Protocol for BART-Related Visibility Impairment Modeling Analyses in North Dakota

(Final)

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North Dakota Department of Health
Division of Air Quality
1200 Missouri Avenue
Bismarck, ND 58506

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1 Overview

On June 15, 2005, EPA issued final amendments to its July 1999 regional haze rule[1]. These amendments apply to the provisions of the regional haze rule that require emission controls known as Best Available Retrofit Technology, or BART, for industrial facilities emitting air pollutants that reduce visibility in PSD Class I areas. These pollutants include fine particulate matter ($PM_{2.5}$), and compounds which contribute to $PM_{2.5}$ formation, such as nitrogen oxides, sulfur dioxide, certain volatile organic compounds, and ammonia. The amendments include final guidelines, known as BART guidelines, for states to use in determining which facilities must install controls and the types of controls the facilities must use.

The June 15 guidelines address how to identify BART-eligible sources, how to identify sources "subject to BART", and the BART determination including analysis of BART options. As part of this process, visibility computer modeling will assist in the identification of sources "subject to BART", and in the consideration of BART options to determine the degree of visibility improvement. The North Dakota Department of Health (NDDH) has established a protocol for BART-related modeling applicable to BART-eligible sources in North Dakota, which is the focus of this document. This protocol is intended to apply to visibility modeling for both identification of sources "subject to BART" (BART screening), and for determining the degree of visibility improvement related to the selection of BART control.

[1]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.

To ultimately determine compliance with Regional Haze visibility improvement goals, four phases of visibility modeling are anticipated. In chronological order, these are:

1) single-source modeling to determine which BART-eligible sources are subject to BART (or BART-applicable),
2) single-source modeling to determine the degree of visibility improvement attributable to proposed BART control for each BART-applicable source,
3) cumulative modeling to determine the combined effect of proposed BART controls for BART-applicable sources in North Dakota, and
4) regional-scale modeling to determine if the combined effect of proposed BART controls, and other emissions reductions, for all western states ultimately satisfies visibility improvement goals.

The protocol outlined in this document applies only to the first two phases involving single-source modeling, that is, screening to determine which BART-eligible sources are subject to BART, and single-source modeling to determine the degree of improvement related to the proposed BART control. With the exception of emission rates and stack parameters, the methodologies for these first two phases of modeling, including all model inputs, are identical. The NDDH recognizes that the "degree of improvement" modeling will be only one of several criteria used to establish optimum BART controls.

The NDDH will conduct visibility modeling to determine which North Dakota BART-eligible sources are subject to BART. It is expected that BART-applicable sources will want to conduct their own single-source modeling to determine the degree of visibility improvement, as they consider a variety of BART control options. Upon request, the NDDH will also perform the single-source degree of improvement modeling. Ultimately, the NDDH will review and verify all single-source degree of visibility improvement modeling analyses. Note that all BART-related single-source modeling for sources in North Dakota must follow the protocol outlined here. Because of this requirement, the NDDH will not expect companies which operate BART-eligible sources to provide individual protocols for their BART-related modeling.

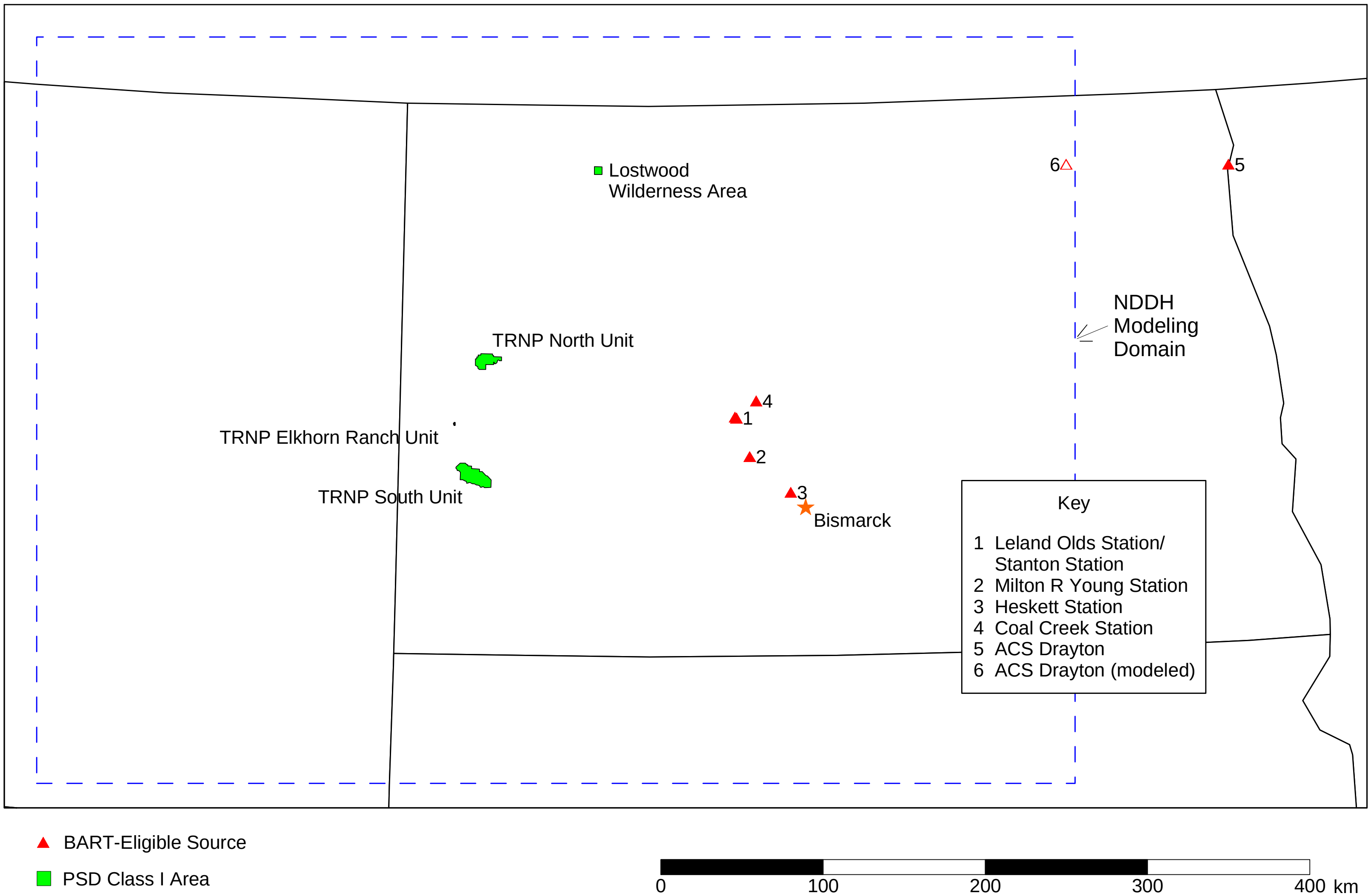
When all BART proposals have been submitted, the NDDH will conduct a cumulative modeling analysis to determine the combined effect of proposed North Dakota BART controls on visibility improvement in North Dakota Class I areas (Phase 3 modeling). A separate protocol for that analysis will be completed by the NDDH prior to modeling. The final regional-scale modeling analysis to ultimately determine compliance with visibility improvement goals (Phase 4 modeling) will be conducted by the Western Regional Air Partnership (WRAP) regional planning organization. WRAP is developing the protocol and establishing input data for that analysis. At this point, the timing of the WRAP regional-scale modeling analysis is unclear. Also unclear is the manner in which the NDDH cumulative analysis might interface with the WRAP regional-scale analysis.

