Draft CALPUFF BART Modeling Protocol For Federal Mandatory Class I Areas

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LIST OF ABBREVIATIONS

Δ	Symbol For Change
b_{abs}	Absorption Gases and Particles
b_{ag}	Light Absorption of Gases
b_{ap}	Light Absorption of Particles (Essentially, Elemental Carbon)
BART	Best Available Retrofit Technology
B_{Coarse}	Light Scattering From Coarse Particles
b_{ext}	Light Extinction Coefficient
BLM	Bureau of Land Management
B_{NO3}	Light Scattering From Ammonium Nitrate, $(NH_4)NO_3$
b_{OC}	Light Scattering From Total Organic Aerosols
b_{ray}	Rayleigh Scattering
b_{scat}	Scattering Gases and Particles
b_{sg}	Light Scattering of Gases
b_{SO4}	Light Scattering From Ammonium Sulfate, $(NH_4)_2SO_2$
b_{SOIL}	Light Scattering From Fine Particles
b_{sp}	Light Scattering of Particles
Btu	British Thermal Unit(s)
C	Centigrade
CFR	Code of Federal Regulations
COOP	National Weather Service (NWS) Cooperative Observer Program
CTG	Composite Theme Grid
DEMs	Digital Elevation Models
dv	Deciviews
EC	Elemental Carbon
EPA	U.S. Environmental Protection Agency
exp	Exponential
F	Fahrenheit
FLAG	Federal Land Managers AQRV (Air Quality Related Values) Workgroup

LIST OF ABBREVIATIONS (continued)

FLM(s)	Federal Land Manager(s)
FR	Federal Register
f(RH)	Relative Humidity Adjustment Factor
ft	Feet
ft/sec	Feet Per Second
FWS	U.S. Fish and Wildlife Service
g/sec	Gram(s)/Second
IMPROVE	Interagency Monitoring of Protected Visual Environments
IWAQM	Interagency Workgroup on Air Quality Modeling
K	Kelvin
K	Koschmieder Coefficient, Unitless, Range: 3.0 - 3.9
km	Kilometer(s)
lb/day	Pounds Per Day
LCC	Lambert Conformal Conic
LULC	Land Use and Land Cover
ln	Natural Logarithm
m	Meter(s)
m^2/g	Meter Squared Per Gram
m/sec	Meters Per Second
MDEQ	Montana Department of Environmental Quality
$\mu g/m^3$	Micrograms Per Cubic Meter
Met	Meteorological
Mm^{-1}	Inverse Megameters
MM4	Fourth Generation Three-Dimensional Mesoscale Weather Prediction Model Developed Penn State/NCAR
MM5	Fifth Generation Three-Dimensional Mesoscale Weather Prediction Model Developed Penn State/NCAR
NAD27	North American Datum 1927
NAD83	North American Datum 1983

LIST OF ABBREVIATIONS (continued)

NCAR	National Center for Atmospheric Research, Boulder, Colorado
NCDC	NOAA National Climatic Data Center
NH_3	Ammonia
NEI	EPA National Emission Inventory
NO_2	Nitrogen Dioxide
NO_3	Nitrates
NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen Oxides
NNDC	NOAA National Data Centers
NP	National Park
NPS	National Park Service
PM	Particulate Matter
PM_{10}	Particulate Matter Less Than Or To Equal 10 Microns
$PM_{2.5}$	Particulate Matter Less Than Or To Equal 2.5 Microns
ppb	Parts Per Billion
QA/QC	Quality Assurance/Quality Control
SO_2	Sulfur Dioxide
SO_4	Sulfates
SOA	Secondary Organic Aerosol
tons/day	Tons Per Day
tpy	Tons Per Year
USDA-FS	U.S. Department of Agriculture - Forest Service
USDI-NPS	U.S. Department of Interior - National Park Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UTM(s)	Universe Transverse Mercator
VIEWS	Visibility Information Exchange Web System
VOC(s)	Volatile Organic Compound(s)
VR	Visual Range

LIST OF ABBREVIATIONS (continued)

WA	Wilderness Area
WBAN	Weather-Bureau-Army-Navy
WRAP	Western Regional Air Partnership

DEFINITIONS

“BART-eligible source” means an existing stationary facility, which emits visibility-impairing pollutant in amounts the Montana Department of Environmental Quality anticipates will cause or contribute to any visibility impairment in any federal mandatory Class I area.

"Best Available Retrofit Technology (BART)" means an emission limitation based on the degree of reduction achievable through the application of the best system of continuous emission reduction for each pollutant, which is emitted by an existing stationary facility. The emission limitation must be established on a case-by-case basis, taking into account the following factors: available technology, the cost of compliance, the energy and non-air quality environmental impacts of compliance, any pollution control equipment in use or in existence at the source, the remaining useful life of the source, and the degree of improvement in visibility, which may reasonably be anticipated to result from the use of such technology.

“Deciview” means a measurement of visibility impairment. A deciview is a haze index derived from calculated light extinction, such that uniform changes in haziness correspond to uniform incremental changes in perception across the entire range of conditions, from pristine to highly impaired. The deciview haze index is calculated based on the following equation (for the purposes of calculating deciview, the atmospheric light extinction coefficient must be calculated from aerosol measurements):

$$\text{Deciview haze index} = 10 \ln (b_{ext}/10\ Mm^{-1})$$

where b_{ext} = the atmospheric light extinction coefficient, expressed in inverse megameters (Mm^{-1}).

“Existing stationary facility” means any of the following stationary sources of air pollutants, including any reconstructed source, which was not in operation prior to August 7, 1962, and was in existence on August 7, 1977, and has the potential to emit 250 tons per year (tpy) or more of any air pollutant. In determining potential to emit, fugitive emissions, to the extent quantifiable, must be counted.

- fossil-fuel fired steam electric plants of more than 250 million British thermal units (Btu) per hour heat input
- coal cleaning plants (thermal dryers)
- kraft pulp mills
- Portland cement plants
- primary zinc smelters
- iron and steel mill plants
- primary aluminum ore reduction plants
- primary copper smelters
- municipal incinerators capable of charging more than 250 tons of refuse per day
- hydrofluoric, sulfuric, and nitric acid plants

- petroleum refineries
- lime plants
- phosphate rock processing plants
- coke oven batteries
- sulfur recovery plants
- carbon black plants (furnace process)
- primary lead smelters
- fuel conversion plants
- sintering plants
- secondary metal production facilities
- chemical process plants
- fossil-fuel boilers of more than 250 million Btu per hour heat input
- petroleum storage and transfer facilities with a capacity exceeding 300,000 barrels
- taconite ore processing facilities
- glass fiber processing plants
- charcoal production facilities

“Federal Land Manager (FLM)” means the Secretary of the Department with authority over a given Federal Class I area. The FLM for the Department of the Interior is the Assistant Secretary for Fish, Wildlife, and Parks; the FLM for the Department of Agriculture is the Forest Service, through the Regional Forester or individual Forest Supervisor.

“Federal Mandatory Class I Area” means certain national parks (over 6000 acres), wilderness areas (over 5000 acres), national memorial parks (over 5000 acres), and international parks, in existence on August 7, 1977 as established by Congress and defined in 40 CFR (Code of Federal Regulations) §81.417, where visibility has been determined to be an important national asset.

“Fixed capital costs” means the capital needed to provide all of the depreciable components.

"Fugitive emissions" means those air pollutant emissions, which could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

"In existence" means that the owner or operator has obtained all necessary preconstruction approvals or permits required by federal, state, or local air pollution emissions and air quality laws or regulations and either has begun, or caused to begin, a continuous program of physical on-site construction of the facility; or entered into binding agreements or contractual obligations, which cannot be canceled or modified without substantial loss to the owner or operator, to undertake a program of construction of the facility to be completed in a reasonable time.

"In operation" means engaged in activity related to the primary design function of the source.

"Installation" means an identifiable piece of process equipment.

"Natural visibility conditions" is visibility under naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration. These phenomena include fog, clouds, wind blown dust, rain, sand, naturally ignited wildfires, and natural aerosols.

"Potential to emit" means the maximum capacity of a stationary source to emit a pollutant under its physical and operational design. Any physical or operational limitation on the capacity of the source to emit a pollutant including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its design if the limitation or the effect it would have on emissions is federally enforceable. Secondary emissions do not count in determining the potential to emit of a stationary source.

"Reasonably attributable" means visibility impairment in a Class I area caused by emissions from one or a small group of sources generally located in close proximity to the Class I area.

"Reconstruction" will be presumed to have taken place where the fixed capital cost of the new component exceeds 50% of the fixed capital cost of a comparable entirely new source. Any final decision as to whether reconstruction has occurred shall be made in accordance with 40 CFR §60.15.

"Regional Haze" means visibility impairment in one or several Class I areas caused by emissions from numerous anthropogenic sources located over a wide geographic area.

"Secondary emissions" means emissions, which occur as a result of the construction or operation of an existing stationary facility, but do not come from the existing stationary facility. Secondary emission may include, but are not limited to, emission from ships or trains coming to or from the existing stationary facility.

"Stationary source" means any building, structure, facility, or installation, which emits or may emit any air pollutant.

"Visibility impairment" means any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions.

1.0 INTRODUCTION

On July 1, 1999, the U.S. Environmental Protection Agency (EPA) published the final rule of the regional haze regulations (64 FR 35714, July 1, 1999; FR means Federal Register). The objective of the federal regional haze regulations is to improve visibility in 156 specific areas across United States, known as “Class I” areas. The Clean Air Act defines federal mandatory Class I areas as certain national parks (over 6000 acres), wilderness areas (over 5000 acres), national memorial parks (over 5000 acres), and international parks that were in existence on August 7, 1977 as defined in 40 CFR §81.417.[1]

States are required to conduct certain analyses to ensure reaching natural visibility conditions in 60 years (from 2004 to 2064) in these federal mandatory Class I areas. To measure progress toward this goal, the regional haze program requires that a comparison with natural conditions for the best 20% natural visibility days and use the worst 20% natural visibility days to calculate ``reasonable progress''. Overall, States must establish goals:

1) to improve the visibility on the 20% haziest days and

2) to ensure no degradation occurs on the 20% cleanest days over the implementation planning period (2004 – 2064).

The first long-term strategy will cover 10 to 15 years with reassessments and revisions of those goals and strategies in 2018 and every 10 years thereafter. A midterm analysis will be conducted around 2013. State strategies should also address their contribution to visibility problems in federal mandatory Class I areas both within and outside the State boundaries due to the long-distance transport of air pollutants that cause haze.

On July 6, 2005, the EPA published the final amendments to its 1999 regional haze rule in the Federal Register providing the final guidance for Best Available Retrofit Technology (BART) determinations including Appendix Y, (70 FR 39104-39172).[2] The BART rule requires the installation of BART on industrial emission sources (“subject-to-BART”) that fit specific criteria and are “anticipated to cause or contribute to visibility impairment in any federal mandatory Class I area.”

The Montana Department of Environmental Quality (MDEQ) is primarily responsible for the BART process. The MDEQ will identify those sources that meet the definition of “BART-eligible source” as defined in 40 CFR §51.031, with assistance from the owner or operator of such source(s). Then the MDEQ will determine whether a BART-eligible

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1. 40 CFR 81. Subpart D – Identification of Mandatory Class I Federal Areas Where Visibility Is an Important Value. Revised July 1, 2003.

2. Federal Register. 2005. EPA Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations; Final Rule. Federal Register. July 6, 2005. Vol. 70. No. 128. p. 39103-39172.

source is subject to BART. The MDEQ has proposed a state regulation establishing a “contribution threshold” of 0.5 deciviews (dv). This is a change in visibility (delta-deciview, Δ dv) caused by the emissions from a BART-eligible source(s) relative to the natural background visibility conditions based on the best 20% natural visibility days at a federally mandated Class I area according to the BART guidelines.

There are twelve federal mandatory Class I areas in Montana. Six other federal mandatory Class I areas in neighboring states will also be included in the BART analysis since Montana BART-eligible sources may affect these areas. All eighteen federal mandatory Class I areas of concern are listed in Table 1.0A.

Table 1.0A: Eighteen Significant Federal Mandatory Class I Areas.

Montana Class I Areas	Class I Areas in Neighboring States
Anaconda-Pintler Wilderness Area	Hells Canyon Wilderness Area – Idaho and Oregon
Bob Marshall Wilderness Area	North Absaroka Wilderness Area – Wyoming
Cabinet Mountains Wilderness Area	Sawtooth Wilderness Area – Idaho
Gates of the Mountains Wilderness Area	Teton Wilderness Area – Wyoming
Glacier National Park	Theodore Roosevelt National Park – North Dakota
Medicine Lake Wilderness Area	Washakie Wilderness Area – Wyoming
Mission Mountain Wilderness Area	
Red Rock Lakes Wilderness Area	
Scapegoat Wilderness Area	
Selway-Bitterroot Wilderness Area – Montana and Idaho	
U.L. Bend Wilderness Area	
Yellowstone National Park – Montana, Idaho, and Wyoming	

As noted in the previous table, three Class I areas are located in more than one state: Hells Canyon Wilderness Area (Idaho and Oregon), Selway-Bitterroot Wilderness Area (Idaho and Montana), and Yellowstone National Park (Idaho, Montana, and Wyoming).

As of February 2006, the MDEQ has identified ten facilities that may possess BART-eligible sources, which are listed in Table 1.0B.

Table 1.0B: Ten Montana Facilities With Potential BART-Eligible Sources.

Facility	Facility
ASARCO Incorporated	Holcim – Trident Plant
Ash Grove Cement Company – Montana City	Montana Sulphur & Chemical Company
CHS Inc. (formerly Cenex Harvest States Cooperatives) – Laurel	PPL Montana, LLC – Corette Plant
Columbia Falls Aluminum LLC	PPL Montana, LLC – Colstrip 1 + 2
ExxonMobil Pipeline Company – Billings Refinery	Smurfit-Stone Container Enterprises, Inc. – Missoula

All federally mandated Class I areas within 300 kilometers (km) of the potential BART-eligible source(s) will be included in the modeling analysis for that source(s). Figure 1.0A displays the Class I areas of concern in the Montana BART-related modeling domain and Figure 1.0B shows the facilities that possess potential BART-eligible sources in the same modeling

The MDEQ will use the Professional CALPUFF (Version 2.28.0) by Bee-Line Software (Asheville, NC) as the CALPUFF platform. This software, also known as CalPuffPro, interfaces with Earth Tech CALPUFF (Earth Tech, Inc., Concord, MA), but simplifies the process and produces excellent graphics.

The modeling process is essentially three-fold: “BART-eligible”, “subject-to-BART”, and effect(s) of BART. In all cases, three years (2001 – 2003) of meteorological data, as recommended by the BART guidelines, will be used. Preliminary modeling was conducted to analyze the various CALMET/CALPUFF model switches using 1996 CALMET data on a 36 kilometer (km) grid basis.

Emissions of the following air pollutants will be addressed: sulfur dioxide (SO_2), nitrogen oxides (NO_X), and particulate matter less than or to equal 10 microns (PM_{10}). To reiterate, any mandatory federal Class I area of interest within 300 kilometers (km) of the source(s) to be modeled will be included to determine the impacts of the emissions on the area’s visibility.

Figure 1.0A: Federal Mandatory Class I Areas In The Montana BART Modeling Domain.

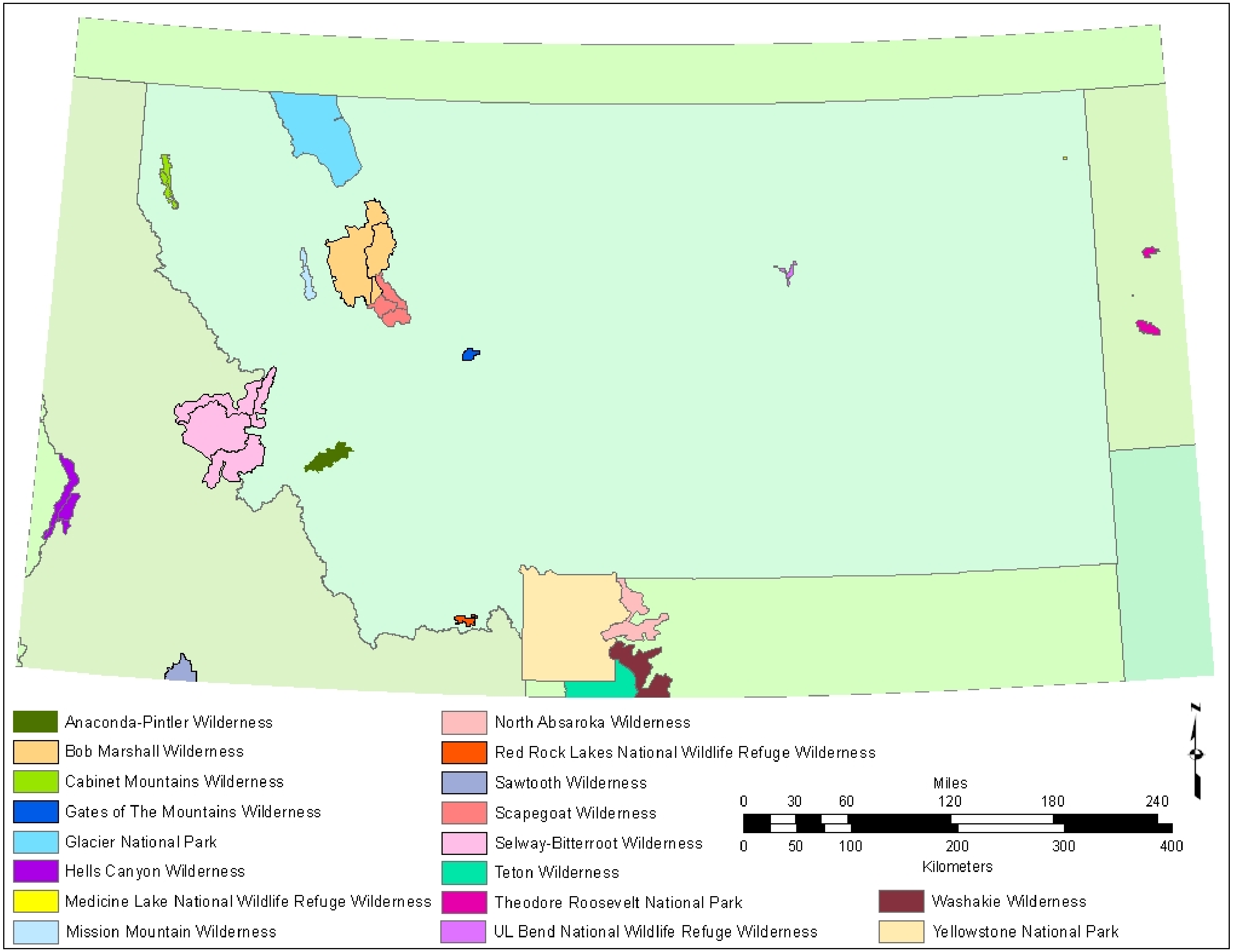
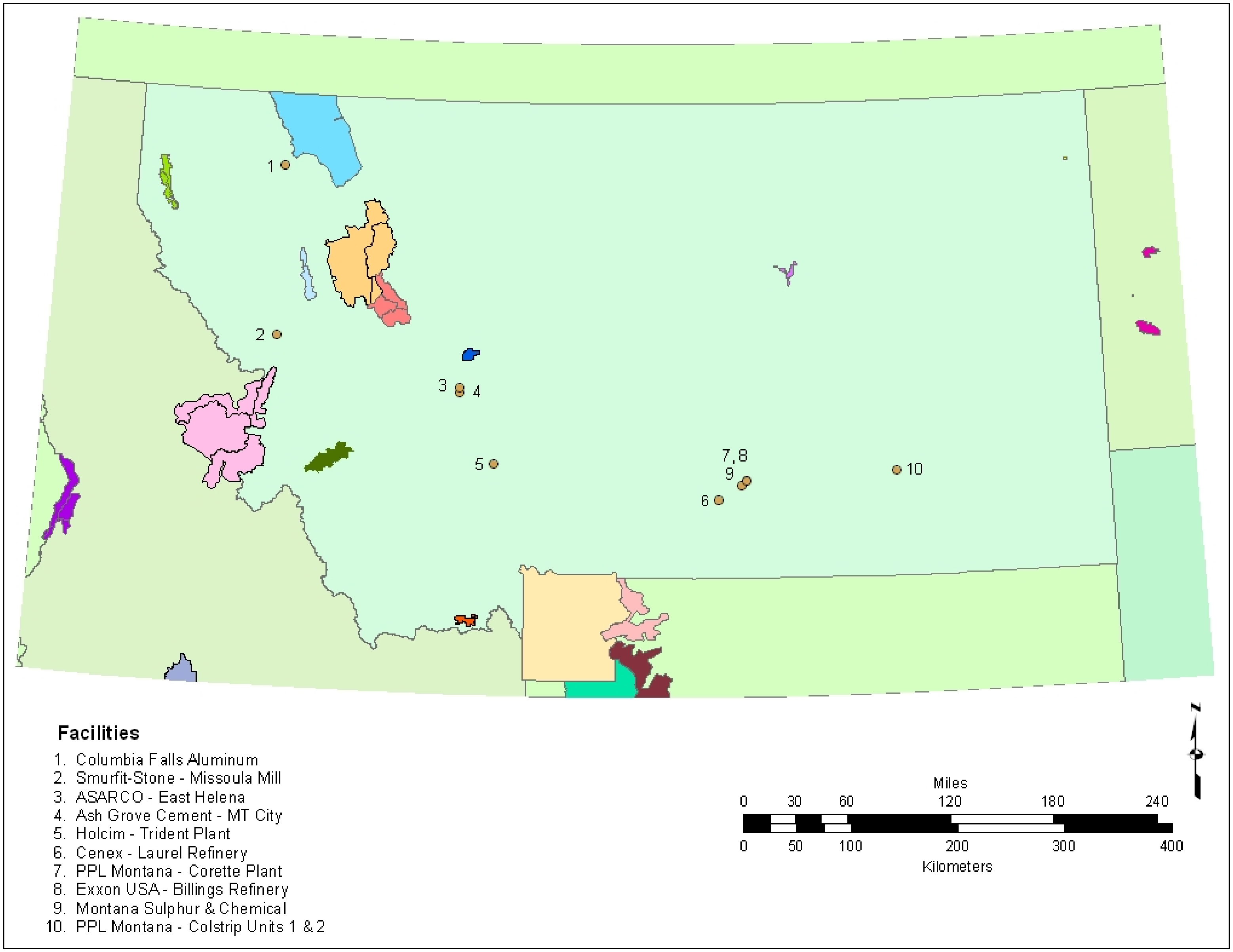


Figure 1.0B: Montana Industries With Potential BART-Eligible Sources.



BART-Eligible Modeling
The first step is referred to as “BART-eligible” modeling analysis. All SO_2, NO_X, and PM_{10} emissions from all of the BART-eligible sources at a given facility will be modeled together. The emission rates will be the maximum steady-state 24-hour actual emissions (ignoring periods of startup, shutdown, and malfunction) produced under maximum production achieved during a calendar year within the 2001 to 2003 time period. If the emissions during this period do not represent maximum capacity, the maximum 24-hour actual emission rates will be obtained from another recent year. The MDEQ will review all emission rates for accuracy.

As stated previously, the MDEQ will apply the CALPUFF computer model with three years of meteorological data. All Class I area receptors within 300 kilometers (km) of the facility with the BART-eligible source(s) will be included in the modeling analysis. The model will calculate the number of days per receptor with a delta-deciview (Δ dv) greater than or equal to 0.5 dv (contribution threshold) for each met year. If the daily 98^{th} percentile value for any year or all met years combined (on a receptor basis) is greater than this contribution threshold, then the source (or sources) is considered “subject-to-BART”. This is a change in visibility (delta-deciview, Δ dv) is relative to the natural background visibility conditions based on the best 20% natural visibility days at a federally mandated Class I area.

For clarification, the EPA recommends calculating the 98^{th} percentile value for one met year as the value on the 8th highest day (8 days/365 total days * 100 ≈ 2% ≈ 98^{th} percentile). Combining all three years of met data, the 98^{th} percentile value would be the value on the 22^{nd} highest day ((22/(365+365+365)) * 100 ≈ 2% ≈ 98^{th} percentile). The greater of these two values will be selected for comparison to the 0.5 dv contribution threshold. If the selected Δ dv value is greater than 0.5 dv, the BART-eligible unit(s) is considered subject-to-BART and a second round of modeling.

BART-Subject Modeling
The MDEQ will again apply the CALPUFF computer modeling system with the same meteorological dataset, but each subject-to-BART source (or “unit”) will be modeled individually on an individual air pollutant basis (SO_2, NO_X, and PM_{10}, where applicable) as the BART guidelines require.

Again, all Class I areas within 300 kilometers (km) of the individual subject-to-BART source will be included in the modeling analysis for that source. The CALPUFF model will calculate the Δ dv contribution for each source on a pollutant basis for each met year and the results will be compared to the contribution threshold. The MDEQ will track the daily 98^{th} percentile values for the BART determination process and provide this data to the owner or operator of the BART-subject source(s).

This modeling scenario is considered the “base case” (before BART) for that source so that the results from subsequent modeling with BART applied (post-BART) can be attributed to the BART emissions reductions. Some emissions control technologies can increase the emissions of another air pollutant of concern; therefore, all air pollutant emissions of interest will be checked post-BART.

The owner or operator of the BART-subject source(s) will perform the BART determination analysis for their respective source(s) considering the following five factors:

- existing control technology in place at the source;
- costs of compliance;
- energy and non-air environmental impacts of compliance;
- remaining useful life of the source; and
- the degree of visibility improvement that is reasonably anticipated from the use of such technology.

BART Results Modeling

After the MDEQ has concurred with the BART analysis, the MDEQ will conduct the third CALPUFF modeling demonstration identical to the base case except with the BART control technology (or technologies) installed. Each subject-to-BART source or "unit" within a facility will be modeled individually on an individual air pollutant basis. The 98^{th} percentile value of the 24-hour change in visibility will once more be compared to the 0.5 dv threshold.

The MDEQ heavily emphasizes that this is a draft BART modeling protocol, not a BART determination protocol. The operator or owner of the BART-subject source(s) is responsible for the BART determinations. The MDEQ will review the determinations on a case-by-case basis, and issue a notice of determination.

The MDEQ will release this draft BART modeling protocol for a 30-day informal public comment period. The MDEQ will use this draft protocol for the initial subject-to-BART modeling analysis. Subsequent modeling performed by the MDEQ may supersede previous results.

This protocol incorporated the latest modeling techniques that are consistent with the EPA, federal land managers' (FLMs) recommendations, and BART guidelines.[2] However, if new EPA and FLM recommendations and/or CALPUFF model inputs/variables related to the BART process become available, the MDEQ will apply these changes into the BART modeling process if time, resources, and other relevant factors permit.

The MDEQ may approve deviations from this protocol for a specific source that are documented in a modeling protocol and accepted by the EPA, if the model performance is improved while retaining consistency with the BART guidelines. All modeling analyses will be subject to MDEQ review and approval.

In addition, the contribution threshold and other criteria documented in this BART modeling protocol have not been finalized and may change in the final rule adopted by the Montana Board of Environmental Review. Therefore, the modeling results performed with this protocol are not a final agency action.

The MDEQ expects to post all input and output files relating to the CALPUFF modeling including any software updates that become available, on the MDEQ CALPUFF Visibility web site (http://www.deq.mt.gov/AirQuality/Visibility.asp). For consistency, the MDEQ highly recommends that these files be used by the owner or operator of the potential BART-eligible/subject source(s) for any BART-related modeling.

2.0 VISIBILITY CALCULATIONS

Visibility monitoring in national parks and wilderness areas is conducted through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. Participants are representatives from the National Park Service (NPS), U.S. Forest Service (USFS), Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (FWS), EPA, and regional-state organizations. The IMPROVE program includes the characterization of haze by photography, the measurement of light extinction with specialized instruments (such as transmissometers and nephelometers), and the measurement of the composition and concentrations of fine particles that produce haze. Fine particle concentrations are the focus of the regional haze program and therein, the BART modeling analysis.

The light extinction coefficient (b_{ext}) has generally been used in the U.S. for many years to describe visibility and the change in visibility due to changes in the concentrations of air pollutants. The light extinction coefficient is also related to the visual range, the greatest distance that an observer can just see a black object viewed against the horizon sky.

In the following equation, the visual range (VR) is measured in kilometers (km) and K is the Koschmieder coefficient, which ranges from 3.0 to 3.9. This unitless coefficient is the natural log of the contrast threshold of the human eye. For regional haze, K equals 3.912, which is often truncated to 3.910, and the light extinction coefficient has units of inverse megameters (Mm^{-1}).

$$VR = K/b_{ext} \rightarrow VR\ (km) = 3.912/\ b_{ext}\ (Mm^{-1})$$

With rearrangement, the equation converts to:

$$b_{ext}\ (Mm^{-1}) = 3.912/VR\ (km)$$

Visibility is measured in deciviews (dv). The scale of this visibility index is linear so a change of 1.0 deciview (more precisely, 0.9531 dv) represents approximately a 10% change in b_{ext}, which is noticeable by most observers under most visibility conditions. The relationship between the light extinction coefficient and deciview is expressed in the following equation.

$$b_{ext}\ (Mm^{-1}) = 10\ exp\ (dv/10\ Mm^{-1})$$
(exp = exponential)

or

$$dv = 10\ ln\ (b_{ext}\ Mm^{-1}/10\ Mm^{-1})$$
(ln = natural logarithm)

Visibility is impaired by scattering (b_{scat}) and absorption (b_{abs}) of atmospheric gases and particles.

$$b_{ext} = b_{scat} + b_{abs}$$

This equation can be further characterized by the following.

$$b_{ext} = b_{sg} + b_{ag} + b_{sp} + b_{ap}$$

where s, a, g, and p refer to scattering, absorption, gases, and particles, respectively.

