean-air agencies in Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, and Texas to participate in its consultations.

Notification of consultations included a United States Postal Service mailing and electronic notification to states projected to contribute greater than 1 Mm^{-1} of light extinction at the Wichita Mountains in 2018. The initial mailing included a consultation plan and agenda for the first meeting. DEQ emailed and posted subsequent meeting materials, including a white paper entitled “Natural Background for Wichita Mountains of Oklahoma,” before the meetings. DEQ posted all materials, including mp3 recordings of the consultations, to its regional haze webpage. The Wichita Mountains Wilderness Area Regional Haze Planning document, included as appendices, includes a list of contacts for state clean air agencies, tribes, and FLM staff.

Arkansas Department of Environmental Quality (ADEQ) Air Division Chief Mike Bates sent a letter dated 17 August 2007, which DEQ received on 20 September 2007. This letter asserted that Arkansas sources do not contribute significantly to visibility impairment at the Wichita Mountains and that Arkansas did not plan to require additional control of any source. ADEQ based this position on the modeling projections for the worst quintile days in 2018 at Wichita Mountains that indicate that Arkansas sources contribute less than 1.5 Mm^{-1} of visibility impairment, which ADEQ estimates correspond to 0.2 deciview.

DEQ evaluated the modeling projections and the information that representatives of the Iowa Department of Natural Resources provided during the consultations. DEQ then sent a letter dated 25 February 2008 to Iowa Department of Natural Resources air quality bureau chief Catharine Fitzsimmons, stating that DEQ reasonably does not anticipate anthropogenic sources from Iowa to contribute significantly to visibility impairment at the Wichita Mountains.

On 24 September 2007, DEQ received a letter dated 18 September 2007 from James L. Kavanugh, director of air-pollution control program at Missouri Department of Natural Resources. Missouri questioned Oklahoma using 1 Mm^{-1} as the threshold for determining that a state contributes significantly to visibility impairment at the Wichita Mountains. They recommended a weight-of-evidence approach. Missouri Department of Natural Resources did not identify any emissions reductions beyond those considered in the modeling but did express intent to consider additional reasonably achievable control technology for sulfureous aerosols and their precursors for several sources as part of their implementation plan for Saint Louis to attain the $PM_{2.5}$ national ambient air quality standard.

In a letter dated 3 August 2007, DEQ requested that Texas Commission on Environmental Quality require new and modified PSD sources to conduct analyses for visibility impairment at the Wichita Mountains using federal land manager guidance. DEQ requested an opportunity to review and comment on best available control technology determinations for the proposed projects for which these analyses suggest that the 98^{th}-percentile values for the change in light extinction are higher than 5% for any year. DEQ also asked Texas Commission on Environmental Quality to expand its evaluation to effects of new or modified sources within 100 km of the Wichita Mountains to all such sources within 300 km, as set out in the FLM guidance. Glenn Shankle, executive director of Texas Commission on Environmental Quality, provided the response for his agency in a letter dated 25 October 2007. Texas Commission on Environmental Quality agreed to provide DEQ an opportunity to review best available control technology determinations for prevention of significant deterioration sources with projected visibility impairment, as DEQ requested, but did not commit to expanding its evaluations to include new and modified sources within 300 km.

In her letter dated 25 March 2008, Susanna Hildebrand, director of air quality division of Texas Commission on Environmental Quality, requested concurrence of Oklahoma that DEQ did not rely on any additional reductions from Texas sources in meeting the reasonable progress goal at the Wichita Mountains. DEQ responded in a letter dated 25 April 2008, confirming that DEQ accounted for all expected reductions.

Each state considered reasonable additional emissions reductions under the factors listed in 40 C.F.R. § 51.308(d)(1). DEQ accepted the projected emissions reductions from Texas and all other states in these consultations concerning visibility impairment at the Wichita Mountains; however, DEQ hopes for emissions reductions from Texas sources beyond those herein explicitly anticipated. Appendix 10-1 includes copies of referenced correspondence.

B. Federal Land Manager Consultation

In development of this implementation plan revision, DEQ consulted the designated federal land manager staff personnel in accordance with the provisions of 40 C.F.R. § 51.308 (i) (2). DEQ provided an opportunity to federal land managers for consultation in person and at least 60 days before holding any public hearing on this implementation plan revision. This consultation gave the federal land managers the opportunity to discuss their assessment of:

- Impairment of visibility at the Wichita Mountains and at other Class I areas;
- Recommendations on the development of reasonable progress goals; and
- Recommendations on strategies to address visibility impairment.

DEQ sent its draft of this implementation plan revision to the federal land manager staff on 1 Oct 2009. DEQ notified the federal land manager staff of the public hearing held on <DATES>. DEQ considered or incorporated the comments of the federal land managers on this implementation plan. These comments are posted on the DEQ webpage at WEBSITE on DATE and copies of comments, along with responses, are included as Appendix 10-2.