BART-eligible sources in North Dakota have been previously determined by NDDH, and are listed in Table 1-1. BART-related visibility modeling for North Dakota BART-eligible sources will focus on PSD Class I areas in North Dakota, which include the Theodore Roosevelt National Park (three units) and the Lostwood Wilderness Area. Note that the three units of Theodore Roosevelt National Park will be treated as separate Class I areas for purposes of interpreting visibility modeling results (Section 4). Locations of BART-eligible sources with respect to PSD Class I areas in North Dakota are illustrated in Figure 1-1.

Table 1-1
BART-Eligible Sources in North Dakota

Facility	**Operator**
Leland Olds Station 1 Leland Olds Station 2	Basin Electric Power Coop.
Milton R. Young Station 1 Milton R. Young Station 2	Minnkota Power Coop.
Heskett Station 2	Montana-Dakota Utilities
Stanton Station 1	Great River Energy
Coal Creek Station 1 Coal Creek Station 2	Great River Energy
Drayton Sugar Beet Processing	American Crystal Sugar
Mandan Refinery	Tesoro

Figure 1-1: BART-Eligible Sources and PSD Class I Areas



Regarding the requirement to use the BART guideline for all BART-related visibility analyses, the guideline states,

> *"Section 169A(b) requires us to issue guidelines for states to follow in establishing BART emission limitations for fossil-fuel fired power plants having a capacity in excess of 750 megawatts .... For sources other than 750 megawatt power plants, however, states retain the discretion to adopt approaches that differ from the guidelines."*

In this matter, the NDDH has elected to use its discretion to require use of the BART guideline for all BART-eligible sources in North Dakota.

The single-source modeling protocol outlined here provides sufficient detail to ensure consistency among BART-related analyses for sources in North Dakota. In developing this protocol, the NDDH has implemented guidance outlined in the June 15, 2005 rule. Where clarification was needed, this guidance has been augmented through communications with EPA and FLM's.[2] To the extent applicable, the NDDH BART modeling protocol is consistent with the North Dakota alternative protocol for PSD Class I increment analyses.[3]

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[2]EPA, 2005. Electronic message from Kathy Kaufman, Research Triangle Park, NC 27711.

[3]NDDH, 2005. A Proposed Alternative Air Quality Modeling Protocol to Examine the Status of Attainment of PSD Class I Increment. North Dakota Department of Health, Bismarck, ND 58506.

The remainder of this document describes the NDDH single-source visibility modeling protocol. Modeling methodology for BART-related visibility analyses is discussed in general in Section 2. Section 3 provides detailed information regarding modeling system components and input data requirements. Model execution and interpretation of output are discussed in Section 4. NDDH Class I area receptor coordinates/elevations are provided in Appendix A.

NDDH contacts for questions on BART-related modeling and general Regional Haze issues are provided in Table 1-2.

Table 1-2
NDDH Contact Information

Name	**Task**	**Phone**	**E-mail**
Dana Mount	General Regional Haze Coordination	(701)328-5150	dmount@state.nd.us
Tom Bachman	Emissions/Rules/BART	(701)328-5188	tbachman@state.nd.us
Steve Weber	Modeling	(701)328-5188	sweber@state.nd.us
Rob White	Modeling	(701)328-5188	rwhite@state.nd.us

2 Modeling Methodology

For the determination of BART applicability for BART-eligible sources (BART screening), modeling methodology involves execution of an appropriate visibility model, then comparison of model predictions with the BART applicability threshold. To determine the degree of improvement from selected BART options, the visibility model is executed again for post-BART control conditions, and results are compared with those for pre-BART conditions. In both cases, modeling is applied on a single facility basis. With the exception of emission rates and stack parameters, model settings and input data for both pre-BART and post-BART model runs are identical.

For BART screening, all BART-eligible units contained within a subject facility must be modeled together before comparing results with the BART applicability threshold. This would include, for example, both BART-eligible units of a power plant. To determine the degree of visibility improvement from selected BART options, however, it may be desirable to model units individually, as required improvement and BART options may vary by unit.

2.1 BART Applicability Threshold

In general, to determine which BART-eligible sources must apply BART, single facility modeling results for PSD Class I areas are compared with a visibility threshold, expressed in deciviews. The NDDH will follow recommendations in the June 15 BART guideline which states,

> *"A single source that is responsible for a 1.0 deciview change or more should be considered to "cause" visibility impairment; a source that causes less than a 1.0 deciview change may still "contribute" to visibility impairment and thus be subject to BART .... As a general matter, any threshold that you use for determining whether a source "contributes" to visibility impairment should not be higher than 0.5 deciviews."*

As a practical matter, the NDDH sees no reason to distinguish among BART-eligible sources which "cause" visibility impairment versus those sources which "contribute" to visibility impairment in PSD Class I areas. Therefore, the NDDH will generally use a 0.5 deciview threshold to determine which BART-eligible sources must apply BART. The NDDH may reconsider the threshold value if subsequent multi-source modeling reveals difficulty in meeting visibility improvement goals.

2.2 Pollutants to Consider

For both BART applicability and degree of visibility improvement analyses, the BART guideline specifies that only primary emissions need to be considered. These primary emissions include SO_2, NO_x, and direct particulate matter (PM) emissions specified as either coarse (PM_{10} minus $PM_{2.5}$) or fine ($PM_{2.5}$). If this distinction in size of PM emissions cannot be made, it would be appropriate to consider all PM_{10} emissions as $PM_{2.5}$.