Light scattering due to air molecules (primarily nitrogen and oxygen molecules) is called Rayleigh scattering (b_{ray}). This component varies slightly due to elevation and temperature; currently, the default value for b_{ray} is 10 Mm^{-1}. The light absorption component of extinction from gases (b_{ag}) is considered negligible. Therefore, the primary factors to visibility impairment are due to particle absorption (b_{ap}) and scattering (b_{sp}).

Scattering by particles (b_{sp}) has five main components as seen in following equation.

$$b_{sp} = b_{SO4} + b_{NO3} + b_{OC} + b_{SOIL} + b_{Coarse}$$

where

b_{SO4} = Light Extinction of Ammonium Sulfate = $3 * f(RH) * [(NH_4)_2SO_2]$
b_{NO3} = Light Extinction of Ammonium Nitrate = $3 * f(RH) * [(NH_4)NO_3]$
b_{OC} = Light Extinction of Total Organic Aerosols = 4 * [OC]
b_{SOIL} = Light Extinction of Fine Particles = 1 * [Soil]
b_{Coarse} = Light Extinction of Coarse Particles = 0.6 * [Coarse Mass]

The numeric factors (i.e., 3) in the beginning of each term refer to the assumed dry scattering efficiencies in meter squared per gram (m^2/g). The values in the brackets are concentrations in micrograms per cubic meter ($\mu g/m^3$). The f(RH) term is the relative humidity adjustment factor, which accounts for the fact that sulfate and nitrate particles grow under high relative humidity conditions. Appendix A shows values of f(RH) determined from the growth of ammonium sulfate.

The final variable is particle absorption (b_{ap}). Elemental carbon (EC) or soot is the primary source of particle absorption in the atmosphere and is defined below.

$$b_{ap} = \text{Light Extinction of Elemental Carbon} = 10 * [EC]$$

The numeric factor (i.e., 10) refers to the assumed dry absorption efficiency in meter squared per gram (m^2/g) and the value in the brackets is the concentration in micrograms per cubic meter ($\mu g/m^3$). The total IMPROVE equation to estimate the total reconstructed light extinction in the atmosphere is summarized below.

$$b_{ext} = b_{SO4} + b_{NO3} + b_{OC} + b_{SOIL} + b_{Coarse} + b_{EC} + b_{ray}$$

b_{SO4} = Light Extinction of Ammonium Sulfate = $3 * f(RH) * [(NH_4)_2SO_2]$
b_{NO3} = Light Extinction of Ammonium Nitrate = $3 * f(RH) * [(NH_4)NO_3]$
b_{OC} = Light Extinction of Total Organic Aerosols = 4 * [OC]
b_{SOIL} = Light Extinction of Fine Particles = 1 * [Soil]
b_{Coarse} = Light Extinction of Coarse Particles = 0.6 * [Coarse Mass]
b_{EC} = Light Extinction of Elemental Carbon = 10 * [EC]
b_{ray} = Rayleigh scattering = 10

To reiterate, the f(RH) term is the relative humidity adjustment factor and the values in the brackets are the concentration in micrograms per cubic meter ($\mu g/m^3$). The units of light extinction are inverse megameters (Mm^{-1}).

The change in visibility (delta-deciview, Δ dv) is relative to the natural background visibility conditions based on the best 20% natural visibility days at a federally mandated Class I area. The delta-deciview value is calculated from the contribution of emission source to the light extinction, b_{Source}, and the natural background extinction, $b_{Background}$, using the following equation.

$$\Delta dv = 10 \ln ((b_{Background} + b_{Source}) / b_{Background})$$

A new IMPROVE haze equation has been developed to correct inadequacies of the current formula. This new algorithm should only be used to estimate the light extinction coefficients (b_{ext}) based on the captured particulate mass collected by the IMPROVE filters, not for CALPUFF modeling.

3.0 CALPUFF MODEL SYSTEM

As specified in the BART guidelines:

> "CALPUFF is the best regulatory modeling application currently available for predicting a single source's contribution to visibility impairment and is currently the only EPA-approved model for use in estimating single source pollutant concentrations resulting from the long-range transport of primary pollutants. It can also be used for some other purposes, such as the

visibility assessments addressed in today's rule, to account for the chemical transformation of SO_2 and NO_X."

The main components of the CALPUFF modeling system are CALMET, CALPUFF, and CALPOST. CALMET is the meteorological model that generates hourly three-dimensional meteorological fields such as wind and temperature. CALPUFF simulates the non-steady state transport, dispersion, and chemical transformation of air pollutants emitted from a source in "puffs". Hourly concentrations and/or deposition flux values are calculated at specified locations (receptors) in a modeling domain. For this visibility modeling analysis, two post-processing programs will be utilized the hourly concentrations: POSTUTIL and CALPOST. POSTUTIL will be used to implement the ammonia-limiting method to address double-counting of available ammonia for NO_x to NO_3 chemical conversion. Then the CALPOST post-processing program will be applied to compute the 24-hour basis light extinction coefficients from the hourly specie concentrations at the selected locations. The number of days greater than the contribution threshold is also computed.

Earth Tech (Earth Tech, Inc., Concord, MA), is the primary CALPUFF model developer and also provides several utility programs to accommodate pre-processing of meteorological and geophysical data for CALMET. The CALPUFF system software and user's guides can be downloaded from the Earth Tech web site (www.src.com/calpuff/calpuff1.htm).[3, 4] The MDEQ will use the CALPUFF modeling versions listed in Table 3.0. However, if new and improved versions become available, the MDEQ will apply those versions and document the changes.

Table 3.0: CALPUFF Modeling System.

Program	Version	Level
CALMET	6.211	060414
CALPUFF	6.112	060412
POSTUTIL	1.52	060412
CALPOST	6.131	060410

The MDEQ expects to post all input and output files relating to the CALPUFF modeling including any software updates that become available on the MDEQ CALPUFF Visibility web site (http://www.deq.mt.gov/AirQuality/Visibility.asp). For consistency, the MDEQ highly recommends the owner or operator of the potential BART-eligible/subject source use these files for BART-related modeling.

3. Earth Tech, Inc. 2000. A User's Guide for the Calmet Meteorological Model (Version 5). Earth Tech, Inc. Concord, MA 01742.

4. Earth Tech, Inc. 2000. A User's Guide for the Calpuff Dispersion Model (Version 5). Earth Tech, Inc. Concord, MA 01742.

3.1 MODELING DOMAIN

The modeling domain will be sufficiently large to include the entire state of Montana and parts of five neighboring states: Idaho, North Dakota, South Dakota, Washington, and Wyoming. A segment of Canada is also included to complete the modeling domain (Figures 1.0A and B).

The map projection will be Lambert Conformal Conic (LCC) and the coordinate system will be Montana State Plane NAD83 (North American Datum 1983), which is a LCC projection. The grid spacing will be 6 kilometers (km), but finer grid spacings may be developed for two potential BART-eligible sources: Ash Grove Cement Company and Columbia Falls Aluminum LLC. Ash Grove Cement Company is approximately 32 km away from the Gates of the Mountains Wilderness Area. Columbia Falls Aluminum LLC is located just west of Glacier National Park.

The southwest corner of the modeling domain is Longitude 117.007 degrees west, Latitude 43.991343 degrees north, which equates to 0,0 in the Montana State Plane Coordinate System. The northeast corner of the modeling domain is approximately Longitude 103 degrees west, Latitude 49.5 degrees north.

According to the IWAQM, Phase 2 report:

> "CALPUFF is recommended for transport distances of 200 km or less. Use of CALPUFF for characterizing transport beyond 200 to 300 km should be done cautiously with an awareness of the likely problems involved."[5]

Since the modeling domain is significantly greater than 300 km (over 1,100 km in length), 300 km modeling subdomains will be created with the potential BART-eligible/subject source(s) located essentially in the center. The visibility impacts from those sources will be evaluated for any Class I area that lies within these subdomain boundaries.

3.2 CALMET INPUTS

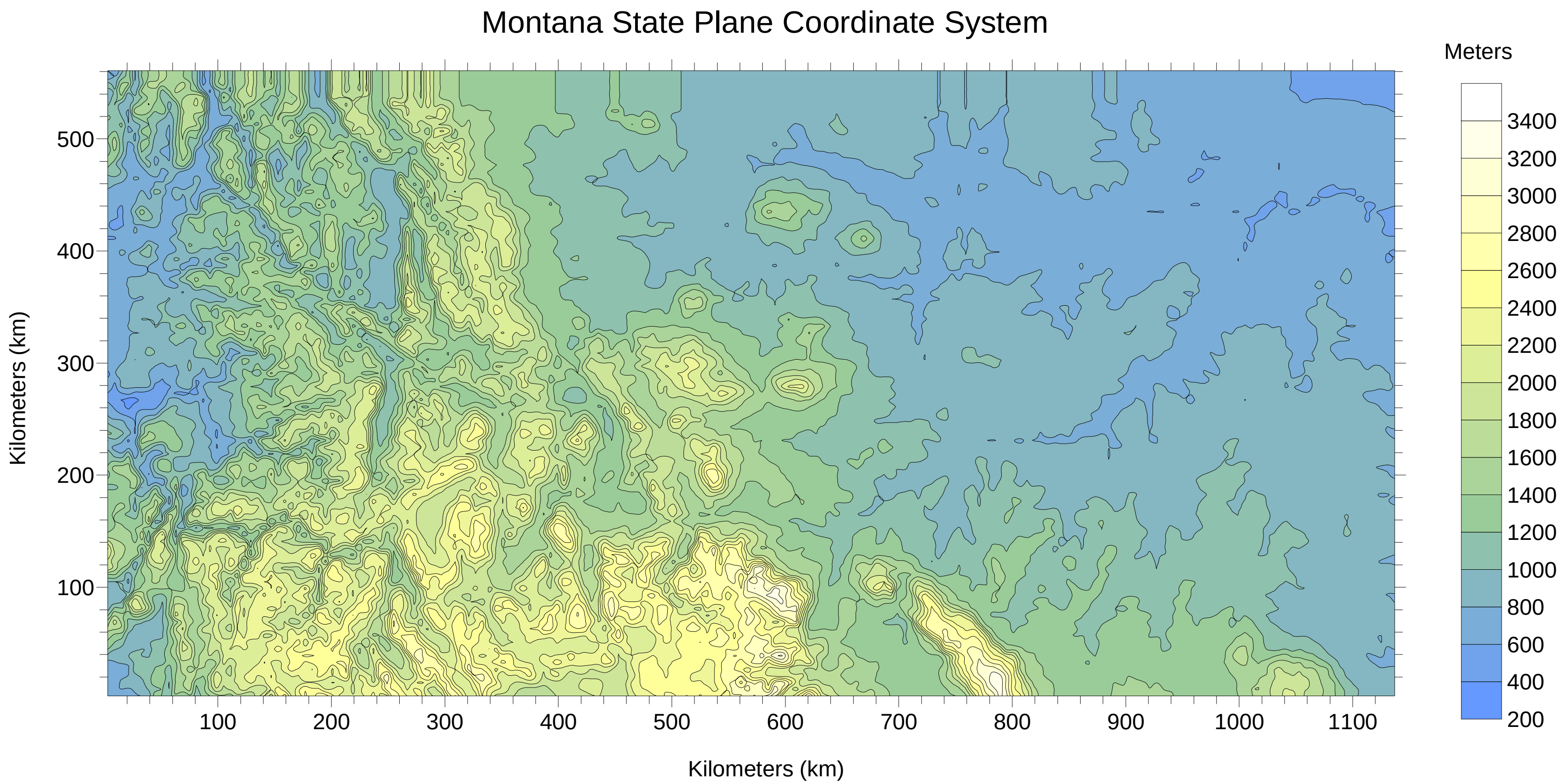
The CALMET component of the CALPUFF modeling system is a complex model that requires detailed geophysical and meteorological data. Geophysical data includes terrain elevation, land use, and surface characteristics. Meteorological data contains surface and upper air data, and precipitation information.

5. EPA. 1998. Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Report and Recommendations for Long-Range Transport Impacts. EPA-454/R-98-019. U.S. Environmental Protection Agency. Research Triangle Park, NC.

3.3 GEOPHYSICAL INPUTS

The Bee-Line CalPuffPro software includes terrain and land use data. The terrain data will be derived from 3-arc second (approximately 90 meters) digital elevation models (DEMs) at the 1:250,000 (250k) scale generated by the U.S. Geological Survey (USGS). Elevations are in meters relative to the mean sea level. Terrain data were unavailable for Canada so it will be extrapolated from the topography immediately to the south as shown in Figure 3.3A.

Figure 3.3A: Modeling Domain Terrain.



The land use data will be based on the Composite Theme Grid (CTG) Land Use and Land Cover (LULC) format at the same 1:250k scale as the terrain data. The land use data will be allocated into fourteen primary CALMET land use categories (Table 3.3). Land use data for Canada were also unavailable so the land will be assigned a rangeland use type (30) as displayed in Figure 3.3B.

Figure 3.3B: Modeling Domain Land Use Categories.

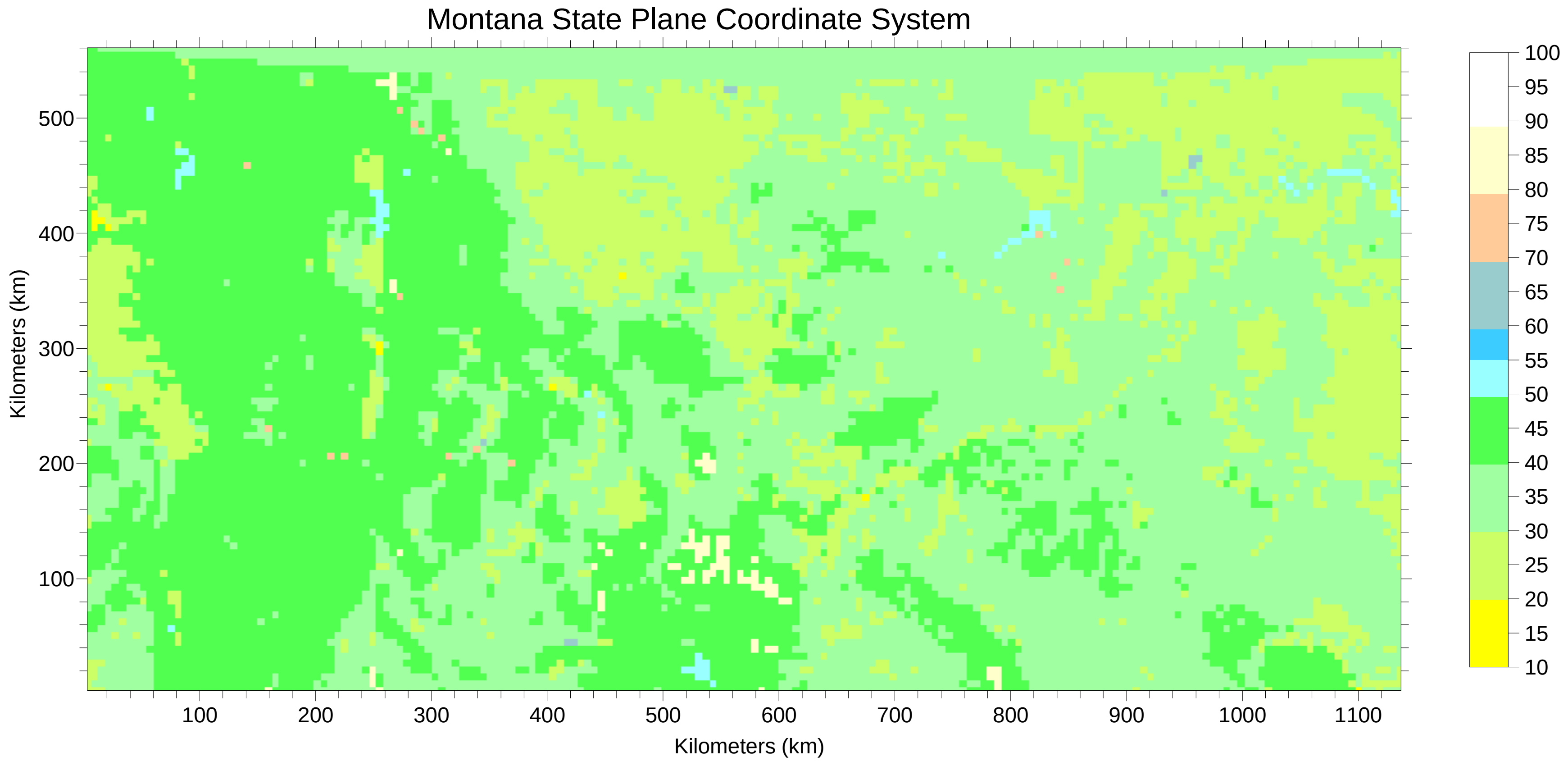


Table 3.3: Fourteen Primary CALMET Land Use Categories.

Default CALMET Land Use Categories and Associated Geophysical Parameters
Based on the U.S. Geological Survey Land Use Classification System
(14-Category System)

Land Use Type	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m²)	Leaf Area Index
10	Urban or Built-up Land	1.0	0.18	1.5	.25	0.0	0.2
20	Agricultural Land - Unirrigated	0.25	0.15	1.0	.15	0.0	3.0
-20'	Agricultural Land - Irrigated	0.25	0.15	0.5	.15	0.0	3.0
30	Rangeland	0.05	0.25	1.0	.15	0.0	0.5
40	Forest Land	1.0	0.10	1.0	.15	0.0	7.0
51	Small Water Body	0.001	0.10	0.0	1.0	0.0	0.0
54	Bays and Estuaries	0.001	0.10	0.0	1.0	0.0	0.0
55	Large Water Body	0.001	0.10	0.0	1.0	0.0	0.0
60	Wetland	1.0	0.10	0.5	.25	0.0	2.0
61	Forested Wetland	1.0	0.1	0.5	0.25	0.0	2.0
62	Nonforested Wetland	0.2	0.1	0.1	0.25	0.0	1.0
70	Barren Land	0.05	0.30	1.0	.15	0.0	0.05
80	Tundra	.20	0.30	0.5	.15	0.0	0.0
90	Perennial Snow or Ice	.20	0.70	0.5	.15	0.0	0.0

' Negative values indicate "irrigated" land use

3.4 METEORLOGICAL INPUTS

The Western Regional Air Partnership (WRAP) Regional Modeling Center (University of California, Riverside, CA) has committed to deliver MM5 meteorological (met) data for the years 2001 through 2003 to the MDEQ. These hourly dataset will be developed from fifth generation Penn State/NCAR (National Center For Atmospheric Research, Boulder, CO) three-dimensional mesoscale weather prediction model that produces wind fields on the same scale. The grids sizes will be 36 km for all three years that will expand the entire modeling domain. The National Park Service has supplied the MDEQ with 1996 MM5 (36 km) meteorological dataset. To assess CALPUFF modeling intricacies, this data will be used for preliminary modeling until the other met data are available.

The surface/upper air and precipitation data will be acquired from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Centers (NCDC). Hourly surface met data includes wind speed and direction, temperature, cloud cover, ceiling height, surface pressure, and relative humidity. Surface meteorological (met) data will also be obtained for two Canadian sites through NCDC: Medicine Hat, Alberta and Estevan, Saskatchewan. Twice-daily upper air data contains wind speed and direction, temperature, pressure, and elevation. The hourly precipitation data contains the precipitation rates and precipitation type code associated with surface data files. Only those precipitation stations located in the modeling domain will be included since the domain is so extensive. Table 3.4A lists thirty-one NCDC surface meteorological stations and relevant information that will be used in the modeling analyses.

Table 3.4A: Surface Meteorological Stations.

Station	State/ Country	WBAN[a] ID	Station Code	Grid Coordinates		Coordinates[b]		Elevation (m)[d]	Anemometer Height (m)	Time Zone
				X	Y	Latitude (NAD83)[c]	Longitude (NAD83)			
Billings	MT	24033	BIL	673825	172705	45.808	108.540	1087	10.00[e]	7
Bozeman	MT	24132	BZN	471785	173608	45.794	111.152	1349	10.00[f]	7
Butte	MT	24135	BTM	367559	193375	45.953	112.513	1689	10.00[f]	7
Cut Bank	MT	24137	CTB	388636	487259	48.608	112.376	1170	10.00[f]	7
Dillon	MT	24138	DLN	360659	115806	45.255	112.552	1598	10.00[f]	7
Glasgow	MT	94008	GGW	814110	444755	48.214	106.621	699	10.00[e]	7
Great Falls	MT	24143	GTF	458135	359171	47.473	111.382	1117	10.00[e]	7
Havre	MT	94012	HVR	580293	477865	48.559	109.780	788	10.00[f]	7
Helena	MT	24144	HLN	411115	264112	46.606	111.964	1167	10.00[e]	7
Kalispell	MT	24146	FCA	248045	462605	48.304	114.264	906	7.92[e]	7
Lewistown	MT	24036	LWT	603797	311134	47.049	109.467	1263	10.06[e]	7
Livingston	MT	24150	LVM	526041	161595	45.699	110.448	1418	10.00[f]	7
Miles City	MT	24037	MLS	877738	248998	46.428	105.886	801	10.00[f]	7
Missoula	MT	24153	MSO	250015	306636	46.921	114.093	973	10.00[e]	7
Boise	ID	24131	BOI	57389	-52671	43.565	116.220	865	10.00[e]	7

Station	State/ Country	WBAN[a] ID	Station Code	Grid Coordinates X	Grid Coordinates Y	Coordinates[b] Latitude (NAD83)[c]	Coordinates[b] Longitude (NAD83)	Elevation (m)[d]	Anemometer Height (m)	Time Zone
Coeur d'Alene	ID	24136	COE	52595	416389	47.679	116.802	707	10.00[f]	7
Pocatello	ID	24156	PIH	349171	-143363	42.92	112.571	1353	10.00[e]	7
Rexburg	ID	94194	RXE	414869	-43649	43.834	111.881	1481	10.00[f]	7
Salmon	ID	24196	SMN	255322	106013	45.074	113.529	1233	10.00[f]	7
Bismarck	ND	24011	BIS	1266552	317294	46.774	100.748	502	10.00[e]	6
Dickinson	ND	24012	DIK	1110543	305206	46.797	102.802	788	10.00[f]	6
Minot	ND	24013	MOT	1208440	468580	48.259	101.281	523	10.00[f]	6
Williston	ND	94014	ISN	1035942	453045	48.195	103.642	580	6.10[e]	6
Rapid City	SD	24090	RAP	1116674	-951	44.046	103.054	963	9.75[g]	7
Spokane	WA	24157	GEG	-2498	405056	47.621	117.528	718	10.00[e]	8
Casper	WY	24089	CPR	859003	-143037	42.898	106.473	1627	10.00[e]	7
Lander	WY	24021	LND	662852	-159097	42.817	108.733	1694	10.00[e]	7
Riverton	WY	24061	RIV	685693	-132898	43.064	108.459	1663	10.00[f]	7
Sheridan	WY	24029	SHR	800522	60712	44.774	106.976	1208	10.00[e]	7
Estevan	CA[h]	24092	YEN	1075467	571843	49.217	102.967	581	10.00[f]	6
Medicine Hat	CA	25118	YXH	512712	641678	50.017	110.717	716	10.00[f]	7

a. WBAN = Weather Bureau Army Navy. WBAN ID is the five-digit station identifier used at NCDC for digital data storage and general station identification purposes invented in the 1950's.
b. U.S. latitudes and longitudes were obtained from following web site except for Coeur d'Alene and Salmon, ID: ftp://ftp.ncdc.noaa.gov/pub/data/inventories/ASOSLST.XLS. For these two sites, the latitudes and longitudes were acquired from ftp://ftp.ncdc.noaa.gov/pub/data/inventories/COOP-ACT.TXT. The coordinates for the two Canadian stations were obtained from ftp://ftp.ncdc.noaa.gov/pub/data/inventories/ISH-HISTORY.TXT.
c. NAD83 = North American Datum 1983.
d. Elevations were obtained NOAA NCDC Integrated Surface Hourly (ISH) Database Station List (http://www.ncdc.noaa.gov/oa/climate/surfaceinventories.html); m = meters.
e. The anemometer heights were obtained from the following web site: http://www.wcc.nrcs.usda.gov/climate/windrose.html.
f. The anemometer heights for these stations could not be identified; therefore, the default National Weather Service anemometer height (10 m) was assigned.
g. This anemometer height was obtained through the following web site: ftp://ftp.ncdc.noaa.gov/pub/data/inventories/.
h. CA = Canada.

The surface data will be augmented by data from five additional met stations that measured the wind speed, wind direction, and air temperature during the period of interest (2001 - 2003). The Air Monitoring and Data Management Section in the Planning, Prevention, and Assistance Division, Montana Department of Environmental Quality oversees two industrial sites: Peabody Coal (site number 30-087-0722) and Spring Creek Coal (site number 30-003-0018). The National Park Service maintains the final three meteorological stations: Glacier (site ID 30-029-8001), Theodore

Roosevelt (site ID 38-007-0002), and Yellowstone (site ID 56-039-1011) National Parks. The met data for these national parks will be obtained from the Air Resources Specialist, Inc. web site for the National Park Service (http://12.45.109.6/pls/portal30/data_request2.mainfile). Table 4.3B lists these five met stations and relevant information.

Table 3.4B: Five Additional Surface Meteorological Stations.

Station	State	Station Code[a]	Grid Coordinates		Coordinates[b]		Elevation (m)[d]	Anemometer Height (m)[d]	Time Zone	Comment
			X	Y	Latitude (NAD83)[c]	Longitude (NAD83)				
Glacier NP	MT	GNP	268075	482914	48.510	113.996	976	10.00	7	Insufficient Temperature Data for 2003
Peabody	MT	PEA	825080	178533	45.819	106.602	992	16.00	7	These data set are complete for 2001 - 2003
Spring Creek	MT	SCR	806341	99821	45.117	106.877	1169	10.00	7	
Theodore NP	ND[e]	TNP	1065769	312123	46.895	103.378	850	10.00	7	
Yellowstone NP	WY[f]	YNP	528398	34873	44.560	110.401	2468	10.00	7	

a. Station Codes are arbitrary.
b. The national park latitude, longitude, and elevations will be obtained from the Air Resources Specialist, Inc. web site for the National Park Service (http://12.45.109.6/pls/portal30/data_request2.mainfile). The corresponding information for the MDEQ met stations is collected internally.
c. NAD83 = North American Datum 1983.
d. m = meters.
e. ND = North Dakota.
f. WY = Wyoming.

Upper air data is available for one Canadian and seven western U.S. sites. Spokane, Washington, will be included to represent western Montana. Table 3.4C lists the eight locations of the upper air data and additional information.

Table 3.4C: Upper Air Sites.