C. Federal Land Manager Contact List

Tim Allen
U.S. Fish & Wildlife Service
7333 W Jefferson Ave Ste 375
Lakewood, CO 80225
Tim_Allen@fws.gov

CDR Meredith Bond, P.E., USPHS
U.S. Fish and Wildlife Service
Deputy Chief, Branch of Air Quality
7333 W Jefferson Ave Ste 375
Lakewood, CO 80235
303-914-3808
303-969-5444 fax
Meredith_Bond@fws.gov

Bruce Polkowsky
National Park Service
Policy Planning and Permit Review Branch Air Resources Division
National Park Service
Phone (303) 987 6944
Fax (303) 969 2822
PO Box 25287
Denver, CO 80225
12795 W Alameda Pkwy
Lakewood, CO 80228
Bruce_Polkowsky@nps.gov

Scott Copeland
USDA Forest Service
Visibility Data Analyst/COTR Washakie Ranger District
333 E Main St
Lander, WY 82520
Work: (307) 332 9737
Cell: (307) 349 3595
copeland@cira.colostate.edu

Chuck Sams
US Forest Service
Eastern and Southern Regions Air Quality Manager
1720 Peachtree Rd
Atlanta, GA 30309
Office: 404-347-4083
Facsimile: 404-347-4154
csams@fs.fed.us
http://www.fs.fed.us/air

Judy Logan, Forest Air Specialist
Ouachita National Forest
PO Box 1270
Hot Springs, AR 71902
(501) 321-5341 Fax: (501) 321-5353
jlogan@fs.fed.us

Ann Mebane
National Regional Haze Coordinator
USDA Forest Service
4307 Cooper Lane
Cody, WY 82414
(307) 578-8241 Fax: (307) 587-4597
amebane@fs.fed.us

D. Public Hearing

DEQ provided notice of the public hearing and opportunity to comment on the implementation plan revision on <DATES> AS REQUIRED BY 40 C.F.R. §51.102. DEQ held a public hearing regarding the implementation plan revision on <DATES>. Notice was provided in the Oklahoman and the Tulsa World newspapers on DATES. This notice also included information on the availability of this proposed implementation plan revision for public inspection at 707 N. Robinson Ave, Oklahoma City, OK, and on the DEQ webpage at WEBSITE. Appendices B and D contain copies of the notice and proofs of publication.

E. Public Comments

DEQ addressed public comments and summarized them in Appendix 10-3.

F. Future Consultation with Federal Land Managers

DEQ will continue to coordinate and consult with the federal land managers as provided in 40 C.F.R §51.308(i)(4). DEQ intends to consult the federal land managers in the following instances:

- Development and review of implementation plan revisions;
- Review of quinquennial progress reports; and
- Development and implementation of other programs that may contribute to impairment of visibility at the Wichita Mountains and other Class I areas.

G. Periodic Updates of Emission Inventories

Recognizing the importance of maintaining current, valid emissions information, DEQ intends to update the Oklahoma statewide emissions inventories periodically. DEQ updates the point source inventories annually. DEQ also coordinates with EPA to update the area and on- and off-road mobile inventories triennially and conforms to emission reporting requirements of EPA.

In addition to completing regular updates of emissions inventory of Oklahoma, DEQ intends to review periodic emissions information from other states and future emissions projections. This effort will consist of reviewing any technical data and assumptions regarding emissions growth rates, implementation of emissions controls, and geographic distribution of emissions. DEQ may coordinate the periodic reviews with other state clean-air agencies and consultation partners in conjunction with the quinquennial progress reports. DEQ finds participation in CENRAP beneficial toward these ends.

H. Periodic Reporting and Determination of Adequacy

40 C.F.R. § 51.308(g) requires quinquennial reports evaluating progress towards the reasonable progress goal established for the Wichita Mountains. DEQ intends to submit the first five-year report by 1 XXXXXX 2015. Using the findings of the quinquennial progress report, DEQ will be able to make a determination regarding the adequacy of the existing plan and take an appropriate action based upon that determination as specified in 51.308(h).

I. Comprehensive Periodic Revisions

The regional haze rule requires periodic progress reports and implementation plan revisions. 40 C.F.R. § 51.308(f) currently requires DEQ to submit a major revision to its implementation plan to EPA by 31 July 2018 and decennially thereafter. DEQ awaits approval of this implementation plan before submitting any such revisions.

J. Conclusion Clause

Now, having fulfilled all requirements of the federal regional haze rule insofar as it is capable, DEQ hereby submits this plan through J.D. Strong, Secretary of the Environment, designee for Governor Brad Henry, for consideration and approval by the EPA.