The BART guideline also discusses VOC or ammonia emissions as possibly impacting visibility. For BART eligible sources in North Dakota, the NDDH considers these emissions (and associated visibility impacts) to be negligible, and will not require inclusion of VOC or ammonia species in BART-related visibility analyses.

Emission rates and stack parameters for BART-related visibility modeling are discussed in detail in Section 3.

2.3 Visibility Modeling System

As shown in Figure 1-1, all BART-eligible sources will be located more than 50 kilometers from the nearest PSD Class I area in North Dakota. Source-receptor distances greater than 50 kilometers constitute long-range transport, and the EPA-approved model for long-range distances is CALPUFF[4]. As specified in the BART guideline,

> *"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 ."*

[4]CFR, 2003. EPA Guideline on Air Quality Models. 40 CFR (Code of Federal Regulations) Part 51, Appendix W.

The NDDH therefore recommends and will use CALPUFF for BART-related modeling.

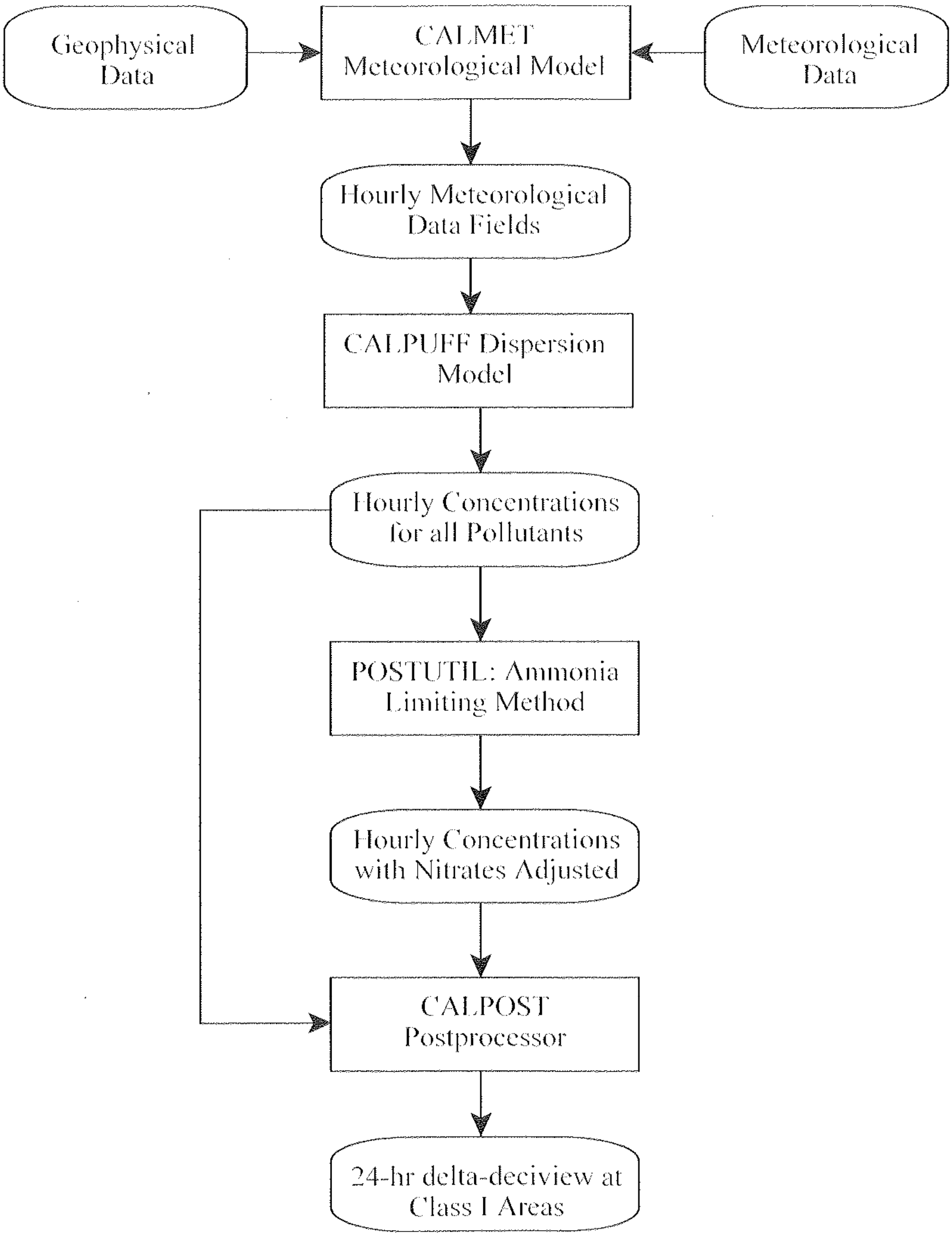
The CALPUFF computer modeling system includes the CALMET meteorological model[5], the CALPUFF dispersion model[6], and the CALPOST post processing program. The CALPOST program accommodates the visibility calculations. For visibility analyses, the CALPUFF system also provides the optional POSTUTIL program. POSTUTIL implements the ammonia limiting method to address double-counting of available ammonia for NO_x to NO_3 conversion chemistry in CALPUFF. In the sequence of execution, POSTUTIL would follow CALPUFF and precede CALPOST. CALPUFF system execution is depicted schematically in Figure 2-1. Earth Tech (Earth Tech, Inc., Concord, MA), the primary model developer, also provides several utility programs to accommodate pre-processing of meteorological and geophysical data for CALMET.

Appropriate versions of CALPUFF software for BART-related modeling are shown in Table 2-1. Note that these newer versions of CALPUFF software are not the same as versions utilized in the recent periodic review of PSD Class I increment in North Dakota. These newer versions, however, contain coding error corrections and other enhancements, and appear to be consistent with the versions being recommended by most Regional Planning Organizations for BART-related modeling. The CALPUFF system software can be downloaded free of charge from the Earth Tech web site

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

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

Figure 2-1. Calpuff Processing to Compute Visibility Impacts



(www.src.com/calpuff/calpuff1.htm). For consistency and to ensure executables can accommodate large file sizes, however, it is recommended that the software be obtained directly from NDDH.

Table 2-1
CALPUFF System Versions
Applicable For BART Modeling

Program	**Version**	**Level**
CALMET	5.53a	040716
CALPUFF	5.711a	040716
POSTUTIL	1.4	040818
CALPOST	5.51	030709

Application of the ammonia limiting method, utilizing POSTUTIL, is recommended by NDDH. The NDDH will be applying the ammonia limiting method in BART-applicability analyses.