Station	State/ Country	WBAN[a] ID	Station Code	Grid Coordinates		Coordinates[b]		Elevation (m)[c]	Time Zone
				X	Y	Latitude	Longitude		
Glasgow	MT	94008	GGW	813957	442859	48.200	106.620	693	7
Great Falls	MT	04102	GTF	458315	357277	47.450	111.380	1130	7
Boise	ID	24131	BOI	57176	-52318	43.570	116.220	871	7
Bismarck	ND	24011	BIS	1266552	317294	46.770	100.750	503	6

Station	State/ Country	WBAN[a] ID	Station Code	Grid Coordinates		Coordinates[b]		Elevation (m)[c]	Time Zone
				X	Y	Latitude	Longitude		
Rapid City	SD	94043	RAP	1103707	223	44.070	103.210	1037	7
Spokane	WA	04106	GEG	-9022	412770	47.680	117.630	728	8
Riverton	WY	24061	RIW	684047	-131807	43.060	108.470	1688	7
Brooks	CA[d]	25146	YBP	429973	711887	50.630	111.900	759	7

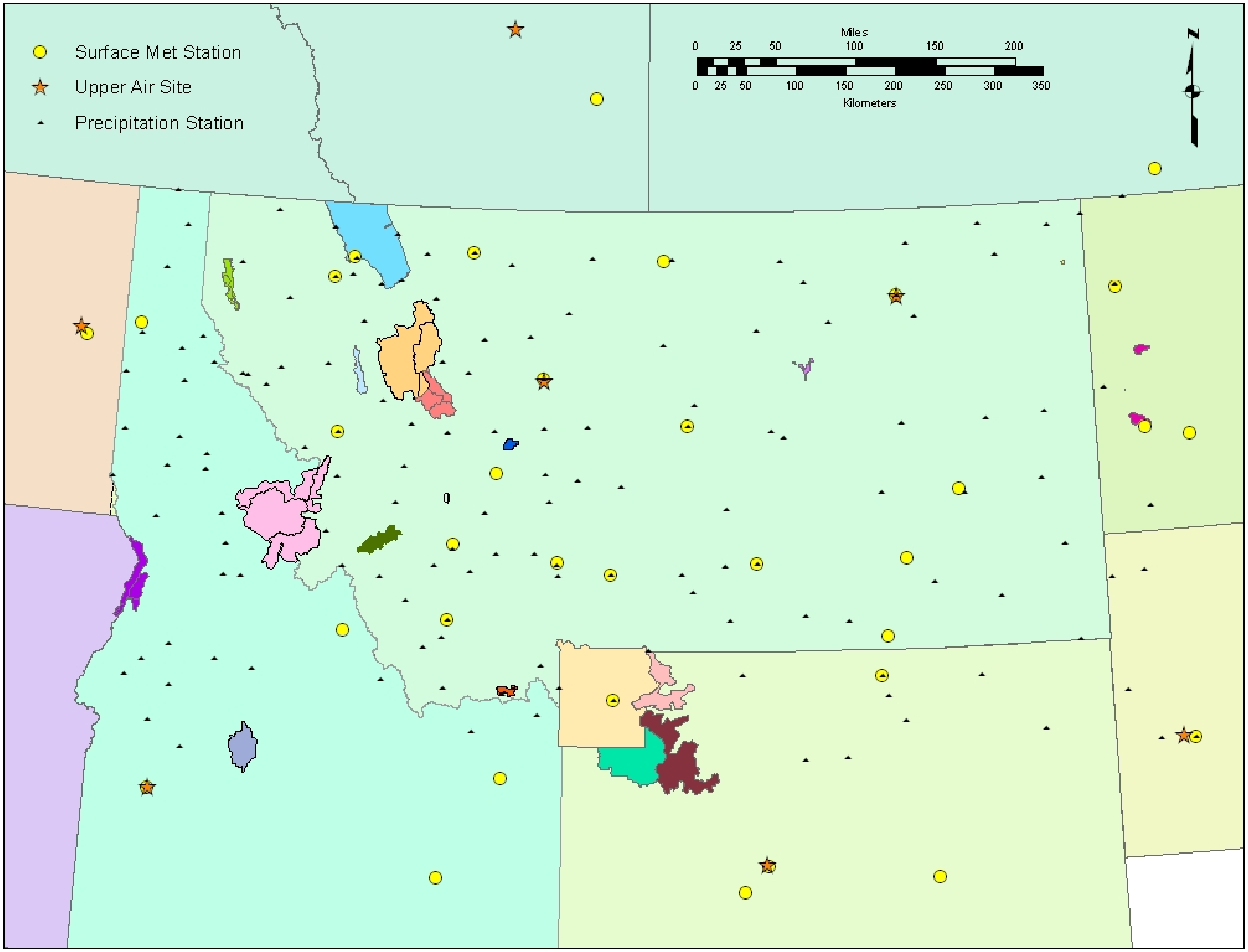
a. WBAN = Weather Bureau Army Navy.
b. Information was obtained from the following web site: http://raob.fsl.noaa.gov/intl/intl2000.wban.
c. m = meters.
d. CA = Canada.

Precipitation data will be obtained from two hundred and twenty-two (222) stations and are listed in Appendix B. Relevant information includes the grid coordinates, latitude and longitude (NAD83), elevation, years of available data, and time zone are included. Table 3.4D summarizes the potential total number and type of met stations, which are displayed in Figure 3.3.

Table 3.4D: Number And Type Of Met Stations.

Met Type	Number of Sites
Surface Air	36
Upper Air	8
Precipitation	148

Figure 3.3: Locations of Met Stations.



Any station, regardless of the type (surface, upper, or precipitation), located within the individual modeling subdomain for a BART-eligible/subject model run will be included in CALMET. Other stations will be selected depending upon their respective locations relative to the modeling subdomain.

3.5 CALMET CONTROL PARAMETERS

A listing of CALMET parameters that will be used in the Montana BART visibility demonstration is provided in Table 3.5. The IWAQM model defaults are also listed for comparison. The settings that differ from the IWAQM defaults are highlighted with the reasons for the differences noted. Some variables will change depending on the met year as noted by "will vary" or "Will Vary".

Table 3.5: Summary of CALMET Parameters.

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
GEO.DAT	Name of Geophysical data file	GEO.DAT	GEO.DAT
SURF.DAT	Name of Surface data file	SURF.DAT	SURF.DAT
PRECIP.DAT	Name of Precipitation data file	PRECIP.DAT	PRECIP.DAT
CALMET.LST	Name of CALMET list file	CALMET.LST	CALMET.LST
CALMET.DAT	Name of CALMET output file	CALMET.DAT	CALMET.DAT
MM4.DAT	MM4/MM5 data file	YEARMM4.DAT, YEARMM5.DAT	MM5.DAT
PACOUT	MM4/MM5 output file {inconsequential}	PACDAT	Not Used
LCFILES	Keep file names in lower case {inconsequential}	T	T
NUSTA	Number of upper air data sites	≥ 1	Will vary depending on met year
UP1.DAT	Name of #1 Upper Air Station {inconsequential}	UPN.DAT	Will Use 5-Number Upper Air Station Code With Met Year (XXXXX-YY.UA)[b]
UP2.DAT	Name of #2 Upper Air Station, etc. {inconsequential}	UPN.DAT	
IBYR	Beginning year	Limited by MM4/MM5 Data	Will Vary
IBMO	Beginning month		Will Vary

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IBDY	Beginning day		Will Vary
IBHR	Beginning hour		Will Vary
IRLG	Length of run		Will Vary
End of Year Specific Inputs			
SEADAT.DAT	Overwater files	SEAn.DAT	Not Used {Domain is land-locked}
Other Files	Subgroup d: Diagnostic, Prognostic, etc. tests	Not Used	Not Used
IBTZ	Base time zone {inconsequential}	No Default	7
IRTYPE	Output file type to create (1 for CALPUFF)	1	1
LCALGRD	Compute Data Fields for CALGRID? (T = run CALGRID)	T	T
ITEST	Flag to stop run after setup phase (2 = run)	2	2
PMAP	Map Projection	LCC	LCC
FEAST	False Easting (km) (if PMAP = TTM, LCC or LAZA) {inconsequential}	0	600
FNORTH	False Northing (km) (if PMAP = TTM, LCC or LAZA)	0	0
IUTMZN	UTM Zone (Used if PMAT = UTM)	User Defined	-999
UTMHEM	Hemisphere for UTM Projection	N	N
RLAT0	Latitude (decimal degrees) of projection origin	User Defined	44.25 N
RLON0	Longitude (decimal degrees) of projection origin	User Defined	109.5 W
XLAT1	Latitude of 1st standard parallel	User Defined	44 N
XLAT2	Latitude of 2nd standard parallel	User Defined	49 N

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
DATUM	Datum region for output coordinates	WGS-G	WGS-G
NX	Number of east-west grid cells	<= 190	To be determined, but <= 190
NY	Number of north-south grid cells	<= 135	To be determined, but <= 135
DGRIDKM	Grid spacing (km)	<= 12	6
XORIGKM	Southwest grid cell X coordinate	Use modeled coordinate system	0
YORIGKM	Southwest grid cell Y coordinate	Use modeled coordinate system	0
NZ	Number of vertical layers	>= 4	10
ZFACE	Vertical cell face heights (NZ + 1 values)	User Defined	0., 20., 40., 80., 160., 300., 600., 1000., 1500., 2200., 3000.
LSAVE	Save met. data fields in an unformatted file?	T	T
IFOMRO	Format of unformatted file (1 for CALPUFF)	1	1
LPRINT	Print met. fields?	F	F
IPRINF	Line printer output options.	Not Used	Not Used
NOOBS	No Observation Mode (MM5 gridded data used for the initial guess field)	0	0
NSSTA	Number of stations in SURF.DAT file	>= 1	Will vary with met year
NPSTA	Number of stations in PRECIP.DAT file	>= 1	Will vary with met year
ICLOUD	Is cloud data to be input as gridded fields? (0 = no) {As recommended by Kevin Golden, EPA Region VIII, 1/17/06}	0	0
IFORMS	Format of surface data (2 = formatted)	2	2
IFORMP	Format of precipitation data (2 = formatted)	2	2
IFORMC	Format of cloud data (2 = formatted)	2	2

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IWFCOD	Generate winds by diagnostic wind module? (1 = yes)	1	1
IFRADJ	Adjust winds using Froude number effects? (1 = yes)	1	1
IKINE	Adjust winds using kinematic effects? (0 = no)	0	0
IOBR	Use O'Brien procedure for vertical winds? (0 = no)	0	0
ISLOPE	Compute slope flows? (1 = yes)	1	1
IEXTRP	Extrapolate surface winds to upper layers (-4 = use similarity theory and ignore layer 1 of upper air station data)	-4	-4
ICALM	Extrapolate surface calms to upper layers? (0 = no)	0	0
BIAS	Surface/upper-air weighting factors (NZ values; IWAQM: NZ*0) other options were not available)	-1, (NZ-1) * 0	-1, (NZ-1) * 0
IPROG	Using prognostic or MM-FDDA data? (Use MM4/5 as initial guess wind)	MM4 or MM5	MM5 = 14
ISTEPPG	Timestep (hours) of the prognostic model input data	1	1
LVARY	Use varying radius to develop surface winds?	F	F
RMAX1	Maximum surface over land extrapolation radius (km)	No Default	40
RMAX2	Maximum aloft over land extrapolation radius (km)	No Default	100
RMAX3	Maximum over water extrapolation radius (km)	No Default	5
RMIN	Minimum extrapolation radius (km)	0.1	0.1
RMIN2	Distance (km) around an upper air site where vertical extrapolation is excluded {set to –1 if IEXTRP = ± 4}	4	-1
TERRAD	Radius of influence of terrain features (km) {evaluated by Kevin Golden, Region VIII, 1/17/06}	No Default	15
R1	Relative weight at surface of Step 1 field and observation (km) {evaluated by Kevin Golden,	No Default	20

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
	Region VIII, 1/17/06}		
R2	Relative weight aloft of Step 1 field and observation (km) {evaluated by Kevin Golden, Region VIII, 1/17/06}	No Default	50
RPROG	Relative weighting parameter of the prognostic wind field data (km)	0	0
DIVLIM	Maximum acceptable divergence	5.0 E-6	5.0 E-6
NITER	Max number of passes in divergence minimization	50	50
NSMTH	Number of passes in Smoothing (NZ values)	2, 4*(NZ-1)	2, 4*(NZ-1)
NINTR2	Max number of stations for interpolations (NZ values)	NZ *99	NZ *99
CRITFN	Critical Froude number	1.0	1.0
ALPHA	Empirical factor triggering kinematic effects	0.1	0.1
FEXTR2	Multiplicative scaling factor for extrapolation of surface observations to upper layers	NZ*0.0	NZ*0.0
NBAR	Number of barriers to interpolation of the wind fields (other variables if NBAR>0)	0	0
IDIOPT1	Compute temperature from observations (0 = true)	0	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	No Default	Will vary with met year
IDIOPT2	Compute domain-average lapse rates? (0 = true)	0	0
IUPT	Station for lapse rates (between 1 and NUSTA)	User Defined	Will vary with met year
ZUPT	Depth of domain-average lapse rate (m)	200.	200.
IDIOPT3	Compute internally initial guess winds? (0 = true)	0	0
IUPWND	Upper air station for domain winds (-1 = $1/r^2$ interpolation of all stations)	-1	-1
ZUPWND	Bottom, top of layer For 1st guess winds (m)	1, 1000	1, 1000

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IDIOPT4	Read surface winds from SURF.DAT? (0 = true)	0	0
IDIOPT5	Read aloft winds from UPN.DAT? (0 = true)	0	0
LLBREZE	Use lake breeze module?	F	F
CONSTB	Neutral mixing height B constant	1.41	1.41
CONSTE	Convective mixing height E constant	0.15	0.15
CONSTN	Stable mixing height N constant	2400	2400
CONSTW	Over water mixing height W constant	0.16	0.16
FCORIOL	Absolute value of Coriolis parameter	1.0 E-4	1.0 E-4
IAVEXZI	Spatial averaging of mixing heights? (1 = true)	1	1
MNMDAV	Max averaging radius (number of grid cells)	1	1
HAFANG	Half-angle for looking upwind (degrees)	30	30
ILEVZI	Layer to use in upwind averaging (between 1 and NZ) {MDEQ professional judgement}	1	3
DPTMIN	Minimum capping potential temperature lapse rate	0.001	0.001
DZZI	Depth for computing capping lapse rate (m)	200	200
ZIMIN	Minimum over land mixing height (m)	50	50
ZIMAX	Maximum over land mixing height above ground level (m) {MDEQ professional judgement}	3000	2800
ZIMINW	Minimum over water mixing height (m)	50	50
ZIMAXW	Maximum over water mixing height (m) {MDEQ professional judgement}	3000	2800
ITPROG	3D temperature from observations or from prognostic data?	0	0

CALMET Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IRAD	Form of temperature interpolation (1 = 1/r)	1	1
TRADKM	Radius of temperature interpolation (km)	500	500
NUMTS	Max number of stations in temperature interpolations	5	5
IAVET	Conduct spatial averaging of temperature? (1 = true)	1	1
TGDEFB	Default temperature gradient below the mixing height over water (K/m)	-0.0098	-0.0098
TGDEFA	Default temperature gradient above the mixing height over water (K/m)	-0.0045	-0.0045
JWAT1	Beginning (JWAT1) and ending (JWAT2) land use categories for temperature interpolation over water (bigger than largest land use to disable)	999	999
JWAT2		999	999
NFLAGP	Method for precipitation interpolation (2 = $1/r^2$)	2	2
SIGMAP	Precipitation radius for interpolation (km)	100.0	100.0
CUTP	Minimum cut off precipitation rate (mm/hr)	0.01	0.01
SSn	NSSTA input records for surface stations	User Defined	Will vary with met year
USn	NUSTA input records for Upper-air stations	User Defined	Will vary with met year
PSn	NPSTA input records for precipitation stations	User Defined	Will vary with met year
JSUP	PG Stability class above mixed layer	5	5

a. IWAQM = Interagency Workgroup on Air Quality Modeling.
b. YY = Year of meteorology: 2001 = 01, 2002 = 02, and 2003 = 03.

The CALMET output will contain the hourly gridded meteorological data. This data is fed into the dispersion model, CALPUFF.

4.0 CALPUFF INPUTS

The CALPUFF model requires the following data: source emissions, receptor locations/elevations (where the air pollutant concentrations will be calculated), meteorological, and geophysical. Background concentrations of ozone and ammonia will also be supplied. The meteorological and geophysical data will be first processed by CALMET, as discussed above, before entering CALPUFF model.

4.1 SOURCE EMISSIONS AND STACK DATA

For both BART applicability and degree of visibility improvement analyses, the guidelines specify that only primary emissions need to be considered.[2] For the Montana BART-related modeling, the emissions of concern are sulfur dioxide (SO_2), nitrogen oxides (NO_x), and directly emitted particulate matter less than or equal to 10 microns (PM_{10}). The PM_{10} component includes both condensable and filterable particulates, if data are available.

The BART guidelines discuss inclusion of volatile organic compounds (VOCs) and ammonia (NH_3) emissions in the modeling analysis, but the States were best qualified to make that decision. Due to lack of data, the MDEQ does not intend to include these emissions.

As of February 2006, ten facilities have been identified with potential Montana BART-eligible sources (Figure 1B). The estimated 2002 annual emissions of SO_2, NO_x, and PM_{10} used in the preliminary regional haze modeling by WRAP are provided in Table 4.1A. These emissions data from nine major point sources were obtained from the EPA National Emission Inventory (NEI). ASARCO was not included in the WRAP modeling since some confusion arose due to Asarco's operational status. This facility's operations were "temporarily suspended" since Spring of 2001. However, Asarco will remain on the MDEQ BART-eligible list, and in the event of reactivation of the East Helena facility, the MDEQ will seek compliance with BART.

Table 4.1A: Nine Facilities With Potential Montana BART-Eligible Sources And WRAP Estimated Annual Emissions.

BART-Eligible Facilities	WRAP[a] Annual Emissions Estimates			Calculated From WRAP Emissions Estimates		
	SO_2 (tpy)[b]	NO_x (tpy)	PM_{10} (tpy)	SO_2 (g/sec)[c]	NO_x (g/sec)	PM_{10} (g/sec)
Ash Grove Cement Company – Montana City	234	1,826	262	6.73	52.53	7.54
CHS Inc. (formerly Cenex Harvest States Cooperatives) – Laurel	2,064	974	91	59.38	28.02	2.62
Columbia Falls Aluminum LLC	584	7	224	16.80	0.20	6.44
ExxonMobil Pipeline Company – Billings Refinery	5,351	962	177	153.93	27.67	5.09
Holcim – Trident Plant	283	1,500	215	8.14	43.15	6.19
Montana Sulphur & Chemical Company	2,403	5	0	69.13	0.14	0.00

BART-Eligible Facilities	WRAP[a] Annual Emissions Estimates			Calculated From WRAP Emissions Estimates		
	SO_2 (tpy)[b]	NO_x (tpy)	PM_{10} (tpy)	SO_2 (g/sec)[c]	NO_x (g/sec)	PM_{10} (g/sec)
PPL Montana, LLC – Corette Plant	3,135	1,703	136	90.19	48.99	3.90
PPL Montana, LLC – Colstrip 1 + 2	16,735	32,631	498	481.40	938.71	14.33
Smurfit-Stone Container Enterprises, Inc.– Missoula	199	1,116	324	5.73	32.10	9.32

a. WRAP = Western Regional Air Partnership.
b. tpy = tons per year.
c. g/sec = grams per second.

The owner or operator of all potential Montana BART-eligible source(s) will be required to submit emissions data of the air pollutants of concern to the MDEQ. These reported emissions data will represent the maximum steady-state 24-hour actual emissions rates (ignoring periods of startup, shutdown, and malfunction) from all BART-eligible source(s) at a given facility during a calendar year in the 2001 to 2003 period.

If the emissions during this period do not represent normal maximum production, the maximum 24-hour actual emission rates will be obtained from another recent year. All emissions data will be compared to the Montana annual emissions inventory reports for major stationary point sources during the same time period (2001 – 2003). For modeling, all emissions will be converted into grams per second (g/sec).

Including emissions data, the owner or operator of all potential Montana BART-eligible source(s) will have an opportunity to submit stack parameter data. Since the stack gas exit temperature and velocity may not be identical to produce the maximum 24-hour emissions of each pollutant, information should be provided on a pollutant basis. The applicable stack parameters are listed in Table 4.1C. The owner or operator of all potential Montana BART-eligible source(s) will also need to specify the relevant units as noted in the table.

Table 4.1C: Example of Facility BART-Eligible Source Information.

Source	Pollutant	24-Hour Maximum Emission Rate		Year of Maximum 24-Hour Actual Emissions	Stack Coordinates			Stack Height[c]		Stack Elevation		Stack Inside Diameter		Gas Exit Temperature		Gas Exit Velocity	
		Value	Units[a]	(2001-2003)	X	Y	Datum[b]	Value	Units[d]	Value	Units[d]	Value	Units[d]	Value	Units[e]	Value	Units[f]
Unit 1	NO_X																
	SO_2																
	PM_{10}																
Unit 2	NO_X																
	SO_2																
	PM_{10}																
Repeat the previous 3 rows, if necessary, for each of the remaining BART-eligible units located at the same facility.																	

a. Typical emission rate units are pounds per day (lb/day) and tons per day (tons/day).
b. Typical stack coordinates would be latitude/longitude and Universe Transverse Mercator UTM). In both cases, datum must be specified: NAD27 or NAD83.
c. Stack height is above ground level.
d. Typical units of stack height, stack elevation, and inside stack diameter are feet (ft) and meters (m).
e. Typical units of gas exit temperature are Fahrenheit (F), Centigrade (C), and Kelvin (K).
f. Typical units of gas exit velocity are feet per second (ft/sec) and meters per second (m/sec).

If the stack parameters are not provided, the MDEQ will be obtained this information from previous MDEQ modeling demonstrations, stack tests, or current Title V permit applications. The stack base elevations will be estimated through use of DEMS (Digital Elevation Models) derived from USGS 1:24,000 topographic map series. Building wake effects (downwash) will not be considered.

The MDEQ will assume that 99% of the PM_{10} emissions are particulate matter less than or equal to 2.5 microns ($PM_{2.5}$). The remaining 1% will be considered elemental carbon (EC).

Several source categories will be treated differently due to available particulate matter (PM) source speciation profile data. Currently, the National Park Service (NSP) has recommended the following PM speciation data for coal-fired power plants:

Fine PM = 8%
Coarse PM = 11%
Elemental Carbon = 1%
Secondary Organic Aerosols (Organic Carbon) = 16%
Sulfates = 64%

The NPS also has PM speciation data for the following source categories: coal thermal dryers, gas-fired combustion turbines, large coal-fired boilers, large residual oil-fired boilers, lime kilns, oil-fired combustion turbines, and Portland cement kilns (http://www2.nature.nps.gov/air/permits/ect/index.cfm). Both the NPS and National Forest Service has requested that for any gas-fired combustion source, the "filterable" PM should be assigned as organic carbon (OC) and the "condensable" PM should be assigned as either primary sulfate or secondary organic aerosol (SOA), depending on the level of the SO_2 emissions. Any applicable PM speciation profiles relevant to the Montana emission sources will be used in the modeling demonstrations. If better speciation data becomes available before modeling is completed, the MDEQ will apply that information if time, resources, and other relevant factors permit.

Each BART-eligible source (unit) will be assigned a unique 3-letter code. This system will simplify the identification of the CALPUFF runs for tracking purposes. Some BART-eligible sources may not be BART-subject, but the identification codes will not change for those sources that continue in the BART modeling process.

4.2 RECEPTOR LOCATIONS

All twelve federally mandated Class I areas in Montana will be included in the modeling domain. These Class I areas are listed in Table 4.2A with the corresponding IMPROVE monitoring site codes, acreage, responsible federal land manager, and the public law and date of the Class I designation. Two of these Class I areas extend into neighboring states: Selway-Bitterroot Wilderness Area (Idaho) and Yellowstone National Park (Idaho and Wyoming).

Table 4.2A: Twelve Montana Federal Mandatory Class I Areas.

Class I Area	IMPROVE Code[a]	Acreage	Federal Land Manager	Public Law	Date
Anaconda-Pintler WA[b]	SULA1	157,803	USDA-FS[c]	88-577	September 3, 1964
Bob Marshall WA	MONT1	950,000	USDA-FS	88-577	September 3, 1964
Cabinet Mountains WA	CABI1	94,272	USDA-FS	88-577	September 3, 1964
Gates of the Mountains WA	GAMO1	28,562	USDA-FS	88-577	September 3, 1964

Class I Area	IMPROVE Code[a]	Acreage	Federal Land Manager	Public Law	Date
Glacier NP[d]	GLAC1	1,012,599	USDI-NPS[e]	61-171	May 11, 1910
Medicine Lake WA	YELL2	11,366	USDI-FWS[f]	94-557	October 19, 1976
Mission Mountain WA	MONT1	73,877	USDA-FS	93-632	January 3, 1975
Red Rock Lakes WA	YELL2	32,350	USDI-FWS	94-557	October 19, 1976
Scapegoat WA	MONT1	239,295	USDA-FS	92-395	August 20, 1972
Selway-Bitterroot WA[g]	SULA1	MT: 251,930 ID: 988,770	USDA-FS	88-577	September 3, 1964
U.L. Bend WA	ULBE1	20,890	USDI-FWS	94-557	October 19, 1976
Yellowstone NP[h]	YELL2	MT: 167,624 ID: 31,488 WY: 2,020,625	USDI-NPS	[i]	March 1, 1872

a. IMPROVE = Interagency Monitoring of Protected Visual Environments monitoring site code.
b. WA = Wilderness Area.
c. USDA-FS = U.S. Department of Agriculture - Forest Service.
d. NP = National Park.
e. USDI-NPS = U.S. Department of Interior - National Park Service.
f. USDI-FWS = U.S. Department of Interior – Fish and Wildlife Service.
g. Selway-Bitterroot Wilderness encompasses 1,240,700 acres; 988,770 acres are in Idaho and 251,930 acres are in Montana.
h. Yellowstone National Park total acreage is 2,219,737; 2,020,625 acres are in Wyoming, 167,624 acres are in Montana, and 31,488 acres are in Idaho.
i. 17 Stat. 32 (42nd Cong.), [44 FR 69124, Nov. 30, 1979; 45 FR 6103, Jan. 25, 1980].

Some of the IMPROVE monitoring site codes correspond to more than one Class I area indicating that a single IMPROVE monitoring site represents more than one Class I area. In these cases, the representative site is influenced by the same regionally important emission sources that impact the Class I area(s) it represents. All of these monitoring sites are also isolated as much as possible from local emission sources.

Six other Class I areas in neighboring states will be included in the analysis. These Class I areas may be affected by Montana BART-eligible/subject sources so they warranted inclusion. These Class I areas are listed in Table 4.2B with the corresponding IMPROVE site codes, location, acreage, responsible federal land manager, and the public law and date of Class I designation. One Class I area, Hells Canyon Wilderness Area, extends into two states: Idaho and Oregon.

Table 4.2B: Eight Neighboring Class I Areas Included In CALPUFF.

Class I Area	IMPROVE Code[a]	State	Acreage	Federal Land Manager	Public Law	Date
Hells Canyon WA[b]	HECA1	Idaho/ Oregon	ID: 83,800 OR: 192,700	USDA-FS[c]	94-199	December 31, 1065
North Absaroka WA	NOAB1	Wyoming	351,101	USDA-FS	88-577	September 3, 1964
Sawtooth WA	SAWT1	Idaho	216,383	USDA-FS	92-400	August 22, 1972
Teton WA	YELL2	Idaho	557,311	USDA-FS	88-577	September 3, 1964
Theodore Roosevelt NP[d]	THRO1	North Dakota	69,675	USDI-NPS[e]	80-38	October 5, 1989

Class I Area	IMPROVE Code[a]	State	Acreage	Federal Land Manager	Public Law	Date
Washakie WA	NOAB1	Wyoming	686,584	USDA-FS	92-476	October 9,1972

a. IMPROVE = Interagency Monitoring of Protected Visual Environments.
b. WA = Wilderness Area.
c. USDA-FS = U.S. Department of Agriculture - Forest Service.
c. USDA-FS = U.S. Department of Agriculture - Forest Service.
d. NP = National Park.
e. USDI-NPS = U.S. Department of Interior - National Park Service.
f. 17 Stat. 32 (42nd Cong.), [44 FR 69124, Nov. 30, 1979; 45 FR 6103, Jan. 25, 1980].

It should be noted that the Theodore Roosevelt National Park is composed of three separate units: North, South, and Elkhorn Ranch in the middle.

The NPS has provided the receptor locations with elevations for all eighteen Class I areas of concern. For the BART-eligible modeling phase, no distinction will be made for those Class I areas that expand into more than one state (i.e., Hells Canyon Wilderness Area extends into both Idaho and Oregon). For the subject-to-BART analyses, the receptors may be separated by State according to the receptor location.

Each Class I area will be assigned a unique MDEQ code for tracking purposes. The assigned MDEQ codes and number of receptors for the eighteen Class I areas are listed in Table 4.2C.

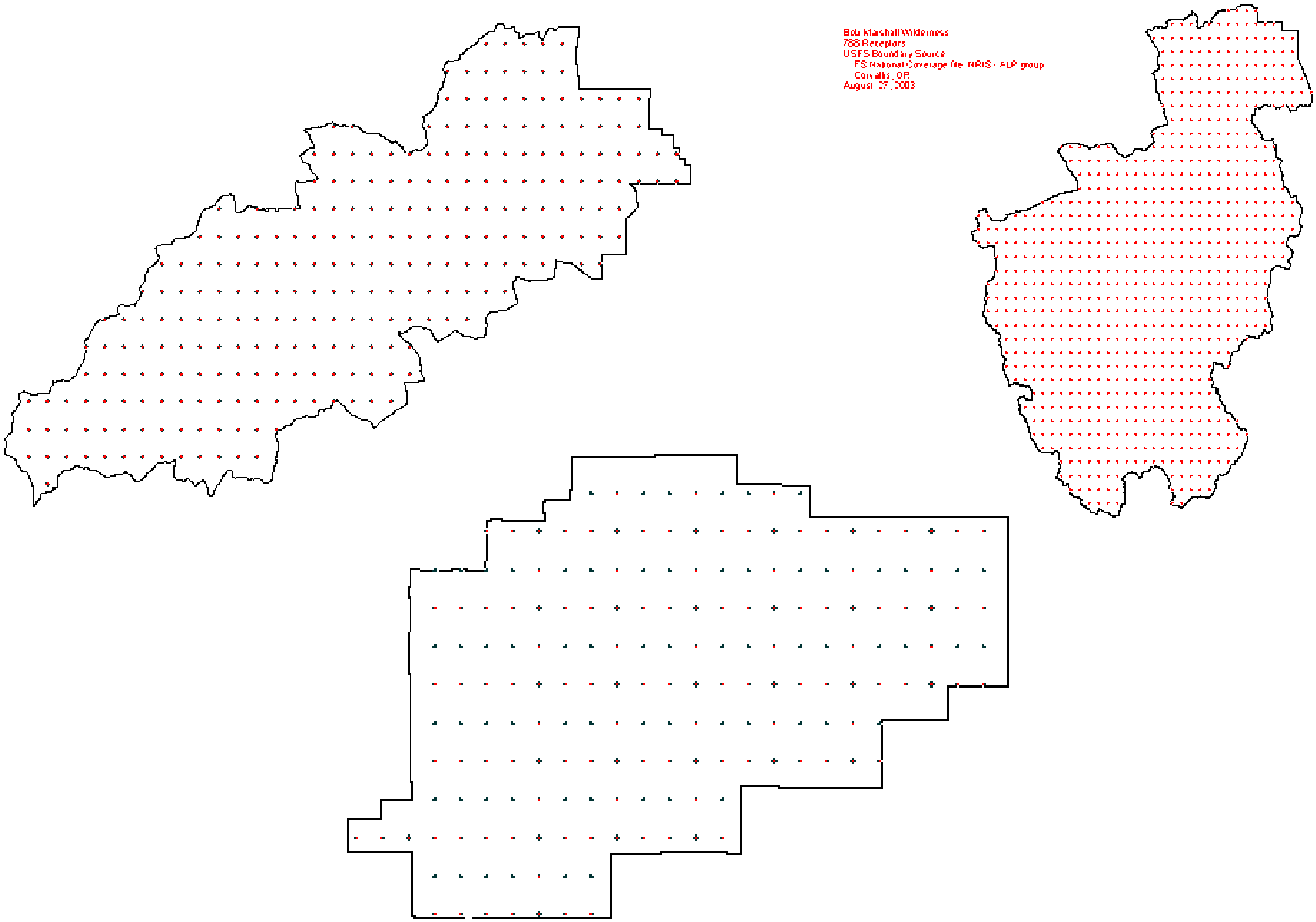
Table 4.2C: MDEQ Code and Number of Receptors Of Significant 18 Class I Areas.