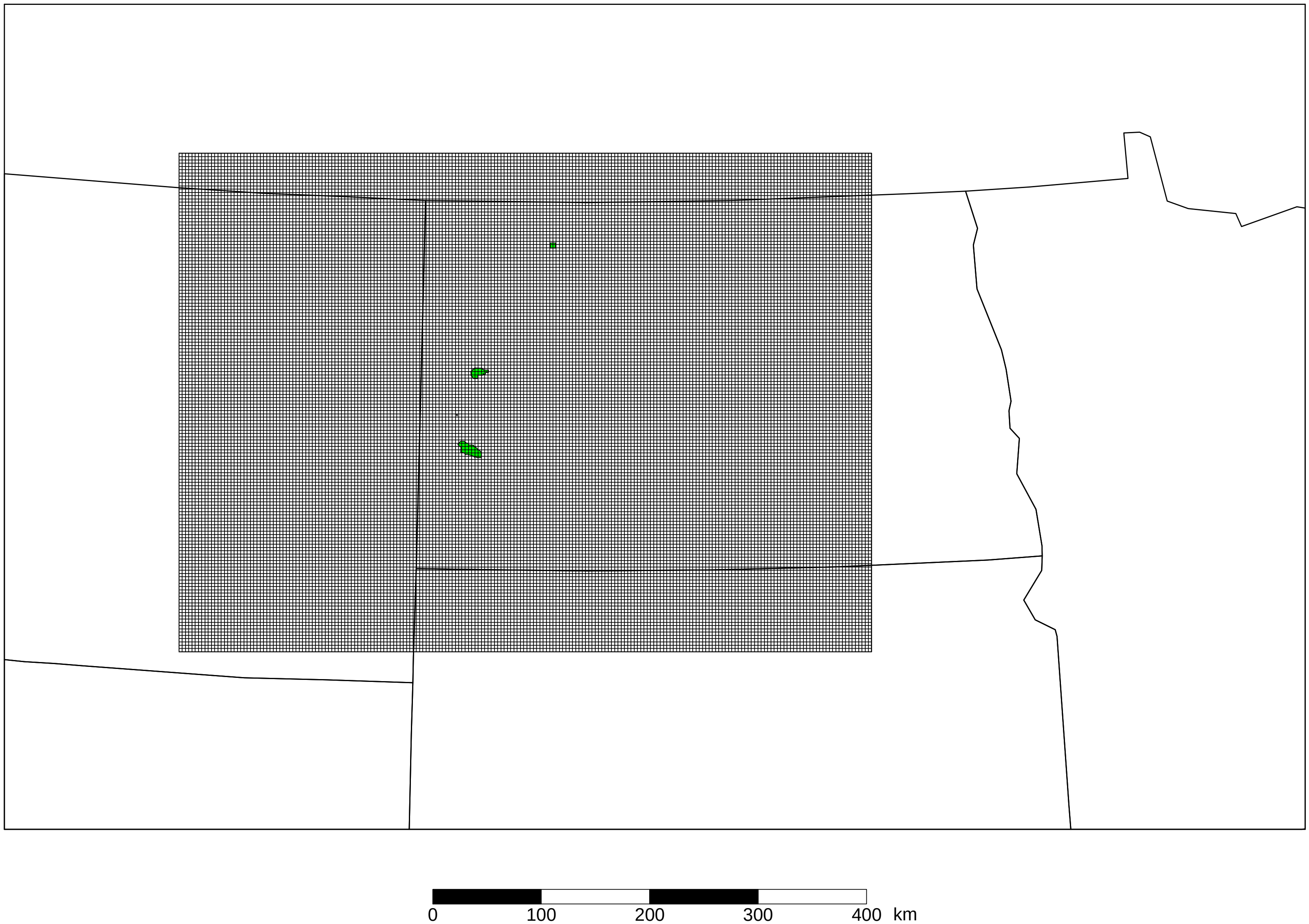
3 Model Input Data/Settings

The CALPUFF modeling system includes the CALMET meteorological model, the CALPUFF dispersion model, the CALPOST postprocessing program, and (optionally) the POSTUTIL program which can be used to implement the ammonia limiting method in visibility analyses. Each of these modules includes a control file which contains user-selected settings to control processing during model execution. CALMET and CALPUFF have additional input data requirements. Input data/settings which are consistent with the use of these programs for BART-related visibility analyses in North Dakota are discussed in Sections 3.1 through 3.4.

The CALMET/CALPUFF modeling domain preferred by the NDDH for BART-related modeling is illustrated in Figure 3-1. Dimensions of the domain are 639 kilometers east-west by 459 kilometers north-south, with a grid cell size of 3 kilometers. In the vertical, the domain is defined by twelve vertical layers. The domain is sized and positioned to encompass all North Dakota PSD Class I areas and BART-eligible sources (with exception noted below), with sufficient buffer area. Because the domain is relatively large, the Lambert Conformal map projection is used to better accommodate the earth's curvature.

As shown in Figure 1-1, the American Crystal Sugar Drayton plant is located outside of the NDDH modeling domain. Even if the domain was extended eastward to incorporate the Drayton plant, the plant is located about 400 kilometers from the nearest Class I area (Lostwood Wilderness Area), and

Figure 3-1: Gridded Modeling Domain



this distance is beyond the accepted range of CALPUFF (about 300 kilometers). For modeling purposes, therefore, the NDDH will reposition the Drayton plant about 100 kilometers to the west, to create a virtual source located just inside the east boundary of the current modeling domain (represented by the "ACS Drayton (modeled)" source in Figure 1-1). This adjustment will provide a source-receptor distance more consistent with the documented limits of CALPUFF, and should ensure conservative results.

3.1 **CALMET Input**

Input requirements for the CALMET model include various meteorological and geophysical data sets, and a control input file with appropriate settings. Required meteorological data include surface, upper-air, and precipitation observations, and mesoscale model output data fields. Geophysical input data include terrain elevation and land-use data. Though CALMET may be run with mesoscale model meteorological data, alone (i.e., no observations), the EPA modeling guideline[4] recommends "blending" observations with the mesoscale model fields. Therefore, the NDDH will include observations in a blended approach. As required in the EPA modeling guideline, meteorological observations and mesoscale model fields for three years (2000-2002) will be used with CALMET.

All meteorological and geophysical input data sets required for CALMET execution have been previously prepared for BART-related modeling analyses in North Dakota. Upon request, NDDH will provide these meteorological and geophysical data sets.

3.1.1 **Meteorological Data**

3.1.1.1 **Mesoscale Model Data**

Mesoscale model wind fields used with CALMET are based on the National Center for Environmental Predictions (NCEP) Rapid Update Cycle (RUC) forecast model. Mesoscale model fields in the MM5.DAT format required by CALMET were developed by a contractor[7]. The contractor obtained and archived RUC hourly initial analyses from NCEP for years 2000 through 2002. Resolution of these initial analyses was 40 km. The contractor used the ARPS Data Assimilation System (ADAS) to enhance resolution to 10 km, and converted the resultant hourly wind fields to the MM5.DAT format recognized by CALMET. The domain of these hourly wind fields is consistent with the CALMET/CALPUFF domain used by NDDH.

3.1.1.2 **Surface Observations**

Concurrent surface observations for the three-year period 2000-2002 were obtained in surface hourly abbreviated format from the National Climatic Data Center (NCDC). Data were obtained for approximately 35 ASOS/manual stations located within or near the NDDH CALMET/CALPUFF domain, although the specific number of stations varied among the three years. The ASOS/manual observations reflect data from stations operated by the National Weather Service, Federal Aviation

[7] WindLogics, 2004. RUC Analysis-Based CALMET Meteorological Data for the State of North Dakota. WindLogics, Inc., St. Paul, MN 55108.

Administration, U.S. Air Force, and Environment Canada. Location of these stations is shown in Figure 3-2.

To compensate for well-documented deficiencies in ASOS cloud data above 12,000 feet, NDDH also obtained concurrent GOES ASOS satellite cloud data for all selected surface stations. The satellite hourly observations included cloud amount (sky cover) and cloud height (ceiling height) data above 12,000 feet, and were therefore used to supplement the ASOS observations.

NDDH prepared custom software to merge the ASOS and satellite data. Earth Tech utility software was then used to quality assure merged data, and convert to the format required by CALMET (SURF.DAT). Standard methods were applied to provide substitutions for missing data.[8,9] The occurrence of missing data elements in the surface observations was generally very limited, and within the tolerances suggested by EPA.

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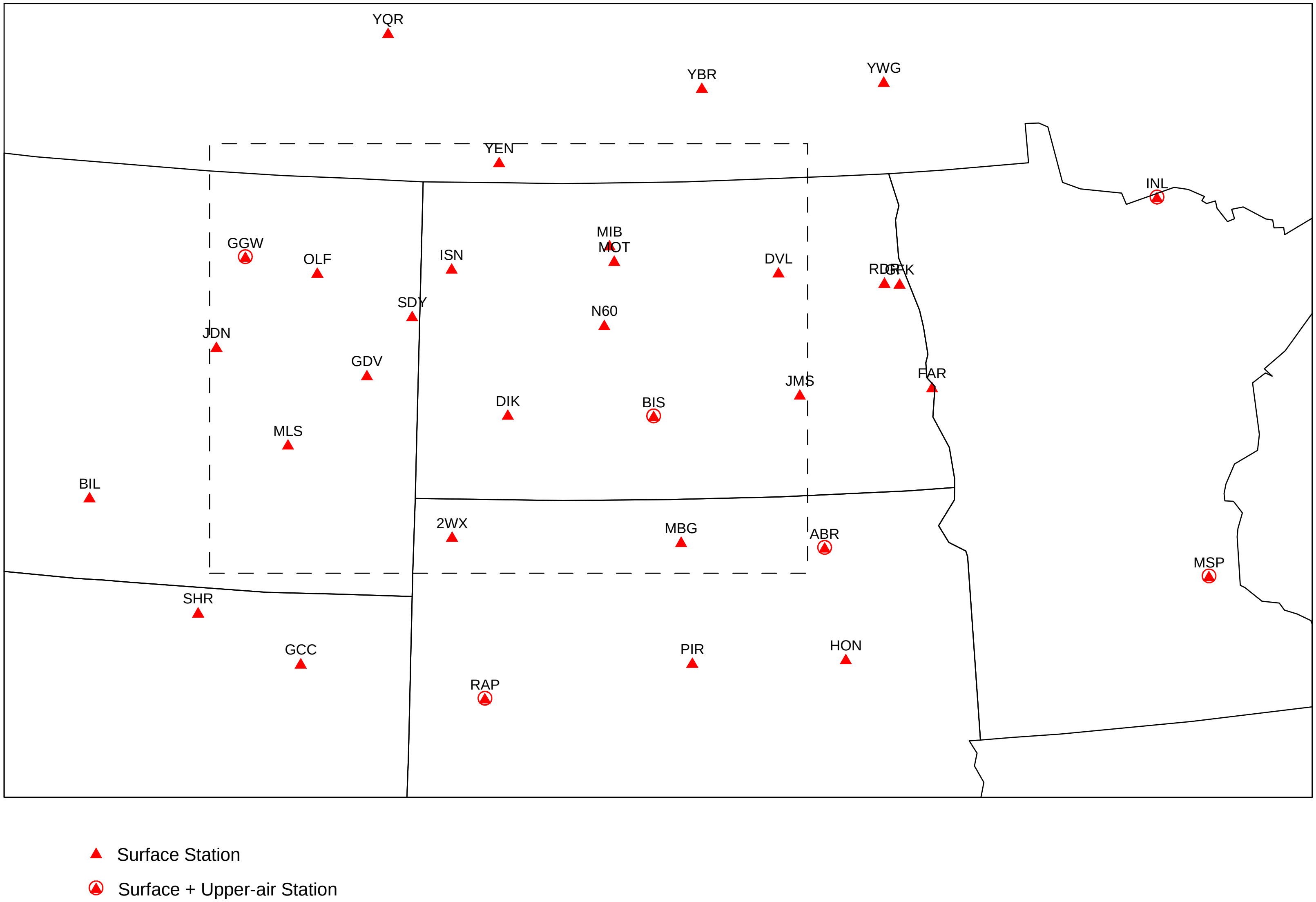
[8]Atkinson, Dennis and Russell F. Lee, 1992. Procedures for Substituting Values for Missing NWS Meteorological Data for Use in Regulatory Air Quality Models.