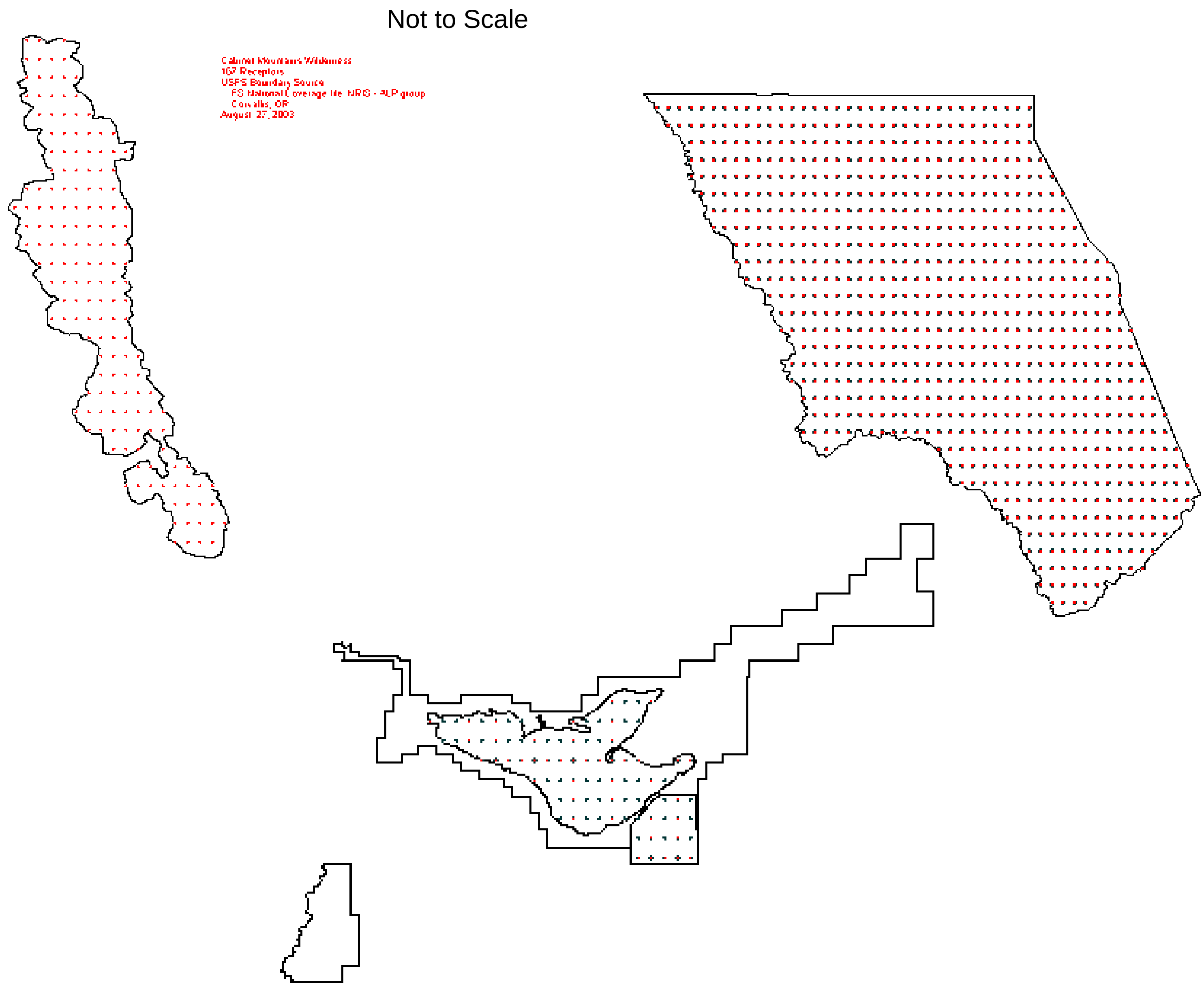
Class I Area	MDEQ Code	Number of Receptors	Class I Area	MDEQ Code	Number of Receptors
Anaconda-Pintler WA[a]	ana	267	Selway-Bitterroot WA – ID, MT	sel	575[c]
Bob Marshall WA	bob	788	U.L. Bend WA	ulb	134
Cabinet Mountains WA	cab	167	Yellowstone NP – ID, MT, WY	ynp	915[d]
Gates of the Mountains WA	gom	194	Hells Canyon – ID, OR	hec	353[d]
Glacier NP[b]	gnp	790	North Absaroka WA - WY	noab	567
Medicine Lake WA	med	89	Sawtooth WA – ID	saw	353
Mission Mountain WA	mim	130	Teton WA – WY	twa	940
Red Rock Lakes WA	red	222	Theodore Roosevelt NP - ND	thr	489[f]
Scapegoat WA	scap	423	Washakie WA	was	509

a. WA = Wilderness Area.
b. NP = National Park.
c. Selway-Bitterroot Wilderness Area receptors are located in Idaho and Montana.
d. Yellowstone National Park receptors are located in Montana, Idaho, and Wyoming.
e. Hells Canyon Wilderness Area receptors are located in Idaho and Oregon.
e. Theodore Roosevelt National Park has three separate units: North, South, and Elkhorn Ranch in the middle.

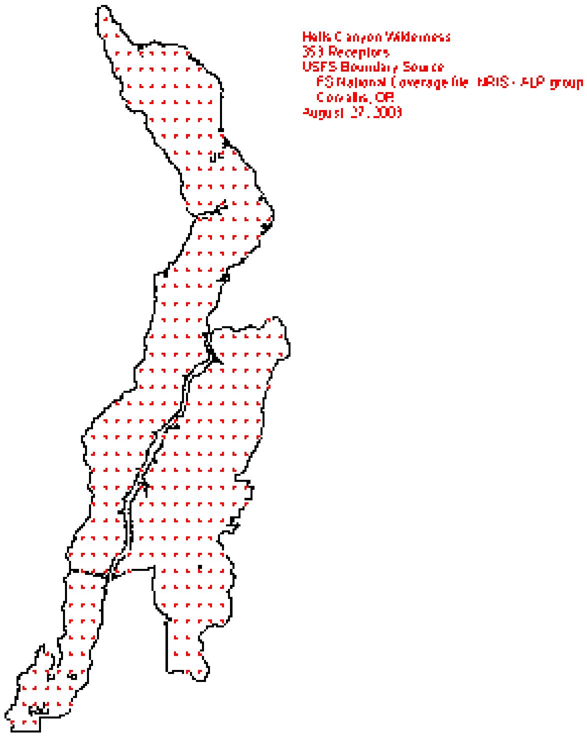
The locations of all relevant receptors are shown in Figure 4.2. Note that the receptor maps are not to scale or in alphabetical order.

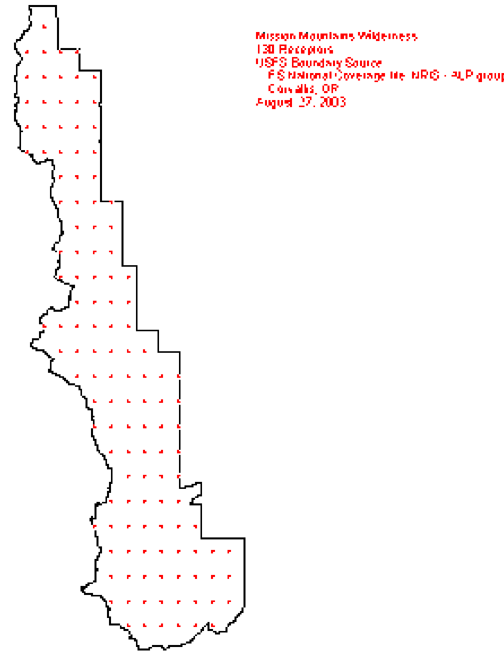
Figure 4.2: Receptor Locations of 18 Significant Class I Areas (Not to Scale).

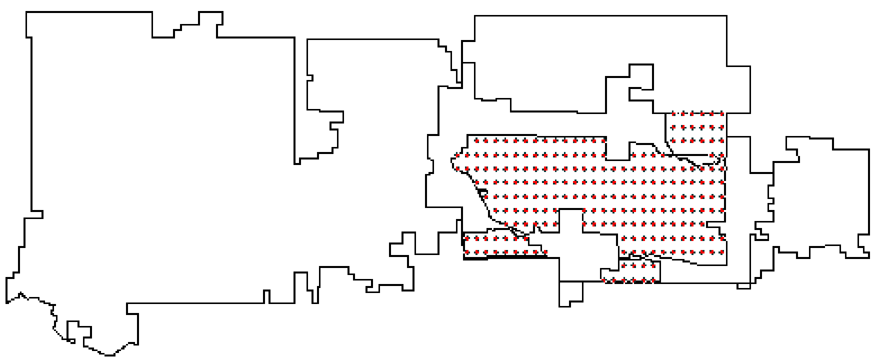



Not to Scale
Cabinet Mountains Wilderness
USFS Boundary Source
FS National Coverage file NRIS - ALP group
Corvallis, OR
August 27, 2003

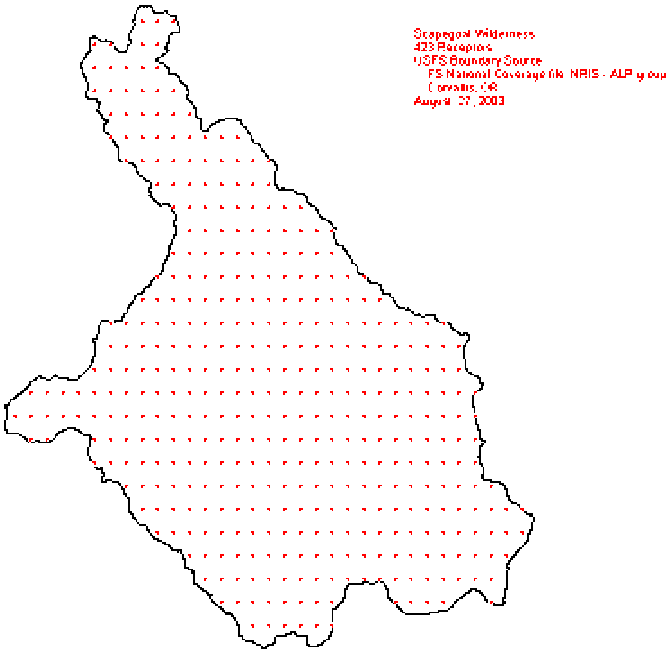
Not to Scale

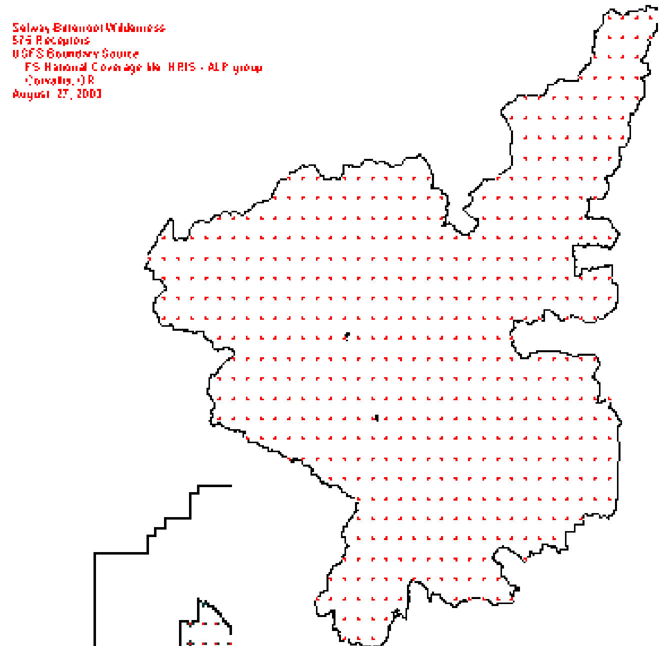

Hells Canyon Wilderness
353 Receptors
USFS Boundary Source
FS National Coverage file NRIS - ALP group
Corvallis, OR
August 27, 2003

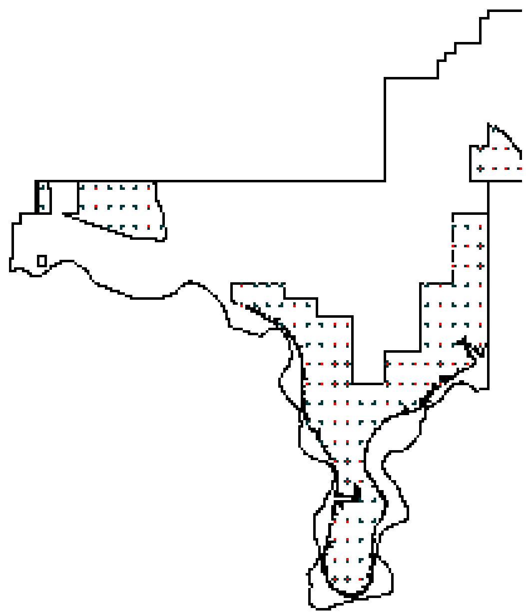

Mission Mountains Wilderness
130 Receptors
USFS Boundary Source
FS National Coverage file NRIS - ALP group
Corvallis, OR
August 27, 2003

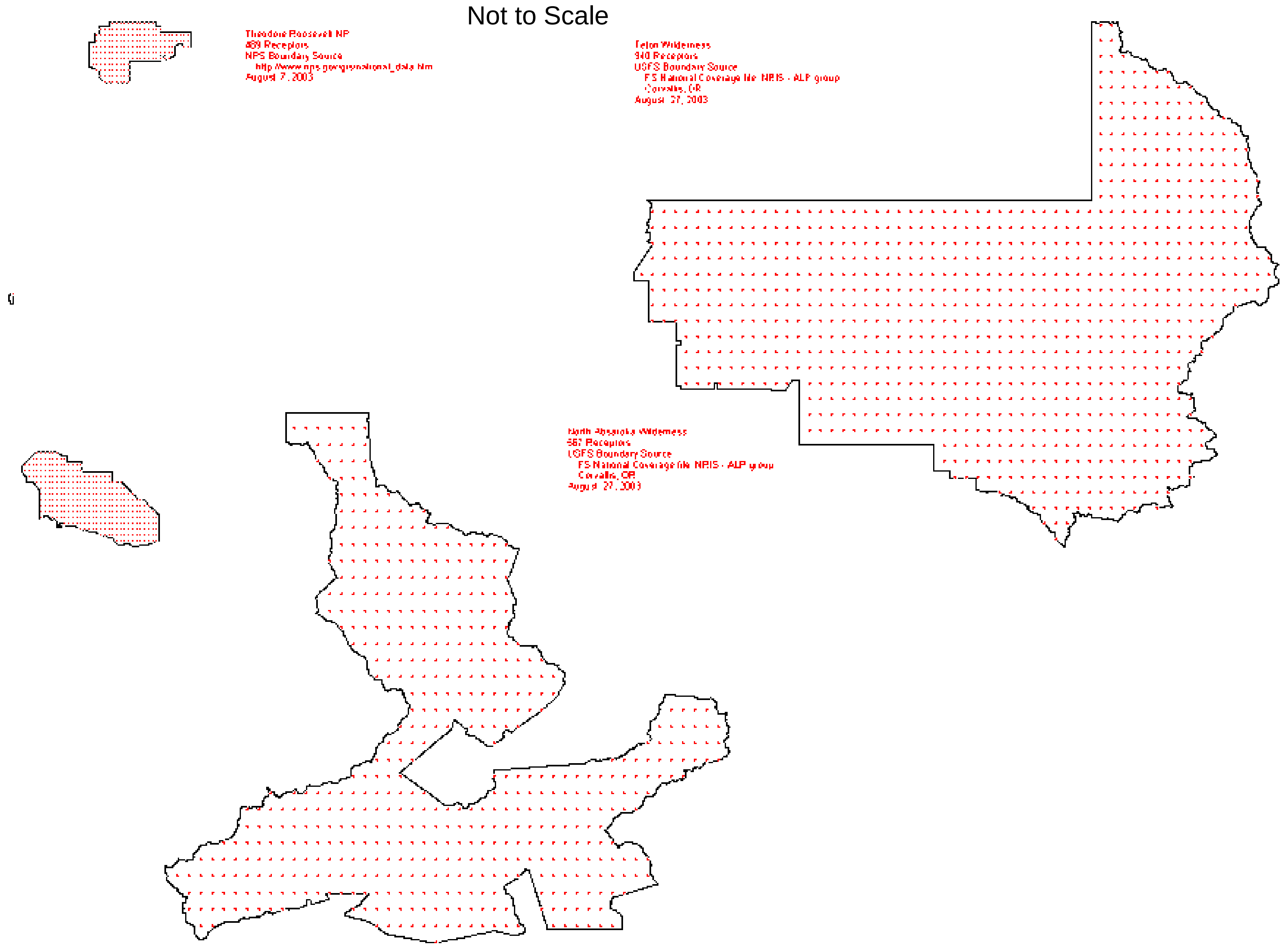


Not to Scale


Scapegoat Wilderness
423 Receptors
USFS Boundary Source
FS National Coverage file NRIS - ALP group
Corvallis, OR
August 27, 2003

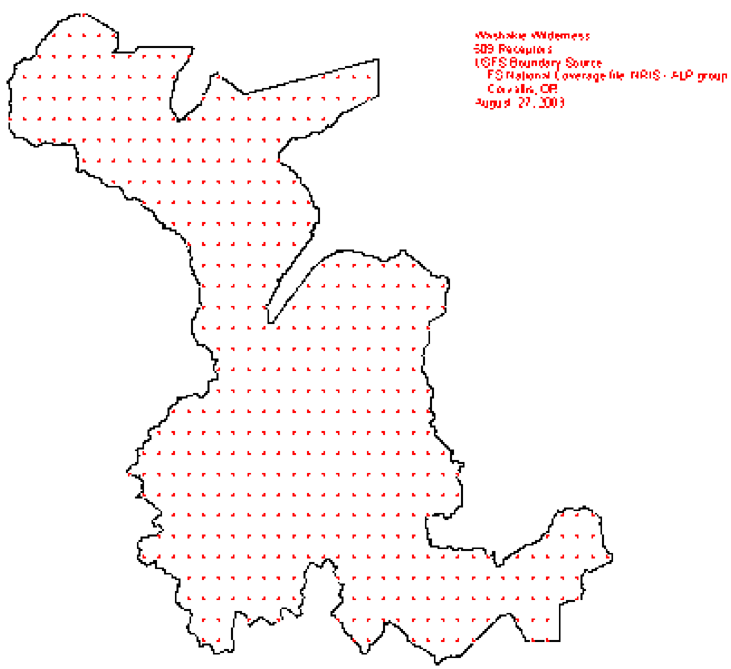

Selway Bitterroot Wilderness
575 Receptors
USFS Boundary Source
FS National Coverage file NRIS - ALP group
Corvallis, OR
August 27, 2003

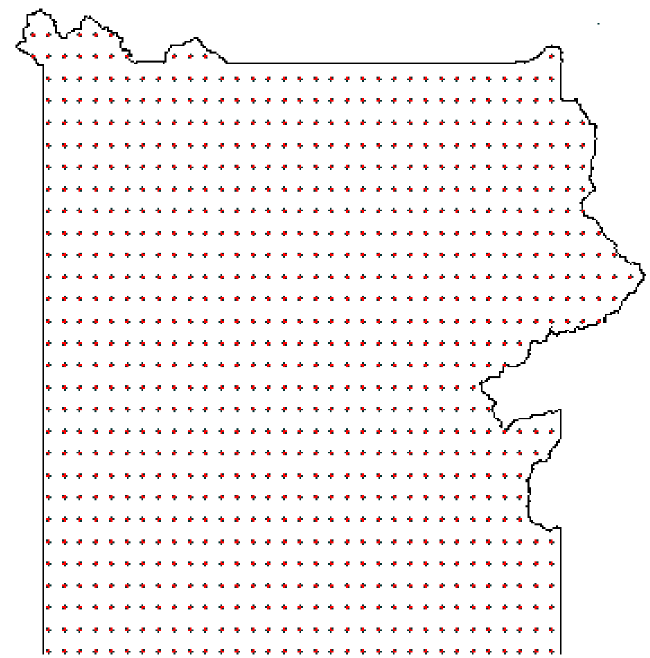




Not to Scale
Theodore Roosevelt NP
489 Receptors
NPS Boundary Source
http://www.nps.gov/gis/national_data.htm
August 7, 2003
Teton Wilderness
940 Receptors
USFS Boundary Source
FS National Coverage file NRIS - ALP group
Corvallis, OR
August 27, 2003
North Absaroka Wilderness
567 Receptors
USFS Boundary Source
FS National Coverage file NRIS - ALP group
Corvallis, OR
August 27, 2003

Not to Scale





The original receptor files were in North America Datum 1983 (NAD83) UTM (Universe Transverse Mercator) coordinates. A Corps of Engineers coordinate conversion software called Corpscon (Version 6.0) will be used to convert the coordinates to the Montana State Plane coordinates. The software can be downloaded from the following web site: (http://crunch.tec.army.mil/software/corpscon/corpscon.html).

4.3 BACKGROUND CONCENTRATIONS OF OZONE AND AMMONIA

CALPUFF allows background concentrations of ozone and ammonia to vary in both space and time. The MDEQ will use the available, albeit limited, data to utilize the chemistry modules more fully in CALPUFF modeling system.

4.3.1 BACKGROUND OZONE

Background ozone concentrations are important for the photochemical conversion of sulfur dioxide (SO_2) and nitrous oxides (NO_x) to sulfates (SO_4) and nitrates (NO_3), respectively. CALPUFF can use either a single background value representative of an area or hourly ozone data from one or more ozone monitoring stations (the preferred method).

Hourly ozone data is collected at three federal mandatory Class I areas of interest: Glacier National Park (Montana), Theodore Roosevelt National Park Wilderness (North Dakota), and Yellowstone National Parks (Wyoming). These data are available on the CASTNET web site (http://www.epa.gov/castnet/ozone.html). CASTNET is the EPA Clean Air Status and Trends Network, and is the primary source for national data on dry acid deposition and rural, ground-level ozone. Three years of data (2001 – 2003) will be used in CALPUFF modeling system.

In addition, the default ozone background will be set to 30 parts for billion (ppb) October through May and 50 ppb June through September. These concentrations are substantially lower than the 80 ppb ozone default for missing data documented in the IWAQM Phase 2 report. As any additional representative data becomes available, it will be utilized.

4.3.2 BACKGROUND AMMONIA

Ambient concentrations of nitrate (NO_3) are limited by the availability of ammonia, which is preferentially scavenged by sulfates (SO_4). Due to this preferential reaction between ammonia and sulfates, a lower ammonia concentration would tend to decrease particle nitrate concentrations prior to affecting particle sulfate concentrations.

In CALPUFF, a continuous emissions plume is represented by a series of puffs. The model allows the full amount of the background ammonia concentrations to be available to each emissions puff to form nitrate, which tends to overestimate nitrate formation. To compensate, an ammonia-limiting method will be used in the post-processing phase of CALPUFF model system.

Ammonia has never been measured in Montana. However, the North Dakota Department of Health collects hourly ammonia data at one site near Beulah, ND. The MDEQ believes this data is representative of Montana background ammonia concentrations and the EPA concurs (John Coefield, MDEQ, telephone conversation with Kevin Golden, EPA Region VIII, January 25, 2006). Monthly values were calculated from hourly ammonia data collected from 2001 to 2002, which are displayed in Table 4.3.2; these background ammonia concentrations will be used in the CALPUFF modeling.

Table 4.3.2: Monthly Background Ammonia Concentrations.

Month	Ammonia Concentration (ppb)[a]
January	1.22
February	1.23
March	1.60
April	1.94
May	2.29
June	1.63
July	1.65
August	1.69
September	0.98
October	1.04
November	1.37
December	1.06

[a.] ppb = parts per billion.

For comparison, the IWAQM Phase 2 report lists the default monthly ammonia background concentrations for forest and grassland are 0.5 and 10.0 ppb, respectively.

4.4 CALPUFF MODEL CONTROL PARAMETERS

A summary of the CALPUFF model control parameters that MDEQ will use are listed in Table 4.4. The IWAQM model defaults are also listed for comparison. The settings that differ from the IWAQM defaults are highlighted with the reasons for the differences noted. Some variables will change depending on the meteorological year as noted by “will vary”.

The Bee-Line CalPuffPro software organizes the files from the CALPUFF model runs (input and output files) in subdirectories under the main file directory of the met year data used in the runs. Therefore, the inclusion of the met year as a component of the various CALPUFF filenames is redundant in Table 4.4.

Table 4.4: Summary of CALPUFF Inputs.