[9]EPA, 1987. On-Site Meteorological Program Guidance for Regulatory Modeling Application. Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

Figure 3-2: Surface / Upper-air Meteorological Stations



3.1.1.3 **Upper-Air Observations**

Upper-air observations for the three-year period 2000-2002 were obtained from NOAA's Forecast Systems Laboratory (FSL) in Boulder, Colorado. Upper-air sounding files were downloaded from the FSL website (www.fsl.noaa.gov) in the original FSL format, which is accepted for CALMET input as the option "NCDC CD-ROM". Data were obtained for six upper-air stations (NWS) located within or near the NDDH CALMET/CALPUFF domain. Location of these stations is shown in Figure 3-2.

Processing of the upper-air data for CALMET input involved using Earth Tech utility software, running custom software written by NDDH staff, and manual editing of data files. The main Earth Tech program quality checked the upper-air data files, output error messages to identify problems in the data to be corrected by the user, and converted the data to the format required by CALMET. The NDDH custom software performed additional quality checks, and, combined with manual editing of data files, corrected additional errors or problems in the data and filled in for missing data when necessary. Substitutions for missing data generally followed standard EPA guidance.[8,9] Upper-air soundings were processed up to the 500-mb level to accommodate mixing heights up to 4000 meters above ground level at Rapid City, South Dakota. In addition, the main Earth Tech processing program had to be modified slightly (corrected) to correctly read longitudes for Glasgow, Montana.

3.1.1.4 **Precipitation Data**

Hourly precipitation data for years 2000-2002 were obtained from NCDC in TD-3240 format. Data were included for approximately 90 NWS hourly recording stations located within or near the NDDH CALMET/CALPUFF modeling domain, although the specific number of stations varied among the three years. Location of these stations is shown in Figure 3-3.

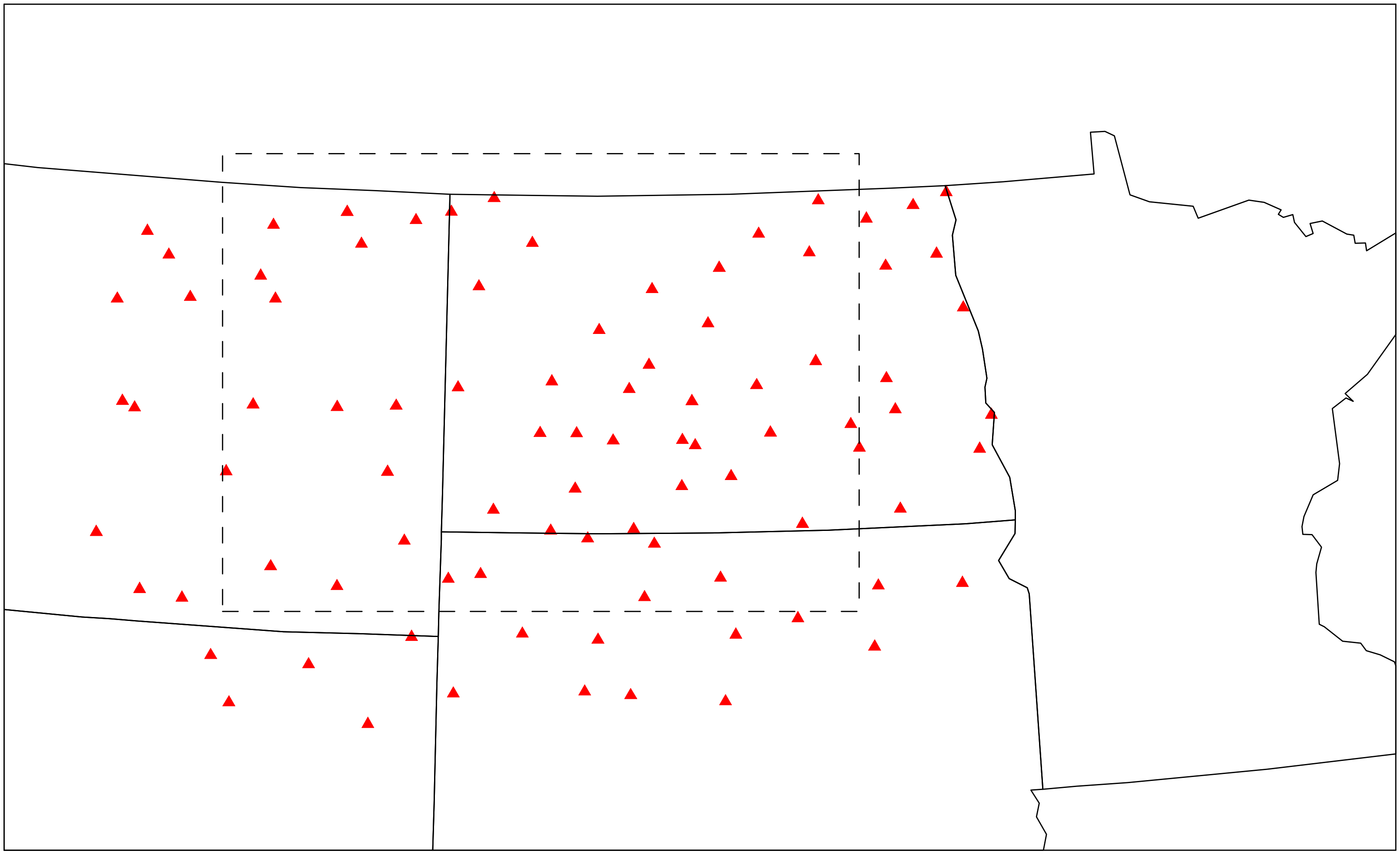
Earth Tech utility software was employed to quality assure the TD-3240 data, and process it into the format required by CALMET (PRECIP.DAT). No substitutions were made for missing data, because CALMET substitutes internally from the nearest available station, and the station resolution was relatively good (Figure 3-3).

3.1.2 **Geophysical Data**

CALMET requires specification of terrain elevation, and parameters related to the land-use profile, for each grid cell in the modeling domain. The NDDH derived terrain elevations from United States Geological Survey (USGS) GTOPO30 data sets for North America central and mountain zones. Land-use profiles were derived from the USGS Global Data Set for North America.

Using Earth Tech utility software, all gridded terrain and land-use data were processed into the single geophysical file (GEO.DAT) required by CALMET. NDDH assumed Earth Tech default values

Figure 3-3: Precipitation Stations



relating surface roughness length, albedo, Bowen ratio, soil heat flux, and leaf area index to land-use type.