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
METDAT	CALMET input data filename	CALMET.DAT	MET.DAT (will vary)
PUFLST	Filename for general output from CALPUFF	CALPUFF.LST	XXX.LST[b] (will vary)
CONDAT	Filename for output concentration data	CONC.DAT	XXXCONC.DAT (will vary)
DFDAT	Filename for output dry deposition fluxes	DFLX.DAT	XXXDFLX.DAT (will vary)
WFDAT	Filename for output wet deposition fluxes	WFLX.DAT	XXXWFLX.DAT (will vary)
VISDAT	Filename for output relative humidities	VISB.DAT	Not Used
OZDAT	Name of ozone data files (GNP = Glacier NP, THR = Theodore Roosevelt NP, YNP = Yellowstone NP)	OZDAT.DAT	GNPOZ.DAT, THROZ.DAT, YNPOZ.DAT
LCFILES	File names converted to lower case if T, upper case if F {inconsequential}	T	F
NMETDAT	Number of CALMET.DAT files for run	1	1
METRUN	Run all periods (1) or period defined (0)?	0	0
XBTZ	Base time zone: PST = 8, MST = 7, CST = 6, EST = 5	7	7
First Met Data Inputs; Repeated for Each Met Year			
IBYR	Beginning year	User Defined	Will vary with met year
IBMO	Beginning month	Limited by MM4/MM5 Data	Will vary with met year
IBDY	Beginning day		Will vary with met year
IBHR	Beginning hour		Will vary with met year
IRLG	Length of run (hours)		Will vary with met year
End of Year-Specific Inputs			

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
NSPEC	Number of species modeled (for MESOPUFF II chemistry)	5	Will vary with source
NSE	Number of species emitted	3	Will vary with source
ITEST	Flag to stop run after SETUP phase (1 = stop, 2 = continue)	2	2
MRESTART	Restart options allows splitting runs into smaller segments options (0=no restart)	0	0
NRESPD	Number of periods in Restart output cycle	0	0
METFM	Format of input meteorology (1 = CALMET)	1	1
AVET	Averaging time lateral dispersion parameters (minutes)	60	60
PGTIME	PG Averaging Time	60	60
MGAUSS	Near-field vertical distribution (1 = Gaussian)	1	1
MCTADJ	Terrain adjustments to plume path (3 = partial plume path adjustment)	3	3
MCTSG	Subgrid-scale complex terrain (0 = not modeled, 1 = modeled)	0	0
MSLUG	Near-field puffs modeled as elongated (0 = no, 1 = slugs modeled)	0	0
MTRANS	Model transitional plume rise? (1 = yes)	1	1
MTIP	Treat stack tip downwash? (1 = yes)	1	1
MBDW	Method used to simulate building downwash (1 = ISC, 2 = PRIME) {building downwash not considered}	2	Not Used
MSHEAR	Vertical wind shear modeled above stack top (0 = no, 1 = yes)	0	0
MSPLIT	Allow puffs to split? (0 = no, 1 = yes) {As recommended by EPA Region VIII, Kevin Golden, 2/23/06}	0	1

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
MCHEM	Chemical mechanism flag (1 = MESOPUFF II chemistry)	1	1
MAQCHEM	Aqueous phase transformation (0 = not modeled, 1 = aqueous phase reactions)	0	0
MWET	Model wet deposition? (1 = yes)	1	1
MDRY	Model dry deposition? (1 = yes)	1	1
MDISP	Method for dispersion coefficients (3 = PG & MP)	3	3
MTURBVW	Turbulence characterization (only if MDISP = 1 or 5) {see previous variable}	3	Not Used
MDISP2	Backup coefficients (only if MDISP = 1 or 5) {see previous variable}	3	Not Used
MROUGH	Adjust PG for surface roughness? (0 = no)	0	0
MPARTL	Model partial plume penetration (1=yes)	1	1
MTINV	Strength of temperature inversion (0 = compute from data)	0	0
MPDF	Use PDF for convective dispersion? (0 = no)	0	0
MSGTIBL	Use TIBL model? (allows treatment of subgrid scale coastal areas, 0 = no)	0	0
MBCON	Boundary condition concentration modeled? (0 = no)	0	0
MFOG	Configure for FOG Model output? (0 = no)	0	0
MREG	Regulatory default checks? (1 = yes)	1	1
CSPEC	Names of species modeled (NSE names)	MESOPUFF II must be SO_2, SO_4, NOx, HNO_3, NO_3	SO_2, SO_4, NOx, HNO_3, NO_3, others may be included depending on the source

<table>
<tr><th>CALPUFF Variable</th><th>Description</th><th>IWAQM[a] Recommended Value or Default</th><th>Value To Be Used</th></tr>
<tr><td colspan="4">EXAMPLE:
<table>
<tr><th>SPECIES NAME</th><th>MODELED
(0 = NO,
1 = YES)</th><th>EMITTED
(0= NO,
1 = YES)</th><th>DRY DEPOSITED
(0= NO,
1 = COMPUTED –GAS
2 = COMPUTED – PARTICLE
3 = USER-SPECIFIED)</th><th>OUTPUT GROUP NUMBER
(0 = NONE
1 = 1st CGRUP,
2 = 2nd CGRUP,
3 = etc.)</th></tr>
<tr><td>SO_2 =</td><td>1,</td><td>1,</td><td>1,</td><td>0!</td></tr>
<tr><td>SO_4 =</td><td>1,</td><td>0,</td><td>2,</td><td>0!</td></tr>
<tr><td>NO_X =</td><td>1,</td><td>1,</td><td>1,</td><td>0!</td></tr>
<tr><td>HNO_3 =</td><td>1,</td><td>0,</td><td>1,</td><td>0!</td></tr>
<tr><td>NO_3 =</td><td>1,</td><td>0,</td><td>2,</td><td>0!</td></tr>
<tr><td>PMF =</td><td>1,</td><td>0,</td><td>2,</td><td>0!</td></tr>
<tr><td>PMC =</td><td>1,</td><td>1,</td><td>2,</td><td>0!</td></tr>
<tr><td>EC =</td><td>1,</td><td>0,</td><td>2,</td><td>0!</td></tr>
</table></td></tr>
<tr><td>CGRUP</td><td>Grouping of species, if any</td><td>User Defined</td><td>Not Used</td></tr>
<tr><td>PMAP</td><td>Map Projection
(Use LCC for source-receptor distance >100 km)</td><td>LCC</td><td>LCC</td></tr>
<tr><td>FEAST</td><td>False Easting
(if PMAP = TTM, LCC or LAZA)
(km)
{inconsequential}</td><td>0</td><td>600</td></tr>
<tr><td>FNORTH</td><td>False Northing
(if PMAP = TTM, LCC or LAZA)
(km)</td><td>0</td><td>0</td></tr>
<tr><td>IUTMZN</td><td>UTM Zone</td><td>User Defined</td><td>12</td></tr>
<tr><td>UTMHEM</td><td>Hemisphere for UTM Projection</td><td>User Defined</td><td>N</td></tr>
<tr><td>RLAT0</td><td>Latitude (decimal degrees) of projection origin</td><td>User Defined</td><td>44.25 N</td></tr>
<tr><td>RLON0</td><td>Longitude (decimal degrees) of projection origin</td><td>User Defined</td><td>109.5 W</td></tr>
<tr><td>XLAT1</td><td>Latitude of 1st standard parallel</td><td>User Defined</td><td>44 N</td></tr>
<tr><td>XLAT2</td><td>Latitude of 2nd standard parallel</td><td>User Defined</td><td>49 N</td></tr>
<tr><td>DATUM</td><td>Datum-region for output coordinates</td><td>WGS-G</td><td>WGS-G</td></tr>
<tr><td>NX</td><td>Number of east-west grid cells</td><td><= 190</td><td>To be determined,
but <= 190</td></tr>
</table>

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
NY	Number of north-south grid cells	<= 135	To be determined, but <= 135
NZ	Number of vertical layers	>= 4	10
ZFACE	Vertical cell face heights (NZ + 1 values)	User Defined	0., 20., 40., 80., 160., 300., 600., 1000., 1500., 2200., 3000.
DGRIDKM	Grid spacing (km)	<= 12	6
XORIGKM	Southwest grid cell X coordinate	Use modeled coordinate system	Varies with subdomain
YORIGKM	Southwest grid cell Y coordinate		Varies with subdomain
IBCOMP	Southwest X-index of computational domain	1 <= IBCOMP <= NX	1
JBCOMP	Southwest Y-index of computational domain	1 <= JBCOMP <= NY	1
IECOMP	Northeast X-index of computational domain	1 <= IBCOMP <= NX	To be determined, but <= 190
JECOMP	Northeast Y-index of computational domain	1 <= JBCOMP <= NY	To be determined, but <= 135
LSAMP	Use gridded receptors? (T = yes) {NPS receptors are discrete}	T	F
IBSAMP	Southwest X-index of receptor grid	IBCOMP <= IBSAMP <= IECOMP	Not Used
JBSAMP	Southwest Y-index of receptor grid	JBCOMP <= JBSAMP <= JECOMP	Not Used
IESAMP	Northeast X-index of receptor grid	IBCOMP <= IESAMP <= IECOMP	Not Used
JESAMP	Northeast Y-index of receptor grid	JBCOMP <= JESAMP <= JECOMP	Not Used
MESHDN	Gridded receptor spacing = DGRIDKM/MESHDN	1	Not Used
ICON	Output concentrations? (1 = yes)	1	1
IDRY	Output dry deposition flux? (1 = yes)	1	1
IWET	Output wet deposition flux? (1= yes)	1	1

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
IVIS	Output RH for visibility calculations? (1 = yes)	1	1
LCOMPRS	Use compression option in output? (T = yes)	T	T
IMFLX	Mass Flux Across Boundary> (0 = no)	0	0
IMBAL	Mass balance for each species? (0 = no)	0	0
ICPRT	Print concentrations? (0 = no) {QA/QC check}[c]	0	1
IDPRT	Print dry deposition fluxes? (0 = no) {QA/QC check}	0	1
IWPRT	Print wet deposition fluxes? (0 = no) {QA/QC check}	0	1
ICFRQ	Concentration print interval (1 = hourly)	1	1
IDFRQ	Dry deposition flux print interval (1 = hourly)	1	1
IWFRQ	Wet deposition flux print interval (1 = hourly)	1	1
IPRTU	Print output units (3 = μg/m^3, μg/m^3/s)	3	3
IMESG	Status messages to screen (2 = yes, date, # of puffs)	2	2
SPECIES	Species List for Output	All species saved on disk	All species printed and saved on disk
LDEBUG	Turn on debug tracking? (F = no)	F	F
IPFDEB	First puff to track	1	1
NPFDEB	Number of puffs to track	1	1
NN1	Met. period (hour) to start debug output	1	1
NN2	Met. period (hour) to end debug output	10	10
NHILL	Number of subgrid terrain (hill) features	0	0

CALPUFF Variable	**Description**	**IWAQM[a] Recommended Value or Default**	**Value To Be Used**
NCTREC	Number of special complex terrain receptors	0	0
MHILL	Terrain and CTSG Receptor data for CTSG hills input in CTDM format ? (1 = Hill and rec. data read from files, 2 = hill data created) {not used since NHILL = 0}	1	0
XHILL2M	Factor to convert horizontal dimensions to meters {not used since NHILL = 0}	1	0
ZHILL2M	Factor to convert vertical dimensions to meters {not used since NHILL = 0}	1	0
XCTDMKM	X-origin of CTDM system relative to CALPUFF coordinate system (km)	0.0E00	0.0E00
YCTDMKM	Y-origin of CTDM system relative to CALPUFF coordinate system (km)	0.0E00	0.0E00
Chemical Parameters Of Gaseous Deposition Species			
	DIFFUSIVITY (cm^2/s)	SO_2 = 0.1509 NOx = 0.1656 HNO_3 = 0.1628	SO_2 = 0.1509 NOx = 0.1656 HNO_3 = 0.1628
	ALPHA STAR	SO_2 = 1000. NOx = 1. HNO_3 = 1.	SO_2 = 1000. NOx = 1. HNO_3 = 1.
	REACTIVITY	SO_2 = 8. NOx = 8. HNO_3 = 18.	SO_2 = 8. NOx = 8. HNO_3 = 18.
	MESOPHYLL RESISTANCE (s/cm)	SO_2 = 0. NOx = 5. HNO_3 = 0.	SO_2 = 0. NOx = 5. HNO_3 = 0.
	HENRY'S LAW COEFFICIENT	SO_2 = 0.04 NOx = 3.5 HNO_3 = 0.00000008	SO_2 = 0.04 NOx = 3.5 HNO_3 = 0.00000008
Size Parameters For Dry Deposition Of Particles			
	GEOMETRIC MASS MEAN DIAMETER (microns)	SO_4 = 0.48 NO_3 = 0.48 PMF = 0.48 PMC = 0.48 EC = 0.48	SO_4 = 0.48 NO_3 = 0.48 PMF = 0.48 PMC = 0.48 EC = 0.48 OC = 0.48 (will vary with source)
	GEOMETRIC STANDARD DEVIATION (microns)	SO_4 = 2. NO_3 = 2. PMF = 2. PMC = 2. EC = 2.	SO_4 = 2. NO_3 = 2. PMF = 2. PMC = 2. EC = 2. OC = 2.

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
			(will vary with source)
RCUTR	Reference cuticle resistance (s/cm)	30.	30.
RGR	Reference ground resistance (s/cm)	10.	10.
REACTR	Reference reactivity	8	8
NINT	Number of particle-size intervals	9	9
IVEG	Vegetative state (1 = active and unstressed)	1	1
Wet Deposition Parameters			
	Scavenging Coefficient, Liquid Precipitation (sec)$^{-1}$	SO_2 = 3.0E-05 SO_4 = 1.0E-04 HNO_3 = 6.0E-05 NO_3 = 1.0E-04 PMF = 1.0E-04 PMC = 1.0E-04 EC = 1.0E-04	SO_2 = 3.0E-05 SO_4 = 1.0E-04 HNO_3 = 6.0E-05 NO_3 = 1.0E-04 PMF = 1.0E-04 PMC = 1.0E-04 EC = 1.0E-04 OC = 1.0E-04 (will vary with source)
	Scavenging Coefficient, Frozen Precipitation (sec^{-1})	SO_2 = 0.0E-00 SO_4 = 3.0E-05 HNO_3 = 0.0E-00 NO_3 = 3.0E-05 PMF = 3.0E-05 PMC = 3.0E-05 EC = 3.0E-05	SO_2 = 0.0E-00 SO_4 = 3.0E-05 HNO_3 = 0.0E-00 NO_3 = 3.0E-05 PMF = 3.0E-05 PMC = 3.0E-05 EC = 3.0E-05 OC = 3.0E-05 (will vary with source)
MOZ	Ozone background (1 = read from ozone.dat)	1	1
BCKO3	Ozone default (ppb) for missing data	12 * 80	Will use hourly ozone data files from Glacier, Theodore Roosevelt, and Yellowstone National Parks. Plus 30 ppb Oct. – May; 50 ppb June – Sept.
BCKNH3	Ammonia background (ppb) {North Dakota data}	12 * 10	1.22, 1.23, 1.60, 1.94, 2.29, 1.63, 1.65, 1.69, 0.98, 1.04, 1.37, 1.06
RNITE1	Nighttime SO_2 loss rate (%/hr)	0.2	0.2
RNITE2	Nighttime NO_X loss rate (%/hr)	2.0	2.0

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
RNITE3	Nighttime HNO_3 loss rate (%/hr)	2.0	2.0
MH202	H2O2 data input option (MAQCHEM = 1; 0 = monthly background, 1 = read hourly conc. file) {using MAQCHEM = 0}	0	Not Used
BCKH2O2	Monthly H2O2 concentrations (ppb)	12 * 1.0	12 * 1.0
BCKPMF	Fine particulate concentration (µg/m^3) (used if MCHEM = 4 with VOC emissions) {using MAQCHEM = 1; no VOC emissions}	12 * 1.00	Not Used
OFRAC	Organic fraction of fine particulate (Used with VOC emissions) {no VOC emissions}	2*0.15, 9*0.20, 1*0.15	Not Used
VCNX	VOC / NO_X ratio (after reaction; Used with VOC emissions) {no VOC emissions}	12 * 50.00	Not Used
SYTDEP	Horizontal size (m) to switch to time dependence	550.	550.
MHFTSZ	Use Heffter for vertical dispersion (0 = no)	0	0.
JSUP	PG Stability class above mixed layer	5	5
CONK1	Vertical stable dispersion constant (Eq. 2.7-3)	0.01	0.01
CONK2	Vertical neutral dispersion constant (Eq. 2.7-4)	0.1	0.1
TBD	Factor for determining Transition-point from Schulman-Scire to Huber-Snyder Building Downwash scheme	0.5	0.5
IURB1	Beginning urban land use type	10	10
IURB2	Ending urban land use type	19	19
XMXLEN	Maximum slug length in units of DGRIDKM	1	1
XSAMLEN	Maximum puff travel distance per sampling step (units of DGRIDKM)	1	1

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
MXNEW	Maximum number of puffs per hour	99	99
MXSAM	Maximum sampling steps per hour	99	99
NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise (for CALMET and PROFILE winds)	2	2
SYMIN	Minimum lateral dispersion of new puff/slug (m)	1.0	1.0
SZMIN	Minimum vertical dispersion of new puff/slug (m)	1.0	1.0
SVMIN	Default minimum turbulence velocities for stability classed A-F (m/s)	6 * 0.50	6 * 0.50
SWMIN		0.20, 0.12, 0.08, 0.06, 0.03, 0.016	0.20, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV(2)	Divergence criterion for dw/dz (s^{-1})	0.0, 0.0	0.0, 0.0
WSCALM	Minimum non-calm wind speed (m/s)	0.5	0.5
XMAXZI	Maximum mixing height (m)	3000	2800
XMINZI	Minimum mixing height (m)	50	50
WSCAT	Upper bounds of first 5 wind speed classes (m/s)	1.54, 3.09, 5.14, 8.23, 10.8	1.54, 3.09, 5.14, 8.23, 10.8
PLX0	Wind speed power-law exponents (rural)	0.07, 0.07, 0.10, 0.15, 0.35, 0.55	0.07, 0.07, 0.10, 0.15, 0.35, 0.55
PTG0	Potential temperature gradients PG E and F (deg K/m)	0.020, 0.035	0.020, 0.035
PPC	Plume path coefficients for stability classes A-F (only if MCTADJ=3)	0.5, 0.5, 0.5, 0.5, 0.35, 0.35	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Maximum Sy/puff length	10	10
NSPLIT	Number of puffs when puffs split {As recommended by EPA Region VIII, Kevin Golden, 2/23/06}	3	2
IRESPLIT	Hours when puff are eligible to split	0, except hr 17 = 1	0, except hr 17 = 1

CALPUFF Variable	Description	IWAQM[a] Recommended Value or Default	Value To Be Used
ZISPLIT	Split allowed last hour's mixing height exceeds minimum value (m)	100	100
ROLDMAX	Previous Max mixing height/current mixing height ratio, must be less than this value to allow puff split	0.25	0.25
NSPLITH	Number of puffs that result every time a puff is split	5	5
SYSPLITH	Min. Sy of puff before it splits	1	1
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr) due to wind shear, before it may be split	2.0	2.0
CNSPLITH	Minimum concentration (g/m^3) of each species in puff before it may be split (Array of NSPEC values or a single value for all species)	1.0E-07	1.0E-07
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	1.0E-04	1.0E-04
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1.0E-06	1.0E-06
DSRISE	Trajectory step-length (m) used for numerical rise integration	1	1
NPT1	Number of point sources	No Default	To be determined
IPTU	Units of emission rates (1 = g/s)	1	1
NSPT1	Number of point source-species combinations	0	0
NPT2	Number of point sources with fully variable emission rates	0	0
IVARY	IVARY determines the type of variation, and is source-specific: (Default: 0 = constant)	0	0
NREC	Number of Non-gridded receptors	>=1	Will vary with subdomain

[a.] IWQMA = Interagency Workgroup on Air Quality Modeling.
[b.] XXX = unique MDEQ identification code for each individual BART-eligible/subject source.
[c.] QA/QC = quality assurance/quality control check.

The CALPUFF outputs will be hourly concentrations of the individual aerosol specie at each receptor for each met year. These results will be post-processed by two programs:

POSTUTIL and CALPOST. The POSTUTIL will be used to implement the ammonia-limiting method before CALPOST calculates the 24-hour visibilities.

5.0 POSTUTIL INPUTS

According to Escoffier-Czaja and Scire:[6]

> "In CALPUFF, a continuous plume is simulated as a series of puffs, or discrete plume elements. The total concentration at any point in the model is the sum of the contribution of all nearby puffs from each source. Because CALPUFF allows the full amount of the specified background concentration of ammonia to be available to each puff for forming nitrate, the same ammonia may be used multiple times in forming nitrate, resulting in an overestimate of nitrate formation. In POSTUTIL, ammonia availability is computed based on receptor concentrations of total sulfate and total nitrate (HNO3 + NO3), not on a puff-by puff basis."

Therefore, POSTUTIL will be used to repartition the nitric acid (HNO_3) and nitrate (NO_3) concentrations (MNITRATE = 1). With this application, the possibility of double-counting the available ammonia in the CALPUFF chemistry is avoided. A summary of the relevant POSTUTIL inputs are listed in the Table 5.0. The program model defaults are also listed for comparison. The settings that differ from the model defaults are highlighted with the reasons for the differences noted.

Table 5.0: Summary of POSTUTIL Inputs.

POSTUTIL Variable	Description	Recommended Value or Default	Value To Be Used
NSPECINP	Number of modeled species to process from CALPUFF input data files	No Default	Will vary with source
NSPECOUT	Number of modeled species to write to CALPUFF output data files	No Default	Will vary with source
MNITRATE	Repartition HNO_3/NO_2 (0 = no) {1 = yes for all sources listed}	0	1
BCKNH3	Background ammonia; same as monthly values used in CALPUFF {North Dakota data}	10	1.22, 1.23, 1.60, 1.94, 2.29, 1.63, 1.65, 1.69, 0.98, 1.04, 1.37, 1.06
MODEL.DAT	Data file containing POSTUTIL results	No Default	XXXPOST.DAT[a]

[6] Escoffier-Czaja, Christelle and J. Scire. 2002. The Effects of Ammonia Limitation on Nitrate Aerosol Formation and Visibility Impacts in Class I Areas. Earth Tech, Inc. Extended Abstract. 12th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association. American Meteorological Society. J5.13. Norfolk, VA.

POSTUTIL Variable	Description	Recommended Value or Default	Value To Be Used
PSTLST	List of POSTUTIL application information	No Default	XXXPOST.LST

[a] XXX = 3-letter code for each BART-eligible/subject source.

6.0 CALPOST INPUTS

For each met year, CALPOST will be run with each individual set of Class I area receptors that are within 300 km of the facility containing the BART-eligible source(s). As discussed previously, for subsequent modeling analyses, the receptors will be segregated on a State basis if a Class I receptor set extends into more than one State. The receptors will also be identified by a unique MDEQ code, which will simplify tracking the CALPOST runs.

6.1 NATURAL BACKGROUND

CALPOST will be used to calculate the daily visibility conditions in deciviews from the estimated individual specie concentrations derived from the BART-eligible/subject source(s) emissions. The modeled deciviews visibility metric will be compared to the natural background visibility conditions (delta-deciviews) of the best 20% natural visibility days at the relevant Class I areas as required by the BART guidelines:[2]

> “Finally, these final BART guidelines use the natural visibility baseline for the 20 percent best visibility days for comparison to the ``cause or contribute'' applicability thresholds. We believe this estimated baseline is likely to be reasonably conservative and consistent with the goal of natural conditions.”

For BART-related analyses, monthly site-specific relative humidity adjustment factors must be applied to both background (best 20% natural visibility days of a Class I area) and modeled sulfates and nitrates (MVISBK = 6). This method computes the extinction from speciated PM measurements using FLAG RH adjustment factor applied to observed and modeled sulfate and nitrate. The acronym FLAG is the Federal Land Managers AQRV (Air Quality Related Values) Workgroup. A different method is used to calculate visibility for major stationary source permit applications.

The “Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program”, (Guidance), contains monthly site-specific relative humidity adjustment factors (f(RH)) values for all federally mandated Class I areas (Table A-2).[7] These long-

7. EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air

term factors were calculated from hourly relative humidity measurements over a 10-year period (1988 – 1997); these values are given in Appendix C.

For CALPOST input, monthly background concentrations for six light extinction species are also required to define the best 20% natural background visibility days for each Class I area of concern. These species are ammonium sulfate, ammonium nitrate, coarse particles, organic carbon, soil dust, and elemental carbon. These concentrations will be estimated for each Class I area using a procedure adapted from the Guidance.

Default average annual aerosol concentrations have been developed based on two general geographic U.S. locations ("East" and "West".). Table 6.1A lists the estimated default natural concentrations of the aerosols for the "West" geographic location, and the corresponding dry extinction efficiency coefficients and dry particulate extinctions.[7]

Table 6.1A: Default West Average Annual Natural Background Levels of Aerosol Components.[7]

Component	**Average Annual Natural Background West ($\mu g/m^3$)[a]**	**Dry Extinction Efficiency Coefficient (m^2/g)[b]**	**Dry Particulate Matter Extinction (Mm^{-1})[c]**
Ammonium Sulfate	0.12	3.0	0.36
Ammonium Nitrate	0.10	3.0	0.30
Organic Carbon Mass	0.47	4.0	1.88
Elemental Carbon	0.02	10.0	0.20
Soil (Fine)	0.50	1.0	0.50
Coarse Mass	3.00	0.6	1.80
Total	Fine = 1.21 Coarse = 3.00		5.04

a. $\mu g/m^3$ = micrograms per cubic meter.
b. m^2/g = meters squared per gram.
c. Mm^{-1} = inverse megameter(s).

The Guidance also lists the default natural background visibility values (measured in deciviews) for all mandatory 156 Class I areas in the nation. The 10th and 90th percentile deciviews values are also included. These values correspond to the visibilities on the best and worse 20% visibility days, respectively; this information is provided in Appendix D. Although the default background visibilities were given, the corresponding aerosol concentrations were not.

Section 2.4 in the Guidance describes a method to determine the average annual natural background extinction (in Mm^{-1}) for a Class I area based on the area's general

Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

geographic location. This method also uses the Class I area's annual relative humidity correction factor, f(RH). By replacing the annual average deciview values in the procedure with the deciviews value for the best 20% visibility days for a particular Class I area, the aerosol concentrations for the best 20% visibility days for that area can be estimated. For demonstration purposes, the aerosol composition of Glacier National Park (GNP) will be calculated using the current IMPROVE light reconstruction equation.

GNP best 20% natural background visibility days[7] = 2.44 dv
Annual relative humidity adjustment factor f(RH)[7] = 3.18

$$dv = 10 \ln (b_{ext}/10) \rightarrow 2.44\ dv = 10 \ln (b_{ext}/10\ Mm^{-1})$$

and with rearrangement:

$$b_{ext} = 10 \exp (dv/10) \rightarrow b_{ext} = 10 \exp (2.44/10)$$

$$\text{Therefore, } b_{ext} = 12.77\ Mm^{-1}$$

The b_{ext}, f(RH) value, and the estimated default natural concentrations of the aerosols for the "West" geographic location are inserted into the IMPROVE reconstructed light extinction equation.

$$b_{ext} = (3)\ f(RH)\ [\text{Ammonium Sulfate}] + (3)\ f(RH)\ [\text{Ammonium Nitrate}] + (0.6)\ [\text{Coarse Mass}] + (4)\ [\text{Organic Carbon}] + (1)\ [\text{Soil}] + (10)\ [\text{Elemental Carbon}] + b_{ray}$$

$$12.77 = (3)\ (3.18)\ [0.12]\ X + (3)\ (3.18)\ [0.1]\ X + (0.6)\ [3.0]\ X + (4)\ [0.47]\ X + (1)\ [0.5]\ X + (10)\ [0.02]\ X + 10$$

The unknown variable, X, is the scaling factor to convert the default annual average natural background specie concentrations to values representing the best 20% visibility days for GNP. Solving for X produces a value of 0.428.

In this example, the background GNP concentration for ammonium sulfate on the best 20% visibility days would be 0.050 $\mu g/m^3$ (0.428 * 0.12 $\mu g/m^3$ = 0.051 $\mu g/m^3$). Table 6.1B lists the default annual average natural background aerosol concentrations and corresponding concentrations for Glacier National Park on the best 20% visibility days.

Table 6.1B: Aerosol Levels For Default West Average Annual Natural Background And GNP Best 20% Visibility Days.

Component	Average Annual Natural Background West ($\mu g/m^3$)[a]	Best 20% Visibility Days Glacier National Park ($\mu g/m^3$)
Ammonium Sulfate	0.12	0.051
Ammonium Nitrate	0.10	0.043
Organic Carbon Mass	0.47	0.200
Elemental Carbon	0.02	0.009
Soil (Fine)	0.50	0.213
Coarse Mass	3.00	1.278
Total	Grand Total = 4.21 Fine = 1.21 Coarse = 3.00	Grand Total = 1.794 Fine = 0.516 Coarse = 1.278

a. $\mu g/m^3$ = micrograms per cubic meter.

The previous table indicates that the visibility at Glacier National Park is substantially cleaner on the best 20% visibility days than the average annual natural background in the West due to lower aerosol concentrations.

This procedure was applied to all eighteen Class I areas of concern using the current IMPROVE reconstructed light extinction equation and the resulting aerosol compositions are provided in Appendix E.

6.2 98TH PERCENTILE METHODS

According the BART guidelines:[2]

> "...you should compare your "contribution" threshold against the 98th percentile of values. If the 98th percentile value from your modeling is less than your contribution threshold, then you may conclude that the source does not contribute to visibility impairment and is not subject to BART."

The BART guidelines do not specify a method for calculating the 98th percentile delta-deciview value nor does CALPOST have the ability to produce the results in this manner. CALPOST reports the number of days with a Δ dv greater than or equal to 0.5 dv for each met year.

The EPA recommends selecting the 98th percentile value from the distribution of values containing the highest modeled Δ dv value for each day from all modeled receptors at a given Class I area. The 98th percentile value can then be determined two ways:

- The 8th highest daily value for each met year modeled
- The 22nd highest daily value for all 3 met years combined

For example, for one met year, the 98th percentile can be approximated by the following: 8 days/365 total days per year * 100 ≈ 2% ≈ 98th percentile.

Both methods will be used and the highest value of the two will be compared to the contribution threshold (Δ dv ≥ 0.5 dv). If there are more than 7 days with values greater than the contribution threshold for any met year for any Class I areas, then the source is considered subject-to-BART. Since CALPOST does not automatically report these values, some sorting of the results will be required.

The contribution threshold has an implied level of precision equal to the level of precision reported by CALPOST. Specifically, the 98th percentile value will be reported to three decimal places.

The 98th percentile Δ dv will also be compared pre- and post-BART control implementation. If several BART strategies are investigated, all scenarios will be documented. Table 6.2 lists a summary of the CALPOST inputs. The program model defaults are also listed for comparison. The settings that differ from the model defaults are highlighted with the reasons for the differences noted. Inputs noted by "will vary" or "Will Vary" will change depending upon the met year.

Table 6.2: Summary of CALPOST Inputs.

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
MODDAT	Concentration output file from CALPUFF {filename will reflect the met year and source(s) involved}	MODEL.DAT	XXXPOST.DAT[a] (will vary)
VISDAT	Relative Humidity file	VISB.DAT	Not Used
BACKDAT	Background data file	BACK.DAT	Not Used
VSRDAT	Transmissometer/ Nephelometer hourly background light data	VSR.DAT	Not Used
CALPOST.LST	Name of CALPOST list file {filename will reflect the met year and source(s) involved}	CALPOST.LST	XXXZZZPOST.LST[b] (will vary)
TSPATH	Pathname for Timeseries files	Not Used	Not Used
PLPATH	Pathname for plot files	Not Used	Not Used
TSUNAM	Timeseries	Not Used	Not Used

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
TUNAM	Top Nth rank plot	Not Used	Not Used
XUNAM	Exceedance plot	Not Used	Not Used
EUNAM	Echo plot (specific days)	Not Used	Not Used
VUNAM	Visibility plot (daily peak summary)	Not Used	Not Used
LCFILES	Keep file names in lower case (F = upper case)	F	F
METRUN	Run period (0 = explicitly defined below; 1 = run all periods in CALPUFF data file(s))	0	0
Met Data Year 1; Repeated for Each Met Year			
ISYR	Beginning year	Can be a subset of CALPUFF Period	Will Vary
ISMO	Beginning month		1
ISDY	Beginning day		1
ISHR	Beginning hour		1
NHRS	Number of hours to process		Will Vary
End of Year-Specific Inputs			
NREP	Process every hour of data? (1 = every hour)	1	1
ASPEC	Species to process (ASPEC = VISIB for visibility processing)	VISIB	VISIB
ILAYER	Layer/deposition code (1 for CALPUFF concentrations)	1	1
A and B	Scaling factors of the form: X(new) = X(old) * A + B (NOT applied if A = B = 0.0)	A = 0.0 B = 0.0	A = 0.0 B = 0.0
LBACK	Add hourly background concentrations/fluxes?	F	F
LG	Gridded receptors processed?	F	F

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
LD	Discrete receptors processed?	F	T
LCT	CTSG Complex terrain receptors processed?	F	F
LDRING	Report results by receptor ring?	F	F
NDRECP	Select specific receptors (-1 = process all)	-1	-1
IBGRID	X index of LL corner (Entire grid is processed if IBGRID=JBGRID=IEGRID=JEGRID=-1) {Class I area receptors are discrete}	-1	Not Used
JBGRID	Y index of LL corner (-1 = use all gridded receptors) {Class I area receptors are discrete}	-1	Not Used
IEGRID	X index of UR corner (-1 = use all gridded receptors) {Class I area receptors are discrete}	-1	Not Used
JEGRID	Y index of UR corner (-1 = use all gridded receptors) {Class I area receptors are discrete}	-1	Not Used
NGONOFF	Number of gridded receptor rows to identify specific gridded receptors to process	0	0
NGXRECP	Specific gridded receptors included/excluded (1 = gridded receptors processed)	1	1
RHMAX	Maximum relative humidity (%) used in particle growth curve {not used with Method 6}	95	Not Used
LVSO4	Include modeled SULFATE in computing the light extinction?	T	T
LVNO3	Include NITRATE?	T	T
LVOC	Include ORGANIC CARBON?	T	T
LVPMC	Include COARSE PARTICLES?	T	T
LVPMF	Include FINE PARTICLES?	T	T
LVEC	Include ELEMENTAL CARBON?	T	T
LVBK	Include background when ranking for TOP-N, TOP-50, and Exceedance tables?	T	F
SPECPMC	Species name used for COARSE particulates in MODEL.DAT file	PMC	PMC

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
SPECPMF	Species name used for FINE particulates in MODEL.DAT file	PMF	PMF

EXAMPLE:

```
Extinction Efficiency (1/Mm per ug/m**3)
----------------------------------------
    MODELED particulate species:
               PM  COARSE      (EEPMC) -- Default: 0.6 ! EEPMC  = 0.6 !
               PM  FINE        (EEPMF) -- Default: 1.0 ! EEPMF  = 1.0 !
    BACKGROUND particulate species:
               PM  COARSE    (EEPMCBK) -- Default: 0.6 ! EEPMCBK = 0.6 !
    Other species:
              AMMONIUM SULFATE (EESO4) -- Default: 3.0 ! EESO4  = 3.0 !
              AMMONIUM NITRATE (EENO3) -- Default: 3.0 ! EENO3  = 3.0 !
              ORGANIC CARBON   (EEOC)  -- Default: 4.0 ! EEOC   = 4.0 !
              SOIL             (EESOIL)-- Default: 1.0 ! EESOIL = 1.0 !
              ELEMENTAL CARBON (EEEC)  -- Default: 10. ! EEEC   = 10.0 !
```

MVISBK	Method used for background light extinction {for BART-related modeling, Method 6 should be used}	2	6
BEXTBK	Background light extinction	0.0	0.0
RHFRAC	Percentage of particles affected by relative humidity {used if MVISBK = 1}	0.0	Not Used
RHFAC	Monthly relative humidity adjustment factors for adjusting extinction coefficients	No Default	Will vary with Class I Area (list of 12 values)
BKSO4	Monthly background concentrations of ammonium sulfate ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKNO3	Monthly background concentrations of ammonium nitrate ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKPMC	Monthly background concentrations of coarse particulates ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKOC	Monthly background concentrations of organic carbon ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKSOIL	Monthly background concentrations of soil ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BKEC	Monthly background concentrations of elemental carbon ($\mu g/m^3$)	No Default	Will vary with Class I Area (list of 12 values)
BEXTRAY	Extinction due to Rayleigh scattering (1/Mm)	10.0	10.0
LDOC	Print documentation image?	F	F
IPRTU	Output units for concentration and deposition {Visibility: extinction expressed in	3 = $\mu g/m^3$, $\mu g/m^2/s$	Not Used

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
	1/Megameters and IPRTU is ignored}		
L1HR	1-hr averages reported {not interested in 1-hr values}	T	F
L3HR	3-hr averages reported {not interested in 3-hr values}	T	F
L24HR	24-hr averages reported	T	T
LRUNL	Run-length averages reported {not interested in these averages}	T	F
NAVG	User-specified averaging time in hours	0	0
Visibility: daily visibility tabulations are always reported for the selected receptors when ASPEC = VISIB.			
LT50	Top 50 table for each averaging time selected [List file only]	T	T
LTOPN	Top 'N' table for each averaging time selected [List file or Plot file]	F	F
NTOP	Number of 'Top-N' values at each receptor selected (<=4)	4	4
ITOP(4) array	Specific ranks of 'Top-N' values reported (NTOP values must be entered)	1, 2, 3, 4	1,2,3,4
LEXCD	Threshold exceedance counts for each receptor and each averaging time selected [List file or Plot file]	F	F
THRESH1	Threshold for 1-hr averages (-1.0 = no threshold)	-1.0	-1.0
THRESH3	Threshold for 3-hr averages (-1.0 = no threshold)	-1.0	-1.0
THRESH24	Threshold for 24-hr averages (-1.0 = no threshold)	-1.0	-1.0
THRESHN	Threshold for NAVG-hr averages (-1.0 = no threshold)	-1.0	-1.0
NDAY	Accumulation period (days)	0	0
NCOUNT	Number of exceedances allowed	1	0
LECHO	Echo option	F	F

CALPOST Variable	Description	Recommended Value or Default	Value To Be Used
LTIME	Timeseries option	F	F
IECHO(366)	Days selected for output (366 values must be entered)	366*0	366*0
LPLT	Generate Plot file output in addition to writing tables to list file?	F	F
LGRD	Use GRID format rather than DATA format, when available?	F	F
LDEBUG	Output selected information to List file for debugging?	F	F

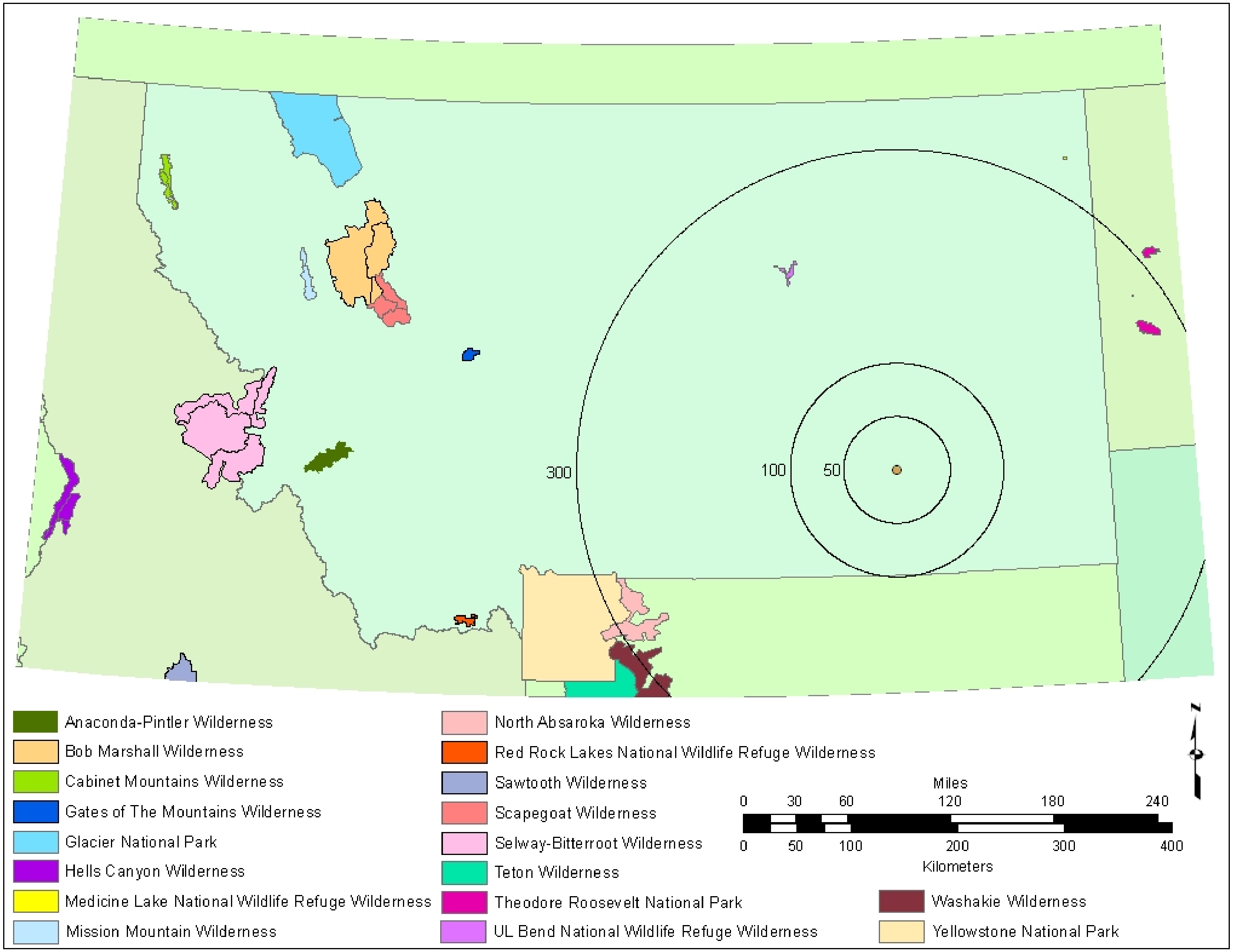
[a.] XXX = 3-letter code for each BART-eligible/subject source.
[b.] ZZZ = unique Class I area MDEQ code.

7.0 RESULTS

The results will be presented in sections according to the facility name in alphabetical order. Within each of those sections, the BART-eligible modeling results for the emission unit(s) will be addressed first, then the individual subject-to-BART analysis.

For each facility, a map will be created of the primary modeling domain with all eighteen Class I areas of concern. Circles of 50, 100, and 300 kilometers centered on the location of the facility will be included to delineate the maximum distance acceptable (300 km) for characterizing air pollution transport by CALPUFF. In addition, the WRAP has developed emissions reports based on 50 km buffer zones surrounding each western federal mandatory Class I area (http://www.wrapair.org/forums/class1/near/htmlfiles/mainmap1.html) so these distances were selected. Figure 7.0A displays an example figure for a facility located in the Colstrip area and the three reference circles.

Figure 7.0A: Example Figure Showing 50, 100, and 300 Kilometer Reference Circles Around A Colstrip Facility.



All results will be compared to the best 20% visibility days for each Class I area of concern. The BART-eligible results will be tabulated for each meteorological year similar to Table 7.0A. In the following tables and graphs, four fictitious Class I areas are located within 300 km of two BART-eligible sources at a facility.

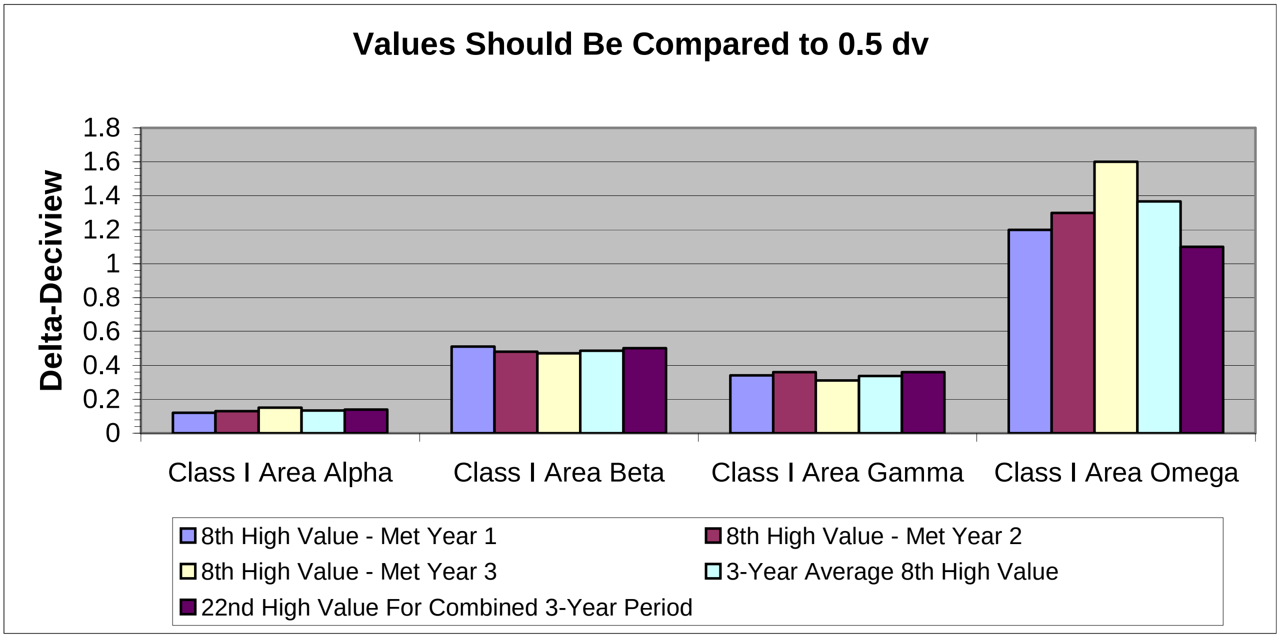
Table 7.0A: Example Table of 98th Percentile Daily Delta-Deciviews From Two BART-Eligible Sources Compared Against Best 20% Visibility Days Conditions To "Contribution Threshold".

FACILITY NAME BART-Eligible Source(s) MDEQ Code(s)	**98th Percentile Daily Change In Visibility From BART-Eligible Source Compared To Natural Background Conditions (Best 20% Visibility Days)**							
	8th High Delta-Deciview Value (Δ dv)[a]							**22nd High Delta-Deciview Value From 3-Year Average Modeling Period (Δ dv)**
	Met Year 1		**Met Year 2**		**Met Year 3**		**3-Year Average**	
Federal Mandatory Class I Area	**Δ dv**	**Number of Days ≥ 0.5 dv**	**Δ dv**	**Number of Days ≥ 0.5 dv**	**Δ dv**	**Number of Days ≥ 0.5 dv**	**Δ dv**	
Class I Area Alpha								
Class I Area Beta								
Class I Area Gamma								
Class I Area Omega								

a. Δ is the symbol for change; dv = deciview.

These results will also be represented by bar charts as shown in Figure 7.0B.

Figure 7.0B: Example Graph For Two BART-Eligible Sources Comparing 98th Percentile Daily Change in Visibility Values In Four Class I Areas.



The individual subject-to-BART sources will be presented in a similar manner, but on an air pollutant emissions basis (SO_2, NO_x, and PM_{10}). The days and receptor locations of the 98[th] percentile change events will also be tabulated.

A summary table of the highest Δ dv 98[th] percentile results from all Montana subject-to-BART sources will be developed, on an individual pollutant basis, similar to Table 7.0B.

Table 7.0B: Example Summary Table of 98[th] Percentile Daily Delta-Deciview Contribution From All Montana BART-Subject Sources Compared Against Best 20% Visibility Days.

BART-Subject Source	**98[th] Percentile Delta-Deciview Contribution (Δ dv)[a]**	**Impacted Class I Area**	**Receptor**	**Critical Met Period**	**Day**
AAA	1.533	Class I Area Alpha			
BBB	0.499	Class I Area Gamma			

[a.] Δ is the symbol for change; dv = deciview.

Another method is to display the results on an individual Class I area and air pollutant basis as shown by Table 7.0C.

Table 7.0C: Example NO_x Summary Table of 98th Percentile Daily Delta-Deciview Contribution From All BART-Subject Sources Compared Against Class I Area Alpha Best 20% Visibility Days.

Pollutant: NO_x Class I Area: Class I Area Alpha						
BART-Subject Source	**98th Percentile Delta-Deciview Contribution (Δ dv)[a]**	**Daily Emissions (lb/day)[b]**	**Distance To Impacted Class I Area (km)[c]**	**Receptor**	**Critical Met Period**	**Day**
AAA[d]						
BBB						
CCC						

a. Δ is the symbol for change; dv = deciviews.
b. lb/day = pounds per day.
c. km = kilometers.
d. Arbitrary code.

Summary tables will also be developed showing the composite effect of all emissions from each subject-to-BART source for each relevant Class I area using the highest 98th percentile daily Δ dv as the metric analogous to Table 7.0D. These results will also be represented by bar graphs.

Table 7.0D: Example Summary Table of 98th Percentile Daily Delta-Deciview Contribution From BART-Subject Sources Composite Emissions Compared Against Class I Area Alpha Best 20% Visibility Days.

BART-Subject Source	**Pollutant: All Class I Area: Alpha**					
	98th Percentile Delta-Deciview Contribution (Δ dv)[a]	**Daily Emissions (lb/day)[b]**	**Distance To Impacted Class I Area (km)[c]**	**Receptor**	**Critical Met Period**	**Day**
AAA[d]						
BBB						
CCC						

a. Δ is the symbol for change; dv = deciviews.
b. lb/day = pounds per day.
c. km = kilometers.
d. Arbitrary code.

APPENDIX A:

Values For f(RH) Determined From The Growth Of Ammonium Sulfate[8]

[8] EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

Guidance for Estimating Natural Visibility

Conditions Under the Regional Haze Program

Table A-I Values for f(RH) determined from the growth of ammonium sulfate

RH	f(RH)	RH	f(RH)	RH	f(RH)
1	1.00	34	1.00	67	2.03
2	1.00	35	1.00	68	2.08
3	1.00	36	1.00	69	2.14
4	1.00	37	1.02	70	2.19
5	1.00	38	1.04	71	2.25
6	1.00	39	1.06	72	2.31
7	1.00	40	1.08	73	2.37
8	1.00	41	1.10	74	2.43
9	1.00	42	1.13	75	2.50
10	1.00	43	1.15	76	2.56
11	1.00	44	1.18	77	2.63
12	1.00	45	1.20	78	2.70
13	1.00	46	1.23	79	2.78
14	1.00	47	1.26	80	2.86
15	1.00	48	1.28	81	2.94
16	1.00	49	1.31	82	3.03
17	1.00	50	1.34	83	3.12
18	1.00	51	1.37	84	3.22
19	1.00	52	1.41	85	3.33
20	1.00	53	1.44	86	3.45
21	1.00	54	1.47	87	3.58
22	1.00	55	1.51	88	3.74
23	1.00	56	1.54	89	3.93
24	1.00	57	1.58	90	4.16
25	1.00	58	1.62	91	4.45
26	1.00	59	1.66	92	4.84
27	1.00	60	1.70	93	5.37
28	1.00	61	1.74	94	6.16
29	1.00	62	1.79	95	7.40
30	1.00	63	1.83	96	9.59
31	1.00	64	1.88	97	14.1
32	1.00	65	1.93	98	26.4
33	1.00	66	1.98		

APPENDIX B:

Precipitation Stations

APPENDIX B: Precipitation Stations.[a]

Station	State	COOP ID[a]	Grid Coordinates X	Y	Latitude (NAD83)[c]	Longitude (NAD83)	Elevation (m)[d]	Available Data (2001 - 2003)	Time Zone
BONNERS FERRY	ID	101079	98940	516326	48.7	116.317	539.5	All	8
CALDER	ID	101370	95302	358599	47.283	116.183	638.9	All	8
CAMBRIDGE 2 NE	ID	101410	34127	62837	44.583	116.633	810.8	All	7
CASCADE 1 NW	ID	101514	79668	51417	44.517	116.05	1492.3	All	7
CENTERVILLE ARBAUGH	ID	101636	90569	-10838	43.967	115.85	1353.3	All	7
COEUR D'ALENE	ID	101956	52997	407009	47.683	116.8	650.1	All	8
COTTONWOOD 2 WSW	ID	102159	66761	221680	46.033	116.4	1202.4	All	8
COUNCIL	ID	102187	51425	78019	44.733	116.433	899.2	All	7
DIXIE	ID	102575	134651	162214	45.55	115.467	1713	All	7
DUBOIS EXPERIMENT ST	ID	102707	384283	3718	44.25	112.2	1661.2	All	7
DWORSHAK FISH HATCH	ID	102845	77689	272770	46.5	116.317	303.3	All	8
ELK CITY	ID	102875	137046	193599	45.833	115.467	1236.9	All	8
ELK RIVER 1 S	ID	102892	90411	301411	46.767	116.183	889.4	All	8
ENAVILLE	ID	102966	92988	390404	47.567	116.25	646.2	All	8
FENN	ID	103143	132882	223637	46.1	115.55	484.6	All	8
HEADQUARTERS	ID	104150	118381	284216	46.633	115.8	964.7	All	8
ISLAND PARK	ID	104598	451286	20304	44.417	111.367	1917.2	All	7
LEADORE	ID	105169	293510	55733	44.683	113.367	1828.8	All	7
LEWISTON NEZ PERCE	ID	105241	22792	262936	46.367	117.017	437.7	All	8
MCCALL	ID	105708	79135	92353	44.883	116.1	1531.6	All	7
MIDDLE FORK LODGE	ID	105897	163169	67269	44.717	115.017	1365.5	All	7
MOSCOW 5 NE	ID	106148	34999	310127	46.8	116.917	914.1	All	8
MULLAN	ID	106230	125821	376512	47.467	115.8	1011	All	8
OLA	ID	106586	57975	16070	44.183	116.283	937.3	All	7
PIERCE	ID	107046	117191	269455	46.5	115.8	970.8	All	8
PLUMMER 3 WSW	ID	107188	36666	367636	47.317	116.967	890	All	8
PORTHILL 1 SW	ID	107269	88479	550740	49	116.5	518.2	All	8
PRICHARD 4 N	ID	107358	114199	403474	47.7	115.983	760.5	All	8

APPENDIX B: Precipitation Stations (continued).

Station	State	COOP ID	Grid Coordinates X	Y	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)	Available Data (2001 - 2003)	Time Zone
SANDPOINT	ID	108137	77839	473556	48.3	116.55	640.1	All	8
YELLOW PINE 7 S	ID	109951	125538	77462	44.783	115.5	1554.5	All	7
YELLOWPINE BAR	ID	109963	151520	160950	45.55	115.25	755.9	All	8
ABSAROKEE	MT	240019	609110	144487	45.55	109.383	1181.1	All	7
ALZADA	MT	240165	1000400	98218	45.017	104.417	1051.6	All	7
ASHLAND RS	MT	240330	852112	155240	45.6	106.267	920.5	All	7
AUGUSTA	MT	240364	381678	365174	47.5	112.4	1240.5	All	7
BAYLOR	MT	240554	822039	496928	48.683	106.483	892.8	All	7
BOZEMAN GALLATIN FLD	MT	240622	470448	171780	45.783	111.167	1349.3	2003	7
BILLINGS/LOGAN INT	MT	240807	673825	172705	45.8	108.55	1087.2	All	7
BOULDER	MT	241008	398297	223767	46.233	112.117	1494.7	All	7
BOZEMAN 6 W EXP FARM	MT	241047	471512	160645	45.683	111.15	1455.4	2001	7
BREDETTE	MT	241088	912310	486273	48.55	105.267	819	All	7
BRIDGER	MT	241102	645756	115017	45.283	108.917	1121.7	All	7
BROADUS	MT	241127	920508	141760	45.45	105.4	924.2	All	7
BROWNING	MT	241202	340601	485512	48.567	113.017	1327.4	All	7
BUTTE 8 S	MT	241309	366052	187874	45.9	112.517	1737.4	All	7
CARDWELL	MT	241500	409869	182642	45.867	111.95	1301.5	All	7
CHOTEAU	MT	241737	397942	399808	47.817	112.2	1172	All	7
CLARK CANYON DAM	MT	241781	335944	89012	45	112.85	1700.8	All	7
COHAGEN	MT	241875	818905	315162	47.05	106.617	827.5	All	7
CONTENT 3 SSE	MT	241984	745484	416651	47.983	107.55	713.2	2001	7
COOKE CITY 2 W	MT	241995	563213	85330	45.017	109.967	2273.8	All	7
CUT BANK MUNI AP	MT	242173	388658	487258	48.6	112.367	1169.8	All	7
DARBY	MT	242221	237707	207168	46.017	114.183	1182.6	All	7
DEBORGIA	MT	242260	153914	365022	47.383	115.417	1063.8	2001	7
DILLON AP	MT	242404	360659	115806	45.25	112.55	1589.8	2003	7
DILLON 9 SSE	MT	242414	354765	99357	45.1	112.617	1676.4	All	7

APPENDIX B: Precipitation Stations (continued).

Station	State	COOP ID	Grid Coordinates X	Y	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)	Available Data (2001 - 2003)	Time Zone
DIVIDE	MT	242421	347278	171946	45.75	112.75	1630.7	All	7
DODSON 11 N	MT	242441	695949	478628	48.55	108.2	826	All	7
DRUMMOND AVIATION	MT	242500	316944	271524	46.633	113.2	1219.2	All	7
DUTTON 6 E	MT	242584	444179	402098	47.85	111.583	1095.5	All	7
EKALAKA	MT	242689	983834	193645	45.883	104.55	1043.9	All	7
ESSEX	MT	242812	294726	456208	48.283	113.617	1179.6	All	7
EUREKA RS	MT	242827	192228	531243	48.9	115.067	771.8	All	7
FORT PECK POWER PLAN	MT	243176	831099	423126	48.017	106.4	630.6	All	7
GIBBONS PASS	MT	243479	253737	170986	45.7	113.95	2133.6	All	7
GIBSON DAM	MT	243489	355804	377311	47.6	112.75	1399	All	7
GLASGOW INT	MT	243558	814134	444723	48.217	106.617	699.2	All	7
GLENDIVE	MT	243581	962674	327765	47.1	104.717	632.8	All	7
GREAT FALLS/INT	MT	243751	458111	359138	47.467	111.383	1116.8	All	7
HAUGAN 3 E DEBORGIA	MT	243984	158934	364644	47.383	115.35	944.9	All	7
HAVRE	MT	243996	587700	479701	48.55	109.767	787.9	All	7
HEBGEN DAM	MT	244038	455117	70246	44.867	111.333	1977.8	All	7
HELENA WSO	MT	244055	459624	262780	46.6	111.333	1166.8	All	7
HILGER	MT	244143	610085	333363	47.25	109.367	1243.6	All	7
HOLTER DAM	MT	244241	408679	306796	46.983	112.017	1062.8	All	7
HUNGRY HORSE DAM	MT	244328	265523	465245	48.35	114.017	963.2	All	7
ILIAD	MT	244368	578781	392652	47.783	109.783	899.2	2001	7
ISMAY	MT	244442	960363	260843	46.5	104.8	762	All	7
JOPLIN	MT	244512	506538	480444	48.567	110.767	1013.5	All	7
KALISPELL GLACIER AP	MT	244558	248043	462572	48.317	114.25	905.6	All	7
LAKEVIEW	MT	244820	416047	41628	44.6	111.817	2045.2	All	7
LAVINA	MT	244904	642351	227957	46.3	108.95	1046.7	All	7
LEWISTOWN 2 SW	MT	244983	603797	311134	47.05	109.45	1249.7	All	7
LIBBY 1 NE RS	MT	245015	153835	478348	48.4	115.533	638.9	All	7

APPENDIX B: Precipitation Stations (continued).