3.1.3 **CALMET Control File Settings**

CALMET control file settings recommended for processing years 2000 through 2002 data for BART-related visibility analyses are generally consistent with guidance from the Interagency Workgroup on Air Quality Modeling (IWAQM)[10]. IWAQM recommendations for CALMET control file variable settings fall into two categories. IWAQM-defined variables are those for which IWAQM provides a default value as a general recommendation for all analyses. User-defined variables are those where IWAQM recognizes the input value will need to be tailored for a given application, and default values are therefore not provided.

For BART-related visibility analyses, the NDDH has established appropriate settings for user-defined variables, and has determined the need to adjust a limited number of IWAQM-defined variables from recommended values, as discussed below. The CALMET control file user-defined settings, as well as the IWAQM-defined settings which have been adjusted by NDDH, are summarized in Table 3-1. IWAQM-defined settings adjusted by NDDH have a highlighted background in the Table.

[10]EPA, 1998. IWAQM Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts. Publication No. EPA-454/R-98-019, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

Table 3-1
User-Defined and
Non-IWAQM Settings for
CALMET Control File

Variable	Description	Value
NSSTA	No. of surface stations	32,41,40*
NUSTA	No. of upper-air stations	5
NPSTA	No. of precipitation stations	89,93,93*
IBTZ	Base time zone	7
PMAP	Map projection (LCC=Lambert Conformal Conic)	LCC
FEAST	False easting at origin	0.0
FNORTH	False northing at origin	0.0
RLAT0	Origin latitude of projection	44.0N
RLON0	Central meridian of projection	102.0W
XLAT1	Latitude of 1st standard parallel for projection	46.0N
XLAT2	Latitude of 2nd standard parallel for projection	48.5N
DATUM	Datum-region for output coordinates	NWS-27
NX	No. of X grid cells	213
NY	No. of Y grid cells	153
DGRIDM	Grid spacing (km)	3.0
XORIGKM	Southwest grid cell X coordinate	-380
YORIGKM	Southwest grid cell Y coordinate	140
NZ	No. vertical layers	12
ZFACE	Cell face heights (m)	0.,20.,50.,90.,140.,200., 270.,370.,500.,1000., 1700.,2500.,4200.
NOOBS	No observation mode (0 = no)	0

Variable	Description	Value
IPROG	Use MM5.DAT file as initial guess wind field (14=yes)	14
RMAX1	Max. radius of influence of surface observation (km)	100
RMAX2	Max. radius of influence of upper-air observation (km)	200
RMAX3	Max. radius of influence over water (km)	200
TERRAD	Radius of influence of terrain features (km)	10
R1	Distance from a surface observation station at which the wind observation and the first guess field are equally weighted (km)	10
R2	Distance from an upper-air observation station at which the wind observation and the first guess field are equally weighted (km)	10
ISURFT	Surface station number used for the surface temperature for the diagnostic wind field module (Bismarck)	12,17,17*
IUPT	Upper-air station number used to compute the domain-scale temperature lapse rate for the diagnostic wind field module (Bismarck)	1
ZUPWND	Bottom and top of layer through which the domain-scale winds are computed (m)	1.,2500.
MNMDAV	Max. search distance (in grid cells) for spatial averaging of mixing ht. and temperature	7
ILEVZI	Layer of winds used in upwind averaging of mixing heights	3
ZIMAX	Maximum over land mixing height (m)	4000.
ZIMAXW	Maximum over water mixing height (m)	4000.

* Values for years 2000, 2001, 2002

Most of the user-defined settings are intuitive, related to parameterization of the meteorological grid used with CALMET, as previously discussed. The remaining user-defined variables, (RMAX1, RMAX2, RMAX3, TERRAD, R1, R2) control the influence of mesoscale model data, station observations, and terrain features in development of the final wind field. Settings for these variables are based on the NDDH alternative protocol for PSD Class I increment analyses.[3]

NDDH settings for IWAQM-defined variables are consistent with IWAQM recommendations, with limited exceptions as established in the alternative protocol for PSD Class I increment analyses. Because the use of mesoscale meteorological data is now being generally recommended for long-range modeling analyses, the IPROG variable has been changed from 0 to 14, which reflects use of MM5 format data (in this case RUC data) as the initial guess wind field. The ZUPWND setting has been changed for consistency with default values in recent versions of CALMET (the IWAQM setting reflected defaults for an older version of CALMET). Based on visual feedback testing, IWAQM settings for variables related to spatial averaging of mixing heights, MNMDAV and ILEVZI, are adjusted to provide averaging over a larger area. Because the NDDH CALMET/CALPUFF modeling domain extends into the western part of the upper Great Plains, maximum mixing height settings (ZIMAX/ZIMAXW) are increased from 3000 to 4000 meters to be consistent with maximum mixing heights reported for this region.[11] Note that the CALMET BIAS factors have no effect when mesoscale data are used as the initial guess wind field.

[11]Holzworth, 1972. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. EPA Publication No. AP-101, Office of Air Programs

Settings as discussed above are incorporated in the CALMET control file prepared by NDDH for BART-related visibility analyses. A sample file with NDDH settings will be provided upon request.

3.2 CALPUFF Input

Along with the CALMET-processed meteorological data, CALPUFF requires the user to provide emissions and stack data, receptor locations, input control file settings, and (optionally) hourly ozone data before the model can be executed. A background ammonia value is also required.

3.2.1 Emissions and Stack Data

To determine which BART-eligible sources are subject to BART, the BART guideline stipulates modeling primary pollutants SO_2, NO_x, and PM_{10} (coarse and fine) using maximum emission rates. The guideline states,

> *"The emissions estimates used in the models are intended to reflect steady-state operating conditions during periods of high capacity utilization. We do not generally recommend that emissions reflecting periods of start-up, shutdown, and malfunction be used, as such emission rates could produce higher than normal effects than would be typical of most facilities. We recommend that States use the 24-hour average actual emission rate from the highest emitting day of the meteorological period modeled, unless this rate reflects periods of start-up, shutdown, or malfunction."*

Since the meteorological period modeled will be 2000 through 2002, the NDDH requested companies operating BART-eligible sources to provide maximum 24-hour emission rates (with exception of start-up, shutdown, and malfunction conditions) for this three-year period. Other stack data required by CALPUFF include stack height, stack diameter, exit velocity, exit temperature, location, and stack-base elevation. Entries for these stack parameters are taken from PSD increment modeling recently completed by NDDH.[3] Entries for the dynamic stack parameters, exit velocity and exit temperature, reflect an average for the 2000-2002 period.