Station	State	COOP ID	Grid Coordinates X	Y	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)	Available Data (2001 - 2003)	Time Zone
LIMA	MT	245030	355350	47425	44.633	112.583	1912	All	7
LINCOLN RS	MT	245040	360410	304841	46.95	112.65	1394.5	All	7
LIVINGSTON	MT	245086	526041	161595	45.7	110.45	1418.2	All	7
LODGE GRASS 4 S	MT	245106	766074	115246	45.267	107.383	1036.3	All	7
LOGAN 2 W	MT	245122	448708	183396	45.883	111.45	1246.3	All	7
LOLO HOT SPRINGS 2NE	MT	245146	217164	290066	46.75	114.517	1236	All	7
MALTA	MT	245335	719780	456834	48.35	107.883	690.4	All	7
MARTINSDALE 3 NNW	MT	245387	536071	250368	46.5	110.333	1463	All	7
MILES CITY	MT	245690	882997	245573	46.433	105.883	801	All	7
MILLEGAN	MT	245706	458170	309123	47.017	111.367	1371.6	All	7
MISSOULA JOHNSON-BELL	MT	245745	250013	306603	46.917	114.1	972.9	All	7
MOLT 6 SW	MT	245791	641456	170543	45.783	108.967	1219.2	All	7
NEIHART 8 NNW	MT	246008	502522	310076	47.033	110.783	1594.1	All	7
OVANDO	MT	246302	324019	313835	47.017	113.133	1252.4	All	7
PHILIPSBURG R S	MT	246472	307505	234904	46.3	113.3	1606.3	All	7
PLAINS RANGER STN	MT	246562	193444	371452	47.467	114.9	759	All	7
PLEASANT VALLEY 6 SE	MT	246580	202006	441408	48.1	114.85	1082	All	7
PLENTYWOOD	MT	246589	964706	515337	48.783	104.533	679.7	All	7
POLARIS	MT	246610	318379	136142	45.417	113.1	1996.4	All	7
POLEBRIDGE	MT	246615	248632	512657	48.767	114.283	1072.9	All	7
REEDPOINT	MT	246946	597407	161147	45.7	109.533	1141.2	All	7
ROUND BUTTE 1 NNE	MT	247204	240265	375820	47.533	114.283	944.9	All	7
RUSSELL	MT	247258	483294	425276	48.067	111.067	975.4	All	7
ST MARY	MT	247292	310826	505473	48.733	113.433	1389.9	All	7
ST REGIS CLARK FORK	MT	247316	178348	353944	47.3	115.083	792.5	All	7
SCOBEY 4 NW	MT	247425	894731	516889	48.833	105.483	722.4	All	7
SEELEY LAKE R S	MT	247448	296059	337449	47.217	113.517	1249.7	All	7
SHELBY	MT	247500	426404	474877	48.5	111.85	1013.5	All	7

APPENDIX B: Precipitation Stations (continued).

Station	State	COOP ID	Grid Coordinates X	Y	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)	Available Data (2001 - 2003)	Time Zone
SILVER STAR	MT	247610	383355	164997	45.7	112.283	1396	All	7
STEVENSVILLE	MT	247894	248683	262164	46.517	114.083	1028.7	All	7
SUMMIT	MT	247978	314669	458911	48.317	113.35	1595	All	7
SWAN LAKE	MT	248087	276529	418233	47.933	113.833	996.7	All	7
SWIFT DAM	MT	248101	349747	440603	48.167	112.867	1456.9	All	7
TERRY 21 NNW	MT	248169	903529	320740	47.067	105.5	992.1	All	7
TOWNSEND 12 ENE	MT	248329	462819	234924	46.35	111.283	1539.2	All	7
VANANDA 6 NE	MT	248511	798397	245889	46.433	106.917	800.1	All	7
WESTBY	MT	248777	999495	526948	48.867	104.05	641	All	7
WEST GLACIER	MT	248809	268948	481750	48.5	113.983	961.3	All	7
WST YELLOWSTONE USFS	MT	248866	473097	47618	44.667	111.1	2030	All	7
WHITE SULPHUR SPRNGS	MT	248927	492698	256541	46.55	110.9	1572.8	All	7
WINNETT	MT	249044	687408	306219	47	108.35	883.9	All	7
WINNETT 8 ESE	MT	249052	700171	300864	46.95	108.183	868.1	All	7
WISDOM	MT	249067	292141	159656	45.617	113.45	1847.1	All	7
YELLOWTAIL DAM	MT	249240	722817	119786	45.317	107.933	1007.4	All	7
ZORTMAN	MT	249900	672220	407884	47.917	108.533	1180.5	All	7
AMBROSE 3 N	ND	320189	1041031	544861.84	49	103.467	617.8	All	6
BOWMAN	ND	320995	1070251	233163.37	46.183	103.4	902.2	All	7
TROTTERS	ND	328812	1023044	352183.31	47.283	103.9	737.6	All	7
WILLISTON/SLOULIN FIELD	ND	329425	1034294	455150.67	48.2	103.65	578.8	All	6
BUFFALO	SD	391114	1063627.8	167654.25	45.6	103.55	887	All	7
CAMP CROOK	SD	391294	1031606.5	159732.29	45.55	103.967	951	All	7
PACTOLA DAM	SD	396427	1081892.7	-1862.166	44.067	103.483	1438.7	All	7
RAPID CITY REGIONAL AIRPORT	SD	396937	1116673.7	-951.132	44.05	103.05	963.2	All	7
SPEARFISH	SD	397882	1047645.1	45752.806	44.517	103.867	1109.5	All	7
BUFFALO	WY	481165	823306	15109	44.35	106.7	1423.4	All	7
LAKE YELLOWSTONE	WY	485345	528486	35617	44.567	110.4	2398.8	All	7

APPENDIX B: Precipitation Stations (continued).

Station	State	COOP ID	Grid Coordinates X	Y	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)	Available Data (2001 - 2003)	Time Zone
MOORCROFT	WY	486395	964939	6939	44.217	104.933	1318.3	All	7
OSAGE	WY	486935	1007850	-16414	43.983	104.417	1316.7	All	
POWELL	WY	487388	658043	59553	44.783	108.767	1332	All	7
RECLUSE	WY	487545	899616	60961	44.733	105.717	1264.9	All	7
SHERIDAN COUNTY WY	WY	488155	800546	60679	44.767	106.967	1208.2	All	7
STORY	WY	488626	806501	40479	44.583	106.9	1549.3	All	7
TEN SLEEP	WY	488855	764430	-21942	44.033	107.45	1375.9	All	7
WORLAND	WY	489770	723028	-24735	44.017	107.967	1237.5	All	7

[a.] Data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Data Centers (NNDC) web site (http://cdo.ncdc.noaa.gov/pls/plclimprod/cdomain.abbrev2id?datasetabbv=DS3240&countryabbv=US&georegionabbv=&forceoutside=).
[b.] COOP ID is the National Weather Service (NWS) Cooperative Observer Program (COOP) number.
[c.] NAD83 is the North American Datum 1983.
[d.] m = meters.
[e.] Elevations were not provided. Elevations were estimated using TopoZone (http://www.topozone.com/map.asp?lat=47.5667&lon=103.8&datum=NAD83&u=5).

APPENDIX C:

Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas[9]

9. EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

APPENDIX C: Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas.

Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule

Table A-2 Recommended Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Representative IMPROVE Site Location

Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Acadia	Acadia	1	ACAD1	ME	44.38	-68.37	3.2	2.8	2.8	3.2	3.2	3.3	3.7	3.7	3.9	3.5	3.4	3.5
Agua Tibia	Agua Tibia	100	AGTI1	CA	33.38	-116.87	2.4	2.3	2.4	2.2	2.2	2.2	2.2	2.3	2.3	2.2	2.1	2.2
Alpine Lakes	Snoqualmie Pass	80	SNPA1	WA	47.38	-121.37	5.3	5.0	3.7	3.6	4.2	3.1	3.5	3.4	3.8	4.9	5.5	5.3
Anaconda – Pintler	Sula	71	SULA1	MT	45.88	-114.12	3.4	3.0	2.6	2.3	2.3	2.2	1.9	1.8	2.0	2.5	3.3	3.4
Ansel Adams	Kaiser	110	KAIS1	CA	37.13	-119.12	3.0	2.7	2.5	2.1	2.0	1.7	1.7	1.7	1.8	1.9	2.3	2.7
Arches	Canyonlands	50	CANY1	UT	38.38	-109.87	2.6	2.3	1.8	1.6	1.5	1.2	1.3	1.5	1.5	1.6	2.0	2.3
Badlands	Badlands	59	BADL1	SD	43.63	-101.87	2.8	2.8	2.8	2.6	2.8	2.7	2.4	2.4	2.3	2.3	2.9	2.8
Bandelier	Bandelier	33	BAND1	NM	35.88	-106.37	2.3	2.1	1.8	1.6	1.6	1.4	1.7	2.0	1.9	1.7	2.0	2.3
Bering Sea (a)																		
Big Bend	Big Bend	31	BIBE1	TX	29.38	-103.12	1.8	1.7	1.5	1.4	1.5	1.5	1.6	1.8	1.9	1.7	1.7	1.7
Black Canyon of the Gunnison	Weminuche	55	WEMI1	CO	37.63	-107.87	2.5	2.3	2.0	1.7	1.7	1.5	1.7	2.0	1.9	1.7	2.2	2.4
Bob Marshall	Monture	73	MONT1	MT	47.13	-113.12	3.3	2.9	2.6	2.4	2.4	2.4	2.1	2.0	2.3	2.7	3.2	3.3
Bosque del Apache	Bosque del Apache	38	BOAP1	NM	33.88	-106.87	2.2	2.0	1.6	1.4	1.4	1.3	1.7	1.9	1.9	1.6	1.8	2.2
Boundary Waters Canoe Area	Boundary Waters	23	BOWA1	MN	47.88	-91.62	2.9	2.6	2.6	2.3	2.5	2.8	3.0	3.1	3.2	2.7	3.1	3.1
Breton	Breton	20	BRET1	LA	29.13	-89.12	3.5	3.3	3.3	3.3	3.4	3.6	3.8	3.8	3.6	3.4	3.4	3.5
Bridger	Bridger	65	BRID1	WY	42.88	-109.87	2.5	2.3	2.3	2.1	2.1	1.8	1.5	1.5	1.8	2.0	2.5	2.4
Brigantine	Brigantine	5	BRIG1	NJ	39.38	-74.37	2.9	2.6	2.7	2.6	2.9	3.0	3.2	3.4	3.4	3.2	2.8	2.9
Bryce Canyon	Bryce Canyon	49	BRCA1	UT	37.63	-112.12	2.6	2.4	2.0	1.6	1.5	1.3	1.3	1.5	1.5	1.6	2.0	2.4
Cabinet Mountains	Cabinet Mountains	75	CABI1	MT	47.88	-115.62	3.7	3.2	2.8	2.5	2.5	2.4	2.1	2.1	2.4	2.9	3.6	3.8
Caney Creek	Caney Creek	29	CACR1	AR	34.38	-94.12	3.3	3.0	2.7	2.8	3.2	3.2	3.0	3.0	3.2	3.2	3.1	3.3
Canyonlands	Canyonlands	50	CANY1	UT	38.38	-109.87	2.6	2.3	1.8	1.6	1.5	1.2	1.3	1.5	1.5	1.6	2.0	2.3
Cape Romain	Cape Romain	15	ROMA1	SC	32.88	-79.62	3.2	2.9	2.8	2.7	2.9	3.3	3.3	3.6	3.5	3.4	3.1	3.1
Capitol Reef	Capitol Reef	52	CAPI1	UT	38.38	-111.37	2.7	2.5	2.0	1.7	1.6	1.4	1.4	1.6	1.6	1.7	2.1	2.5
Caribou	Lassen Volcanic	90	LAVO1	CA	40.63	-121.62	3.7	3.1	2.8	2.4	2.3	2.1	2.0	2.0	2.1	2.3	3.1	3.5
Carlsbad Caverns	Guadalupe Mountains	32	GUMO1	TX	31.88	-104.87	2.4	2.0	1.6	1.4	1.6	1.5	1.9	2.2	2.4	1.7	1.9	2.3
Chassahowitzka	Chassahowitzka	18	CHAS1	FL	28.63	-82.62	3.5	3.2	3.1	3.0	3.0	3.5	3.5	3.7	3.7	3.5	3.4	3.6
Chiricahua NM	Chiricahua	39	CHIR1	AZ	32.13	-109.37	2.0	1.9	1.6	1.2	1.2	1.1	1.7	2.0	1.7	1.5	1.6	2.1
Chiricahua W	Chiricahua	39	CHIR1	AZ	32.13	-109.37	2.0	1.9	1.6	1.2	1.2	1.1	1.7	2.0	1.7	1.5	1.6	2.1
Cohutta	Cohutta	12	COHU1	GA	34.88	-84.62	3.4	3.1	2.9	2.7	3.2	3.6	3.6	3.7	3.7	3.5	3.2	3.4
Crater Lake	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
Craters of the Moon	Craters of the Moon	69	CRMO1	ID	43.38	-113.62	3.1	2.7	2.3	2.0	2.0	1.8	1.4	1.4	1.6	2.0	2.7	3.0
Cucamonga	San Gabriel	93	SAGA1	CA	34.38	-118.12	2.6	2.5	2.5	2.2	2.2	2.1	2.2	2.2	2.3	2.2	2.2	2.3
Denali	Denali	102	DENA1	AK	63.75	-148.75	2.5	2.3	2.1	1.9	1.8	2.1	2.5	2.9	2.8	3.0	2.9	3.0
Desolation	Bliss	95	BLIS1	CA	38.88	-120.12	3.2	2.8	2.5	2.0	1.9	1.6	1.5	1.5	1.7	1.8	2.4	3.0
Diamond Peak	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
Dolly Sods	Dolly Sods	8	DOSO1	WV	39.13	-79.37	3.0	2.7	2.7	2.5	3.5	3.1	3.2	3.5	3.5	3.1	2.8	3.1
Dome Land	Dome Land	109	DOME1	CA	35.63	-118.12	2.6	2.3	2.2	1.9	1.9	1.8	1.8	1.8	1.9	1.9	2.0	2.2
Eagle Cap	Starkey	76	STAR1	OR	45.13	-118.62	4.3	3.8	3.2	2.9	2.7	2.4	2.0	2.1	2.4	3.3	4.2	4.5
Eagles Nest	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1
Emigrant	Yosemite	96	YOSE1	CA	37.63	-119.62	3.0	2.9	2.7	2.2	2.1	1.7	1.5	1.5	1.6	1.8	2.3	2.7
Everglades	Everglades	19	EVER1	FL	25.38	-80.62	2.6	2.5	2.5	2.3	2.3	2.6	2.5	2.8	2.9	2.7	2.5	2.6
Fitzpatrick	Bridger	65	BRID1	WY	42.88	-109.87	2.5	2.3	2.3	2.1	2.1	1.8	1.5	1.5	1.8	2.0	2.5	2.4
Flat Tops	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1

APPENDIX C: Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas (continued).

Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule

Table A-2 Recommended Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Representative IMPROVE Site Location

Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Galiuro	Chiricahua	39	CHIR1	AZ	32.13	-109.37	2.0	1.9	1.6	1.2	1.2	1.1	1.7	2.0	1.7	1.5	1.6	2.1
Gates of the Mountains	Gates of the Mountains	74	GAMO1	MT	46.88	-111.62	2.8	2.5	2.4	2.3	2.3	2.2	2.0	1.9	2.1	2.4	2.7	2.7
Gearhart Mountain	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
Gila	Gila Cliffs	42	GICL1	NM	33.13	-108.12	2.1	1.9	1.6	1.3	1.3	1.2	1.9	1.9	1.8	1.6	1.8	2.2
Glacier	Glacier	72	GLAC1	MT	48.63	-114.12	3.9	3.4	3.1	2.9	3.0	3.0	2.5	2.5	3.0	3.3	3.7	3.8
Glacier Peak	North Cascades	81	NOCA1	WA	48.63	-121.12	4.5	4.1	3.6	3.4	3.3	3.0	2.9	3.1	3.5	4.2	4.7	4.7
Goat Rocks	White Pass	79	WHPA1	WA	46.63	-121.37	4.8	4.2	3.8	3.6	3.4	3.1	2.9	3.0	3.5	4.3	4.9	5.0
Grand Canyon	Grand Canyon, Hance	48	GRCA2	AZ	35.88	-111.87	2.5	2.4	2.0	1.6	1.4	1.2	1.4	1.7	1.7	1.7	2.0	2.3
Grand Teton	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Great Gulf	Great Gulf	4	GRGU1	NH	44.38	-71.12	2.8	2.6	2.6	2.8	2.9	3.0	3.3	3.5	3.6	3.2	3.0	2.9
Great Sand Dunes	Great Sand Dunes	53	GRSA1	CO	37.63	-105.62	2.4	2.3	2.0	1.9	1.9	1.7	1.9	2.3	2.2	1.9	2.3	2.4
Great Smoky Mountains	Great Smoky Mountains	10	GRSM1	TN	35.63	-83.87	3.6	3.0	3.0	2.8	3.2	3.6	3.6	3.6	3.7	3.4	3.3	3.5
Guadalupe Mountains	Guadalupe Mountains	32	GUMO1	TX	31.88	-104.87	2.4	2.0	1.6	1.4	1.6	1.5	1.9	2.2	2.4	1.7	1.9	2.3
Haleakala	Haleakala	108	HALE1	HI	20.75	-156.25	2.7	2.6	2.5	2.5	2.4	2.3	2.4	2.4	2.3	2.5	2.7	2.6
Hawaii Volcanoes	Hawaii Volcanoes	107	HAVO1	HI	19.25	-155.25	3.0	2.9	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	3.3	3.0
Hells Canyon	Hells Canyon	77	HECA1	OR	44.88	-116.87	3.7	3.1	2.4	2.1	2.0	1.8	1.5	1.4	1.6	2.2	3.4	3.8
Hercules - Glade	Hercules - Glade	28	HEGL1	MO	36.63	-92.87	3.2	2.9	2.6	2.6	3.0	3.0	3.0	3.0	3.2	2.9	3.0	3.2
Hoover	Hoover	97	HOOV1	CA	38.13	-119.12	3.1	2.7	2.5	2.0	1.9	1.6	1.5	1.5	1.6	1.8	2.3	2.8
Isle Royale	Isle Royale	25	ISLE1	MI	47.38	-88.12	3.1	2.6	2.7	2.5	2.4	2.9	3.2	3.4	3.5	2.9	3.3	3.3
James River Face	James River Face	7	JARI1	VA	37.63	-79.62	2.9	2.7	2.6	2.4	2.9	3.1	3.2	3.3	3.4	3.0	2.7	3.0
Jarbidge	Jarbidge	68	JARB1	NV	41.88	-115.37	2.9	2.6	2.1	2.1	2.2	2.0	1.6	1.4	1.4	1.6	2.4	2.8
John Muir	Kaiser	110	KAIS1	CA	37.13	-119.12	3.0	2.7	2.5	2.1	2.0	1.7	1.7	1.7	1.8	1.9	2.3	2.7
Joshua Tree	Joshua Tree	101	JOSH1	CA	34.13	-116.37	2.4	2.3	2.3	2.0	2.0	1.9	1.5	2.0	2.0	2.0	1.9	2.1
Joyce Kilmer - Slickrock	Great Smoky Mountains	10	GRSM1	TN	35.63	-83.87	3.6	3.0	3.0	2.8	3.2	3.6	3.6	3.6	3.7	3.4	3.3	3.5
Kaiser	Kaiser	110	KAIS1	CA	37.13	-119.12	3.0	2.7	2.5	2.1	2.0	1.7	1.7	1.7	1.8	1.9	2.3	2.7
Kalmiopsis	Kalmiopsis	89	KALM1	OR	42.63	-124.12	4.5	3.9	3.7	3.5	3.3	3.1	2.9	3.0	3.1	3.6	4.4	4.4
Kings Canyon	Sequoia	98	SEQU1	CA	36.38	-118.87	2.9	2.6	2.5	2.2	2.1	1.8	1.7	1.7	1.8	1.9	2.3	2.5
La Garita	Weminuche	55	WEMI1	CO	37.63	-107.87	2.5	2.3	2.0	1.7	1.7	1.5	1.7	2.0	1.9	1.7	2.2	2.4
Lassen Volcanic	Lassen Volcanic	90	LAVO1	CA	40.63	-121.62	3.7	3.1	2.8	2.4	2.3	2.1	2.0	2.0	2.1	2.3	3.1	3.5
Lava Beds	Lava Beds	87	LABE1	CA	41.63	-121.62	4.0	3.4	3.1	2.8	2.6	2.4	2.2	2.2	2.4	2.8	3.6	4.0
Linville Gorge	Linville Gorge	13	LIGO1	NC	35.88	-81.87	3.2	3.0	2.9	2.7	3.2	3.6	3.6	3.9	3.9	3.4	3.1	3.2
Lostwood	Lostwood	62	LOST1	ND	48.63	-102.37	3.0	2.9	3.0	2.3	2.2	2.5	2.5	2.3	2.2	2.4	3.2	3.2
Lye Brook	Lye Brook	3	LYBR1	VT	43.13	-73.12	2.8	2.6	2.7	2.6	2.8	2.9	3.1	3.3	3.4	3.2	2.9	2.9
Mammoth Cave	Mammoth Cave	9	MACA1	KY	37.13	-86.12	3.3	3.0	2.9	3.0	4.1	4.7	4.6	3.5	3.5	3.2	3.1	3.4
Marble Mountain	Trinity	104	TRIN1	CA	40.88	-122.87	4.0	3.4	3.2	2.9	2.8	2.6	2.5	2.6	2.7	2.9	3.6	3.9
Maroon Bells – Snowmass	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1
Mazatzal	Ike's Backbone	46	IKBA1	AZ	34.38	-111.62	2.2	2.0	1.8	1.4	1.3	1.2	1.4	1.7	1.6	1.5	1.8	2.1
Medicine Lake	Medicine Lake	63	MELA1	MT	48.38	-104.37	3.0	2.9	2.9	2.2	2.2	2.4	2.4	2.1	2.2	2.3	3.1	3.1
Mesa Verde	Mesa Verde	54	MEVE1	CO	37.13	-108.37	2.8	2.6	2.2	1.7	1.7	1.3	1.7	2.0	1.9	1.8	2.2	2.6
Mingo	Mingo	26	MING1	MO	36.88	-90.12	3.2	2.9	2.7	2.6	2.9	3.0	3.1	3.1	3.2	2.9	3.0	3.2
Mission Mountain	Monture	73	MONT1	MT	47.13	-113.12	3.3	2.9	2.6	2.4	2.4	2.4	2.1	2.0	2.3	2.7	3.2	3.3
Mokelumne	Bliss	95	BLIS1	CA	38.88	-120.12	3.2	2.8	2.5	2.0	1.9	1.6	1.5	1.5	1.7	1.8	2.4	3.0
Moosehorn	Moosehorn	2	MOOS1	ME	45.13	-67.37	3.0	2.7	2.7	2.9	2.9	3.1	3.5	3.6	3.8	3.3	3.2	3.2

Table A-2 Recommended Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Representative IMPROVE Site Location

Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
Mount Adams	White Pass	79	WHPA1	WA	46.63	-121.37	4.8	4.2	3.8	3.6	3.4	3.1	2.9	3.0	3.5	4.3	4.9	5.0
Mount Baldy	Mount Baldy	43	BALD1	AZ	34.13	-109.37	2.2	2.1	1.7	1.4	1.3	1.2	1.6	1.9	1.7	1.6	1.9	2.3
Mount Hood	Mount Hood	85	MOHO1	OR	45.38	-121.87	4.6	4.1	3.7	3.6	3.2	3.0	2.7	2.8	3.2	4.1	4.8	4.8
Mount Jefferson	Three Sisters	84	THSI1	OR	44.38	-122.12	5.3	4.6	4.4	4.3	3.8	3.4	2.7	2.7	3.1	4.3	5.2	5.3
Mount Rainier	Mount Rainier	78	MORA1	WA	46.88	-122.12	5.3	4.7	4.4	4.3	3.9	3.7	3.4	3.6	4.2	5.1	5.5	5.6
Mount Washington	Three Sisters	84	THSI1	OR	44.38	-122.12	5.3	4.6	4.4	4.3	3.8	3.4	2.7	2.7	3.1	4.3	5.2	5.3
Mount Zirkel	Mount Zirkel	58	MOZI1	CO	40.63	-106.62	2.2	2.2	2.0	2.1	2.2	1.8	1.7	1.8	2.0	1.9	2.1	2.1
Mountain Lakes	Crater Lake	86	CRLA1	OR	42.88	-122.12	4.6	4.0	3.7	3.5	3.2	2.9	2.6	2.7	2.9	3.6	4.6	4.7
North Absaroka	North Absoraka	67	NOAB1	WY	44.63	-109.37	2.4	2.2	2.2	2.1	2.1	1.9	1.6	1.5	1.8	2.0	2.3	2.4
North Cascades	North Cascades	81	NOCA1	WA	48.63	-121.12	4.5	4.1	3.6	3.4	3.3	3.0	2.9	3.1	3.5	4.2	4.7	4.7
Okefenokee	Okefenokee	16	OKEF1	GA	30.63	-82.12	3.3	3.0	3.2	3.0	3.2	3.8	3.4	3.6	3.6	3.4	3.3	3.4
Olympic	Olympic	83	OLYM1	WA	48.13	-122.87	4.2	3.9	3.6	3.5	2.9	3.2	2.7	3.3	3.8	4.3	4.5	4.4
Otter Creek	Dolly Sods	8	DOSO1	WV	39.13	-79.37	3.0	2.7	2.7	2.5	3.5	3.1	3.2	3.5	3.5	3.1	2.8	3.1
Pasayten	Pasayten	82	PASA1	WA	48.38	-119.87	4.6	4.1	3.5	3.3	3.2	2.9	2.8	2.9	3.4	4.1	4.7	4.8
Pecos	Wheeler Peak	35	WHPE1	NM	36.63	-105.37	2.4	2.2	1.9	1.8	1.8	1.6	1.8	2.1	2.1	1.8	2.2	2.4
Petrified Forest	Petrified Forest	41	PEFO1	AZ	35.13	-109.87	2.4	2.1	1.7	1.4	1.3	1.2	1.5	1.8	1.6	1.6	2.0	2.3
Pine Mountain	Ike's Backbone	46	IKBA1	AZ	34.38	-111.62	2.2	2.0	1.8	1.4	1.3	1.2	1.4	1.7	1.6	1.5	1.8	2.1
Pinnacles	Pinnacles	92	PINN1	CA	36.38	-121.12	3.4	3.4	3.5	2.6	2.4	2.2	2.1	2.2	2.2	2.4	2.4	2.9
Point Reyes	Point Reyes	91	PORE1	CA	38.13	-122.87	3.6	3.2	3.1	2.6	2.5	2.3	2.4	2.4	2.5	2.5	2.9	3.3
Presidential Range - Ory River	Great Gulf	4	GRGU1	NH	44.38	-71.12	2.8	2.6	2.6	2.8	2.9	3.0	3.3	3.5	3.6	3.2	3.0	2.9
Rawah	Mount Zirkel	58	MOZI1	CO	40.63	-106.62	2.2	2.2	2.0	2.1	2.2	1.8	1.7	1.8	2.0	1.9	2.1	2.1
Red Rock Lakes	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Redwood	Redwood	88	REDW1	CA	41.63	-124.12	3.8	3.6	3.8	3.6	3.8	3.9	4.2	4.2	3.7	3.4	3.6	3.4
Rocky Mountain	Rocky Mountain	57	ROM1	CO	40.38	-105.62	1.9	2.0	2.0	2.1	2.3	2.0	1.9	1.9	2.0	1.8	2.0	1.9
Roosevelt Campobello	Moosehorn	2	MOOS1	ME	45.13	-67.37	3.0	2.7	2.7	2.9	2.9	3.1	3.5	3.6	3.8	3.3	3.2	3.2
Saguaro	Saguaro	40	SAGU1	AZ	32.13	-110.62	1.8	1.6	1.4	1.1	1.1	1.0	1.4	1.7	1.5	1.4	1.5	2.0
Saint Marks	Saint Marks	17	SAMA1	FL	30.13	-84.12	3.5	3.3	3.2	3.1	3.2	3.6	3.8	3.8	3.7	3.5	3.4	3.6
Salt Creek	Salt Creek	36	SACR1	NM	33.38	-104.37	2.2	1.9	1.5	1.5	1.6	1.5	1.7	1.9	2.0	1.7	1.8	2.0
San Gabriel	San Gabriel	93	SAGA1	CA	34.38	-118.12	2.6	2.5	2.5	2.2	2.2	2.1	2.2	2.2	2.3	2.2	2.2	2.3
San Gorgonio	San Gorgonio	99	SAGO1	CA	34.13	-116.87	2.5	2.6	2.4	2.1	2.1	1.8	1.7	1.8	1.9	1.8	1.9	2.1
San Jacinto	San Gorgonio	99	SAGO1	CA	34.13	-116.87	2.5	2.6	2.4	2.1	2.1	1.8	1.7	1.8	1.9	1.8	1.9	2.1
San Pedro Parks	San Pedro Parks	34	SAPE1	NM	36.13	-106.87	2.4	2.2	1.9	1.6	1.6	1.4	1.7	2.0	1.9	1.7	2.1	2.3
San Rafael	San Rafael	94	RAFA1	CA	34.63	-120.12	3.0	2.8	2.8	2.5	2.5	2.4	2.5	2.6	2.7	2.6	2.4	2.6
Sawtooth	Sawtooth	70	SAWT1	ID	44.13	-114.87	3.3	2.8	2.3	2.0	2.0	1.8	1.4	1.4	1.5	2.0	2.9	3.3
Scapegoat	Monture	73	MONT1	MT	47.13	-113.12	3.3	2.9	2.6	2.4	2.4	2.4	2.1	2.0	2.3	2.7	3.2	3.3
Selway - Bitterroot	Sula	71	SULA1	MT	45.88	-114.12	3.4	3.0	2.6	2.3	2.3	2.2	1.9	1.8	2.0	2.5	3.3	3.4
Seney	Seney	22	SENE1	MI	46.38	-85.87	3.3	2.8	2.9	2.7	2.6	3.0	3.3	3.6	3.7	3.3	3.5	3.4
Sequoia	Sequoia	98	SEQU1	CA	36.38	-118.87	2.9	2.6	2.5	2.2	2.1	1.8	1.7	1.7	1.8	1.9	2.3	2.5
Shenandoah	Shenandoah	6	SHEN1	VA	38.63	-78.37	2.9	2.6	2.7	2.4	2.9	3.1	3.2	3.5	3.5	3.0	2.7	2.9
Shining Rock	Shining Rock	11	SHRO1	NC	35.38	-82.87	3.3	3.0	2.9	2.7	3.2	3.6	3.6	3.9	3.9	3.5	3.2	3.3
Sierra Ancha	Sierra Ancha	45	SIAN1	AZ	34.13	-110.87	2.2	2.0	1.7	1.4	1.3	1.1	1.5	1.8	1.6	1.5	1.8	2.2
Simeonof	Simeonof	105	SIME1	AK	55.25	-160.75	4.2	4.2	3.8	4.0	4.2	4.6	5.0	5.2	4.5	3.7	3.9	4.2
Sipsey	Sipsey	21	SIPS1	AL	34.38	-87.37	3.3	3.0	2.8	2.7	3.1	3.4	3.5	3.5	3.5	3.3	3.1	3.3

APPENDIX C: Monthly Site-Specific f(RH) Values For All National 156 Federally Mandated Class I Areas (continued).

Table A-2 Recommended Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area, Based on the Representative IMPROVE Site Location

Class I Area	Site Name		Code	Site St	LAT	LONG	Jan f(RH)	Feb f(RH)	Mar f(RH)	Apr f(RH)	May f(RH)	Jun f(RH)	Jul f(RH)	Aug f(RH)	Sep f(RH)	Oct f(RH)	Nov f(RH)	Dec f(RH)
South Warner	Lava Beds	87	LABE1	CA	41.63	-121.62	4.0	3.4	3.1	2.8	2.6	2.4	2.2	2.2	2.4	2.8	3.6	4.0
Strawberry Mountain	Starkey	76	STAR1	OR	45.13	-118.62	4.3	3.8	3.2	2.9	2.7	2.4	2.0	2.1	2.4	3.3	4.2	4.5
Superstition	Tonto	44	TONT1	AZ	33.63	-111.12	2.1	1.9	1.6	1.3	1.2	1.1	1.4	1.7	1.6	1.5	1.7	2.1
Swanquarter	Swanquarter	14	SWAN	NC	35.38	-76.12	2.9	2.7	2.6	2.4	2.7	3.0	3.1	3.2	3.1	3.0	2.7	2.9
Sycamore Canyon	Sycamore Canyon	47	SYCA1	AZ	35.13	-111.87	2.4	2.4	2.0	1.6	1.5	1.2	1.5	2.0	1.9	1.8	2.0	2.3
Teton	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Theodore Roosevelt	Theodore Roosevelt	61	THRO1	ND	46.88	-103.37	2.9	2.8	2.8	2.4	2.4	2.5	2.4	2.2	2.2	2.3	3.0	3.0
Thousand Lakes	Lassen Volcanic	90	LAVO1	CA	40.63	-121.62	3.7	3.1	2.8	2.4	2.3	2.1	2.0	2.0	2.1	2.3	3.1	3.5
Three Sisters	Three Sisters	84	THSI1	OR	44.38	-122.12	5.3	4.6	4.4	4.3	3.8	3.4	2.7	2.7	3.1	4.3	5.2	5.3
Tuxedni	Tuxedni	103	TUXE1	AK	59.75	-152.75	3.6	3.4	2.9	2.8	2.8	2.9	3.6	3.9	3.8	3.4	3.5	3.7
U.L. Bend	U L Bend	64	ULBE1	MT	47.63	-108.62	2.6	2.4	2.4	2.3	2.2	2.1	1.9	1.8	1.9	2.2	2.6	2.6
Upper Buffalo	Upper Buffalo	27	UPBU1	AR	35.88	-93.12	3.2	2.9	2.6	2.7	3.1	3.1	3.0	3.0	3.2	3.0	3.0	3.2
Ventana	Pinnacles	92	PINN1	CA	36.38	-121.12	3.4	3.4	3.5	2.6	2.4	2.2	2.1	2.2	2.2	2.4	2.4	2.9
Virgin Islands (b)	Virgin Islands	106	VIIS1	VI	18.75	-155.75												
Voyageurs	Voyageurs	24	VOYA2	MN	48.38	-92.87	2.7	2.4	2.3	2.2	2.2	2.8	2.5	2.7	2.9	2.5	2.8	2.7
Washakie	North Absoraka	67	NOAB1	WY	44.63	-109.37	2.4	2.2	2.2	2.1	2.1	1.9	1.6	1.5	1.8	2.0	2.3	2.4
Weminuche	Weminuche	55	WEMI1	CO	37.63	-107.87	2.5	2.3	2.0	1.7	1.7	1.5	1.7	2.0	1.9	1.7	2.2	2.4
West Elk	White River	56	WHRI1	CO	39.13	-106.87	2.2	2.2	2.0	2.0	2.0	1.7	1.8	2.1	2.1	1.8	2.1	2.1
Wheeler Peak	Wheeler Peak	35	WHPE1	NM	36.63	-105.37	2.4	2.2	1.9	1.8	1.8	1.6	1.8	2.1	2.1	1.8	2.2	2.4
White Mountain	White Mountain	37	WHIT1	NM	33.38	-105.62	2.2	1.9	1.6	1.5	1.5	1.4	1.7	1.9	2.0	1.7	1.8	2.1
Wichita Mountains	Wichita Mountains	30	WIMO1	OK	34.63	-98.62	2.8	2.6	2.4	2.4	2.7	2.5	2.2	2.4	2.7	2.5	2.6	2.8
Wind Cave	Wind Cave	60	WICA1	SD	43.63	-103.37	2.5	2.5	2.5	2.5	2.6	2.5	2.2	2.2	2.1	2.2	2.6	2.5
Wolf Island	Okefenokee	16	OKEF1	GA	30.63	-82.12	3.3	3.0	3.2	3.0	3.2	3.8	3.4	3.6	3.6	3.4	3.3	3.4
Yellowstone	Yellowstone	66	YELL2	WY	44.63	-110.37	2.5	2.3	2.2	2.1	2.1	1.9	1.7	1.6	1.8	2.1	2.4	2.5
Yolla Bolly - Middle Eel	Trinity	104	TRIN1	CA	40.88	-122.87	4.0	3.4	3.2	2.9	2.8	2.6	2.5	2.6	2.7	2.9	3.6	3.9
Yosemite	Yosemite	96	YOSE1	CA	37.63	-119.62	3.0	2.9	2.7	2.2	2.1	1.7	1.5	1.5	1.6	1.8	2.3	2.7

a: No particulate matter sampling or visibility monitoring is conducted in the Bering Sea Wilderness.
b: *f(RH)* values for Virgin Islands National Park were not calculated because of the limited RH data available.

APPENDIX D:

APPENDIX D: Default Natural Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and Best and Worse 20% Natural Visibility Days[10]

[10]. EPA. 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. EPA-454/B-03-005. U.S. Environment Protection Agency. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Air Quality Trends Analysis Group. Research Triangle Park, NC.

APPENDIX D: Default Natural Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and Best and Worse 20% Natural Visibility Days.

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile

***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Acadia NP	ME	44.35	-68.24	21.40	7.61	3.77	11.45
Agua Tibia Wilderness	CA	33.42	-116.99	15.86	4.61	2.05	7.17
Alpine Lake Wilderness	WA	47.55	-121.16	16.99	5.30	2.74	7.86
Anaconda-Pintler Wilderness	MT	45.95	-113.50	16.03	4.72	2.16	7.28
Arches NP	UT	38.73	-109.58	15.58	4.43	1.87	6.99
Badlands NP	SD	43.81	-102.36	16.06	4.74	2.18	7.30
Bandelier NM	NM	35.79	-106.34	15.62	4.46	1.90	7.02
Bering Sea	AK	60.46	-172.75				
Big Bend NP	TX	29.33	-103.31	15.48	4.37	1.81	6.93
Black Canyon of the Gunnison NM	CO	38.57	-107.75	15.68	4.50	1.94	7.06
Bob Marshall Wilderness	MT	47.68	-113.23	16.17	4.80	2.24	7.36
Bosque del Apache	NM	33.79	-106.85	15.54	4.41	1.85	6.97
Boundary Waters Canoe Area	MN	48.06	-91.43	20.89	7.37	3.53	11.21
Breton	LA	29.87	-88.82	21.57	7.69	3.85	11.53
Bridger Wilderness	WY	42.99	-109.49	15.71	4.52	1.96	7.08
Brigantine	NJ	39.49	-74.39	21.05	7.44	3.60	11.28
Bryce Canyon NP	UT	37.57	-112.17	15.58	4.43	1.87	6.99
Cabinet Mountains Wilderness	MT	48.18	-115.68	16.27	4.87	2.31	7.43
Caney Creek Wilderness	AR	34.41	-94.08	21.14	7.49	3.65	11.33
Canyonlands NP	UT	38.23	-109.91	15.60	4.45	1.89	7.01
Cape Romain	SC	32.99	-79.49	21.22	7.52	3.68	11.36
Capitol Reef NP	UT	38.06	-111.15	15.63	4.47	1.91	7.03
Caribou Wilderness	CA	40.49	-121.21	16.05	4.73	2.17	7.29
Carlsbad Caverns NP	NM	32.12	-104.59	15.61	4.46	1.90	7.02
Chassahowitzka	FL	28.69	-82.66	21.46	7.63	3.79	11.47
Chiricahua NM	AZ	32.01	-109.34	15.47	4.36	1.80	6.92
Chiricahua Wilderness	AZ	31.86	-109.28	15.45	4.35	1.79	6.91
Cohutta Wilderness	GA	34.93	-84.57	21.39	7.60	3.76	11.44
Crater Lake NP	OR	42.92	-122.13	16.74	5.15	2.59	7.71
Craters of the Moon NM	ID	43.39	-113.54	15.80	4.57	2.01	7.13
Cucamonga Wilderness	CA	34.24	-117.59	15.85	4.61	2.05	7.17
Denali Preserve NP	AK	63.31	-151.19	16.27	4.86	2.30	7.42
Desolation Wilderness	CA	38.90	-120.17	15.80	4.57	2.01	7.13
Diamond Peak Wilderness	OR	43.53	-122.10	16.84	5.21	2.65	7.77
Dolly Sods Wilderness	VW	39.00	-79.37	21.13	7.48	3.64	11.32
Dome Land Wilderness	CA	35.84	-118.23	15.70	4.51	1.95	7.07
Eagle Cap Wilderness	OR	45.22	-117.37	16.12	4.78	2.22	7.34

APPENDIX D: Default Natural Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and Best and Worse 20% Natural Visibility Days (continued).

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile

***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Eagles Nest Wilderness	CO	39.67	-106.29	15.72	4.52	1.96	7.08
Emigrant Wilderness	CA	38.18	-119.77	15.81	4.58	2.02	7.14
Everglades NP	FL	25.35	-80.98	20.77	7.31	3.47	11.15
Fitzpatrick Wilderness	WY	43.24	-109.60	15.73	4.53	1.97	7.09
Flat Tops Wilderness	CO	39.95	-107.30	15.70	4.51	1.95	7.07
Galiuro Wilderness	AZ	32.60	-110.39	15.40	4.32	1.76	6.88
Gates of the Mountains Wilderness	MT	46.86	-111.82	15.93	4.66	2.10	7.22
Gearhart Mountain Wilderness	OR	42.51	-120.86	16.33	4.90	2.34	7.46
Gila Wilderness	NM	33.21	-108.47	15.51	4.39	1.83	6.95
Glacier NP	MT	48.64	-113.84	16.48	5.00	2.44	7.56
Glacier Peak Wilderness	WA	48.21	-121.00	16.88	5.24	2.68	7.80
Goat Rocks Wilderness	WA	46.52	-121.47	16.93	5.26	2.70	7.82
Grand Canyon NP	AZ	36.30	-112.79	15.51	4.39	1.83	6.95
Grand Teton NP	WY	43.82	-110.71	15.74	4.53	1.97	7.09
Great Gulf Wilderness	NH	44.30	-71.28	21.10	7.47	3.63	11.31
Great Sand Dunes NM	CO	37.77	-105.57	15.74	4.54	1.98	7.10
Great Smoky Mountains NP	TN	35.60	-83.52	21.39	7.60	3.76	11.44
Guadalupe Mountains NP	TX	31.91	-104.85	15.64	4.47	1.91	7.03
Haleakala NP	HI	20.71	-156.16	16.02	4.71	2.15	7.27
Hawaii Volcanoes NP	HI	19.41	-155.34	16.33	4.91	2.35	7.47
Hells Canyon Wilderness	OR	45.54	-116.59	16.09	4.76	2.20	7.32
Hercules-Glades Wilderness	MO	36.68	-92.90	21.03	7.43	3.59	11.27
Hoover Wilderness	CA	38.11	-119.37	15.78	4.56	2.00	7.12
Isle Royale NP	MI	48.01	-88.83	20.91	7.38	3.54	11.22
James River Face Wilderness	VA	37.59	-79.44	20.96	7.40	3.56	11.24
Jarbidge Wilderness	NV	41.77	-115.35	15.75	4.54	1.98	7.10
John Muir Wilderness	CA	36.97	-118.88	15.80	4.58	2.02	7.14
Joshua Tree NM	CA	33.92	-115.88	15.72	4.52	1.96	7.08
Joyce-Kilmer-Slickrock Wilderness	TN	35.44	-83.99	21.40	7.61	3.77	11.45
Kaiser Wilderness	CA	37.28	-119.17	15.80	4.57	2.01	7.13
Kalmiopsis Wilderness	OR	42.26	-123.92	16.74	5.15	2.59	7.71
Kings Canyon NP	CA	36.92	-118.61	15.79	4.57	2.01	7.13
La Garita Wilderness	CO	37.95	-106.83	15.69	4.50	1.94	7.06
Lassen Volcanic NP	CA	40.49	-121.41	16.08	4.75	2.19	7.31
Lava Beds NM	CA	41.76	-121.52	16.37	4.93	2.37	7.49
Linville Gorge Wilderness	NC	35.88	-81.90	21.36	7.59	3.75	11.43
Lostwood	ND	48.59	-102.46	16.11	4.77	2.21	7.33

APPENDIX D: Default Natural Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and Best and Worse 20% Natural Visibility Days (continued).

Default Natural b_{ext}, *dv,* and 10th and 90th Percentile
***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Lye Brook Wilderness	VT	43.13	-73.02	20.99	7.41	3.57	11.25
Mamrnoth Cave NP	KY	37.20	-86.15	21.58	7.69	3.85	11.53
Marble Mountain Wilderness	CA	41.51	-123.21	16.65	5.10	2.54	7.66
Maroon Bells-Snowmass Wilderness	CO	39.10	-107.02	15.70	4.51	1.95	7.07
Mazatzal Wilderness	AZ	34.13	-111.56	15.44	4.35	1.79	6.91
Medicine Lake	MT	48.49	-104.35	16.07	4.74	2.18	7.30
Mesa Verde NP	CO	37.25	-108.45	15.73	4.53	1.97	7.09
Minarets Wilderness	CA	37.74	-119.19	15.78	4.56	2.00	7.12
Mingo	MO	37.00	-90.19	21.03	7.43	3.59	11.27
Mission Mountain Wilderness	MT	47.48	-113.87	16.21	4.83	2.27	7.39
Mokelumne Wilderness	CA	38.57	-120.06	15.80	4.58	2.02	7.14
Moosehorn	ME	45.09	-67.29	21.22	7.52	3.68	11.36
Mount Adams Wilderness	WA	46.20	-121.49	16.86	5.22	2.66	7.78
Mount Baldy Wilderness	AZ	33.95	-109.54	15.51	4.39	1.83	6.95
Mount Hood Wilderness	OR	45.37	-121.73	16.83	5.21	2.65	7.77
Mount Jefferson Wilderness	OR	44.61	-121.84	16.91	5.25	2.69	7.81
Mount Rainier NP	WA	46.86	-121.72	17.05	5.34	2.78	7.90
Mount Washington Wilderness	OR	44.30	-121.88	17.03	5.33	2.77	7.89
Mount Zirkel Wilderness	CO	40.75	-106.68	15.71	4.52	1.96	7.08
Mountain Lakes Wilderness	OR	42.33	-122.11	16.50	5.01	2.45	7.57
North Absaroka Wilderness	WY	44.74	-109.80	15.74	4.53	1.97	7.09
North Cascades NP	WA	48.83	-121.35	16.86	5.22	2.66	7.78
Okefenokee	GA	30.82	-82.33	21.41	7.61	3.77	11.45
Olympic NP	WA	47.77	-123.74	17.02	5.32	2.76	7.88
Otter Creek Wilderness	WV	38.99	-79.65	21.14	7.49	3.65	11.33
Pasayten Wilderness	WA	48.89	-120.44	16.84	5.21	2.65	7.77
Pecos Wilderness	NM	35.90	-105.62	15.65	4.48	1.92	7.04
Petrified Forest NP	AZ	34.99	-109.79	15.54	4.41	1.85	6.97
Pine Mountain Wilderness	AZ	34.31	-111.80	15.47	4.36	1.80	6.92
Pinnacles NM	CA	36.48	-121.19	16.12	4.78	2.22	7.34
Point Reyes NS	CA	38.06	-122.90	16.20	4.83	2.27	7.39
Presidential Range-Dry River Wilderness	NH	44.20	-71.34	21.15	7.49	3.65	11.33
Rainbow Lake Wilderness	WI	46.42	-91.31	20.99	7.42	3.58	11.26
Rawah Wilderness	CO	40.69	-105.95	15.72	4.52	1.96	7.08
Red Rock Lakes	MT	44.64	-111.78	15.81	4.58	2.02	7.14
Redwood NP	CA	41.44	-124.03	16.90	5.25	2.69	7.81
Rocky Mountain NP	CO	40.35	-105.70	15.67	4.49	1.93	7.05

APPENDIX D: Default Natural Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and Best and Worse 20% Natural Visibility Days (continued).

Default Natural b_{ext}, *dv*, and 10th and 90th Percentile

***dv* Values at All Mandatory Federal Class I Areas**

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Roosevelt Campobello International Park	ME	44.85	-66.94	21.22	7.52	3.68	11.36
Saguaro NM	AZ	32.17	-110.61	15.35	4.28	1.72	6.84
Salt Creek	NM	33.60	-104.41	15.58	4.43	1.87	6.99
San Gabriel Wilderness	CA	34.27	-117.94	15.86	4.61	2.05	7.17
San Gorgonio Wilderness	CA	34.12	-116.84	15.74	4.54	1.98	7.10
San Jacinto Wilderness	CA	33.75	-116.64	15.78	4.56	2.00	7.12
San Pedro Parks Wilderness	NM	36.11	-106.81	15.63	4.47	1.91	7.03
San Rafael Wilderness	CA	34.76	-119.81	16.03	4.72	2.16	7.28
Sawtooth Wilderness	ID	43.99	-115.06	15.82	4.59	2.03	7.15
Scapegoat Wilderness	MT	47.16	-112.74	16.05	4.73	2.17	7.29
Selway-Bitterroot Wilderness	ID	46.12	-114.86	16.09	4.76	2.20	7.32
Seney	MI	46.25	-86.09	21.23	7.53	3.69	11.37
Sequoia NP	CA	36.51	-118.56	15.79	4.57	2.01	7.13
Shenandoah NP	VA	38.47	-78.49	20.98	7.41	3.57	11.25
Shining Rock Wilderness	NC	35.38	-82.85	21.40	7.61	3.77	11.45
Sierra Ancha Wilderness	AZ	33.85	-110.90	15.46	4.36	1.80	6.92
Simeonof	AK	54.91	-159.28	17.21	5.43	2.87	7.99
Sipsey Wilderness	AL	34.32	-87.44	21.28	7.55	3.71	11.39
South Warner Wilderness	CA	41.31	-120.20	16.09	4.76	2.20	7.32
St. Marks	FL	30.11	-84.15	21.54	7.67	3.83	11.51
Strawberry Mountain Wilderness	OR	44.29	-118.74	16.37	4.93	2.37	7.49
Superstition Wilderness	AZ	33.50	-111.27	15.40	4.32	1.76	6.88
Swanquarter	NC	35.39	-76.39	20.91	7.38	3.54	11.22
Sycamore Canyon Wilderness	AZ	35.01	-112.09	15.53	4.40	1.84	6.96
Teton Wilderness	WY	44.04	-110.17	15.74	4.53	1.97	7.09
Theodore Roosevelt NP	ND	46.96	-103.46	16.08	4.75	2.19	7.31
Thousand Lakes Wilderness	CA	40.70	-121.58	16.10	4.76	2.20	7.32
Three Sisters Wilderness	OR	44.04	-121.91	17.01	5.31	2.75	7.87
Tuxedni	AK	60.14	-152.61	16.58	5.06	2.50	7.62
UL Bend	MT	47.54	-107.89	15.87	4.62	2.06	7.18
Upper Buffalo Wilderness	AR	36.17	-92.41	21.04	7.44	3.60	11.28
Ventana Wilderness	CA	36.21	-121.60	16.09	4.76	2.20	7.32
Virgin Islands NP (b)	VI	18.35	-64.74				
Voyageurs NP	MN	48.47	-92.80	20.64	7.25	3.41	11.09
Washakie Wilderness	WY	44.10	-109.57	15.73	4.53	1.97	7.09
Weminuche Wilderness	CO	37.61	-107.25	15.68	4.50	1.94	7.06
West Elk Wilderness	CO	38.75	-107.21	15.71	4.51	1.95	7.07

APPENDIX D: Default Natural Visibility Values For 156 Federally Mandated Class I Areas: Annual Natural Background, and Best and Worse 20% Natural Visibility Days (continued).

Mandatory Federal Class I Area	State	Lat.	Long.	bext (Mm-1)	Ann. Avg. (dv)	Best Days (dv) (a)	Worst Days (dv) (a)
Wheeler Peak Wilderness	NM	36.57	-105.40	15.70	4.51	1.95	7.07
White Mountain Wilderness	NM	33.48	-105.85	15.56	4.42	1.86	6.98
Wichita Mountains	OK	34.75	-98.65	20.60	7.23	3.39	11.07
Wind Cave NP	SO	43.58	-103.47	15.97	4.68	2.12	7.24
Wolf Island	GA	31.33	-81.30	21.33	7.58	3.74	11.42
Yellowstone NP	WY	44.63	-110.51	15.77	4.56	2.00	7.12
Yolla Bolly Middle Eel Wilderness	CA	40.09	-122.96	16.25	4.85	2.29	7.41
Yosemite NP	CA	37.85	-119.54	15.81	4.58	2.02	7.14
Zion NP	UT	37.32	-113.04	15.56	4.42	1.86	6.98

(a) Values for the best and worst days are estimated from a statistical approach described in Section 2.6 of this document.
(b) *f(RH)* values for Virgin Islands National Park were not calculated because of the limited RH data available. As such no estimates for Natural Visibility Conditions are presented at this time.

APPENDIX E:

Best 20% Natural Visibility Days Aerosol Concentrations For 18 Significant Federally Mandated Class I Areas Using Current IMPROVE Reconstructed Light Extinction Equation

APPENDIX E: Best 20% Natural Visibility Days Aerosol Concentrations For 18 Significant Federally Mandated Class I Areas Using Current IMPROVE Reconstructed Light Extinction Equation.

Component	Average Annual Natural Background West	Class I Area Best 20% Visibility Days						
		Anaconda-Pintler WA[a]	Bob Marshall WA	Cabinet Mountains WA	Gates of the Mountains WA	Glacier National Park NP[b]	Medicine Lake WA	Mission Mountain WA
Ammonium Sulfate (µg/m^3)	0.12	0.048	0.049	0.050	0.046	0.051	0.048	0.050
Ammonium Nitrate (µg/m^3)	0.10	0.040	0.041	0.042	0.039	0.043	0.040	0.042
Organic Carbon Mass (µg/m^3)	0.47	0.187	0.193	0.196	0.181	0.200	0.189	0.197
Elemental Carbon (µg/m^3)	0.02	0.008	0.008	0.008	0.008	0.009	0.008	0.008
Soil (Fine) (µg/m^3)	0.50	0.199	0.205	0.208	0.193	0.213	0.201	0.210
Coarse Mass (µg/m^3)	3.00	1.191	1.231	1.248	1.155	1.278	1.205	1.259
Total Fine (µg/m^3)	1.21	0.482	0.496	0.504	0.467	0.516	0.486	0.507
Total Coarse (µg/m^3)	3.00	1.191	1.231	1.248	1.155	1.278	1.205	1.259
Grand Total (µg/m^3)	4.21	1.673	1.727	1.752	1.622	1.794	1.691	1.766
Annual f(RH)	2.44[c]	2.56	2.63	2.83	2.57	3.18	2.57	2.57
b_{ext} (Mm^{-1})[d]	15.99 (Estimated)	12.42	12.51	12.60	12.35	12.77	12.44	12.54
Visibility (dv)[e]	4.694 (Estimated)	2.166	2.236	2.313	2.107	2.442	2.182	2.266

APPENDIX E: Best 20% Natural Visibility Days Aerosol Concentrations For 18 Significant Federally Mandated Class I Areas Using Current IMPROVE Reconstructed Light Extinction Equation (continued).

Component	**Average Annual Natural Background West**	**Class I Area Best 20% Visibility Days**						
		Red Rock Lakes WA	**Scapegoat WA**	**Selway-Bitterroot WA (ID/MT)[f]**	**U.L. Bend WA**	**Yellowstone NP (ID/MT/WY)[g, h]**	**Hells Canyon WA (ID/OR)[i]**	**North Absaroka WA (WY)**
Ammonium Sulfate ($\mu g/m^3$)	0.12	0.047	0.047	0.049	0.047	0.046	0.049	0.046
Ammonium Nitrate ($\mu g/m^3$)	0.10	0.039	0.040	0.041	0.039	0.038	0.041	0.038
Organic Carbon Mass ($\mu g/m^3$)	0.47	0.183	0.186	0.190	0.184	0.180	0.193	0.179
Elemental Carbon ($\mu g/m^3$)	0.02	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Soil (Fine) ($\mu g/m^3$)	0.50	0.194	0.198	0.203	0.195	0.192	0.206	0.190
Coarse Mass ($\mu g/m^3$)	3.00	1.165	1.187	1.216	1.171	1.150	1.235	1.142
Total Fine ($\mu g/m^3$)	1.21	0.471	0.479	0.491	0.473	0.464	0.497	0.461
Total Coarse ($\mu g/m^3$)	3.00	1.165	1.187	1.216	1.171	1.150	1.235	1.142
Grand Total ($\mu g/m^3$)	4.21	1.636	1.666	1.707	1.644	1.614	1.732	1.603
Annual f(RH)	2.44[c]	2.10	2.63	2.60	2.25	2.10	2.42	2.04
b_{ext} (Mm^{-1})[d]	15.99 (Estimated)	12.25	12.42	12.46	12.29	12.21	12.45	12.19
Visibility (dv)[e]	4.694 (Estimated)	2.027	2.168	2.203	2.065	1.998	2.194	1.977

APPENDIX E: Best 20% Natural Visibility Days Aerosol Concentrations For 18 Significant Federally Mandated Class I Areas Using Current IMPROVE Reconstructed Light Extinction Equation (continued).

Component	Average Annual Natural Background West	Class I Area 20% Best Visibility Days	Class I Area Best 20%Visibility Days		
		Sawtooth WA (ID)[i]	Teton WA (WY)	Theodore Roosevelt NP (ND)	Washakie WA (ID)
Ammonium Sulfate (µg/m^3)	0.12	0.050	0.051	0.048	0.046
Ammonium Nitrate (µg/m^3)	0.10	0.042	0.042	0.040	0.038
Organic Carbon Mass (µg/m^3)	0.47	0.197	0.200	0.189	0.179
Elemental Carbon (µg/m^3)	0.02	0.008	0.008	0.008	0.008
Soil (Fine) (µg/m^3)	0.50	0.209	0.212	0.201	0.190
Coarse Mass (µg/m^3)	3.00	1.256	1.275	1.208	1.142
Total Fine (µg/m^3)	1.21	0.506	0.513	0.486	0.461
Total Coarse (µg/m^3)	3.00	1.256	1.275	1.208	1.142
Grand Total (µg/m^3)	4.21	1.762	1.788	1.694	1.603
Annual f(RH)	2.60[c]	2.23	2.10	2.58	2.04
b_{ext} (Mm^{-1})[d]	16.10 (Estimated)	12.45	12.44	12.44	12.19
Visibility (dv)[e]	4.762 (Estimated)	2.189	2.186	2.187	1.977

a. WA = Wilderness Area.
b. NP = National Park.
c. The f(RH), the relative humidity adjustment factor, for the West average annual natural background category was calculated from the f(RH) average values of the eighteen Class I areas.
d. Mm^{-1} = inverse megameters.
e. dv = deciviews.
f. The f(RH), the relative humidity adjustment factor, for the Selway-Bitterroot WA represents the wilderness area in Idaho (ID) and Montana (MT).
g. The f(RH), the relative humidity adjustment factor, for the Yellowstone NP represents the national park in Idaho (ID), Montana (MT), and Wyoming (WY).
h. The f(RH), the relative humidity adjustment factor, for the Hells Canyon WA represents the wilderness area in Idaho (ID) and Oregon (OR).
i. ND = North Dakota.