Emission rates provided by BART-eligible source companies, and appropriate for BART-related visibility modeling, are shown in Table 3-2. When the BART-eligible source company only provided total particulate matter emission rates, PM_{10} emission rates were calculated based on data from recent Annual Emission Inventory Reports. Furthermore, the NDDH believes that assuming all PM_{10} emissions are $PM_{2.5}$ would be too conservative. Therefore, $PM_{2.5}$ emissions were calculated based on data in the 2004 Annual Emission Inventory Report. The NDDH recognizes that better data may become available on the particle size distribution of PM emissions at individual sources. BART-applicable source companies are free to use the better data in the BART-related modeling provided a justification is included as part of the BART analysis.

Associated stack parameters for modeling are found in Table 3-3. Tables 3-2 and 3-3 provide the appropriate emission rates and stack data to use in the CALPUFF analyses to determine which BART-eligible sources are subject to BART. Building downwash effects will not be considered in the CALPUFF visibility analyses.

To determine the degree of visibility improvement from BART controls, the BART guideline recommends comparing results of pre-control modeling with results of post-control modeling. Pre-control emission rates and stack data would be equivalent to those used for the BART screening analysis from Tables 3-2 and 3-3. Post-control emission rates and stack data must be provided by the BART applicable source company as part of the BART analysis. Post-control emission rates are calculated as a percentage of the pre-control emission rates, using the efficiency of the proposed control equipment and/or process changes.

If CALPUFF multi-source analyses are eventually conducted to address the combined effect of proposed BART controls, as alluded to in Section 1, it may be appropriate to reevaluate the use of peak 24-hour emission rates. Use of a non-peak emission characterization may be more realistic for determination of cumulative visibility impact.

3.2.2 **Ozone Background**

CALPUFF utilizes background ozone values in its chemistry module. The model accepts either a single constant background ozone value, or an input file of hourly ozone values commensurate with

Table 3-2
BART Eligible Sources
Screening Analysis
Emission Rates

Company	**Unit**	**PM_{10} (lb/hr)**	**$PM_{2.5}$ (Fine) (lb/hr)**	**PM Coarse* (lb/hr)**	**SO_2 (lb/hr)**	**NO_x (lb/hr)**
Basin Electric Power Coop.	Leland Olds 1	155.2	16.5	138.7	5,970.0	813.0
Basin Electric Power Coop.	Leland Olds 2	253.2	26.9	226.3	12,205.0	3,959.0
Minnkota Power Coop.	M.R. Young 1	42.2	5.5	36.7	7,231.2	2,855.2
Minnkota Power Coop.	M.R. Young 2	206.8	28.1	178.7	6,879.0	5,364.2
Montana Dakota Utilities	Heskett 2	25.8	21.6	4.2	1,475.5	302.8
Great River Energy	Stanton 1	31.8	1.9	29.9	3,418.0	669.0
Great River Energy	Coal Creek 1	249.2	101.9	147.3	5,733.5	1,772.3
Great River Energy	Coal Creek 2	216.1	88.4	127.7	4,969.3	1,822.4
American Crystal Sugar	Drayton Boiler Drayton Lime Kiln**	25.7 1.0	4.9 0.2	20.8 0.8	197.0 0.2	150.0 2.5
Tesoro	Mandan Ref CO Furn	14.4	14.4	0.0	55.8	46.6

*PM coarse = PM_{10} - $PM_{2.5}$
**Entries reflect total for lime kiln emission points.

Table 3-3
BART Eligible Sources
Screening Analysis
Stack Parameters

Unit	X Coord.* (km)	Y Coord.* (km)	Stack Height (m)	Base Elevation (m)	Stack Diam. (m)	Exit Velocity (m/s)	Exit Temp. (K)
Leland Olds 1	51.180	365.146	106.7	518.3	5.3	19.7	450.0
Leland Olds 2	51.282	365.080	152.4	518.3	6.7	25.0	448.6
M.R. Young 1	59.473	341.392	91.4	597.4	5.8	18.5	449.1
M.R. Young 2	59.455	341.308	167.6	597.4	7.6	19.2	361.8
Heskett 2	84.846	319.403	91.4	514.8	3.7	17.4	419.7
Stanton 1	50.361	365.705	77.7	518.3	4.6	19.9	411.1
Coal Creek 1	63.387	376.062	201.0	602.0	6.7	25.9	358.5
Coal Creek 2	63.492	376.068	201.0	602.0	6.7	24.9	354.5
Drayton Boiler**	254.569	521.644	36.6	245.1	2.4	21.7	493.2
Drayton L. Kiln**	254.554	521.657	35.1	245.1	0.3	21.0	376.5
Mandan Ref CO F.	85.094	317.518	60.5	518.5	2.44	12.6	333.0

*Coordinates reflect North Dakota Lambert Projection.
**The coordinates for Drayton boiler and lime kiln reflect the location of the repositioned virtual sources used for modeling. Stack parameters for the lime kiln reflect a composite of all lime kiln emission points.

the period of meteorological data. The NDDH uses the hourly ozone file option with CALPUFF, and would regard this as the appropriate implementation for BART-related visibility modeling (this is also the IWAQM default option). The hourly ozone file option is implemented using year 2000-2002 hourly ozone data obtained from four NDDH monitoring sites located within the corridor of primary plume transport between major electric generating stations and Theodore Roosevelt National Park (TRNP). These monitoring sites include Hannover, Beulah, Dunn Center and TRNP South Unit. As indicated in Section 3.2.5, a constant ozone background value is also entered in the CALPUFF control file, so that it can be substituted when the hourly value is missing.

The NDDH prepared software to merge and format these ozone data into the input file required by CALPUFF (OZONE.DAT). The NDDH CALPUFF-compatible hourly ozone files for years 2000-2002 will be provided upon request.

3.2.3 **Ammonia Background**

The need for ammonia background concentrations in CALPUFF is also related to chemistry processing. CALPUFF accepts either a single annual value, or twelve monthly averages. To achieve a more realistic seasonal progression of nitrate predictions, the NDDH will be using monthly average ammonia background values for BART-related visibility analyses.

Monthly average ammonia concentrations suitable for visibility modeling in North Dakota are provided in Table 3-4. These values were derived from data collected at the State’s only ammonia monitor located near Beulah. Hourly monitor data from years 2001-2002 (data not available for year 2000) were filtered to eliminate data from wind directions associated with sources causing a local bias, then remaining data were processed to produce the monthly averages. The Table 3-4 values should be generally representative of background ammonia concentrations in western North Dakota.

Table 3-4
Monthly Ammonia Background Concentrations*

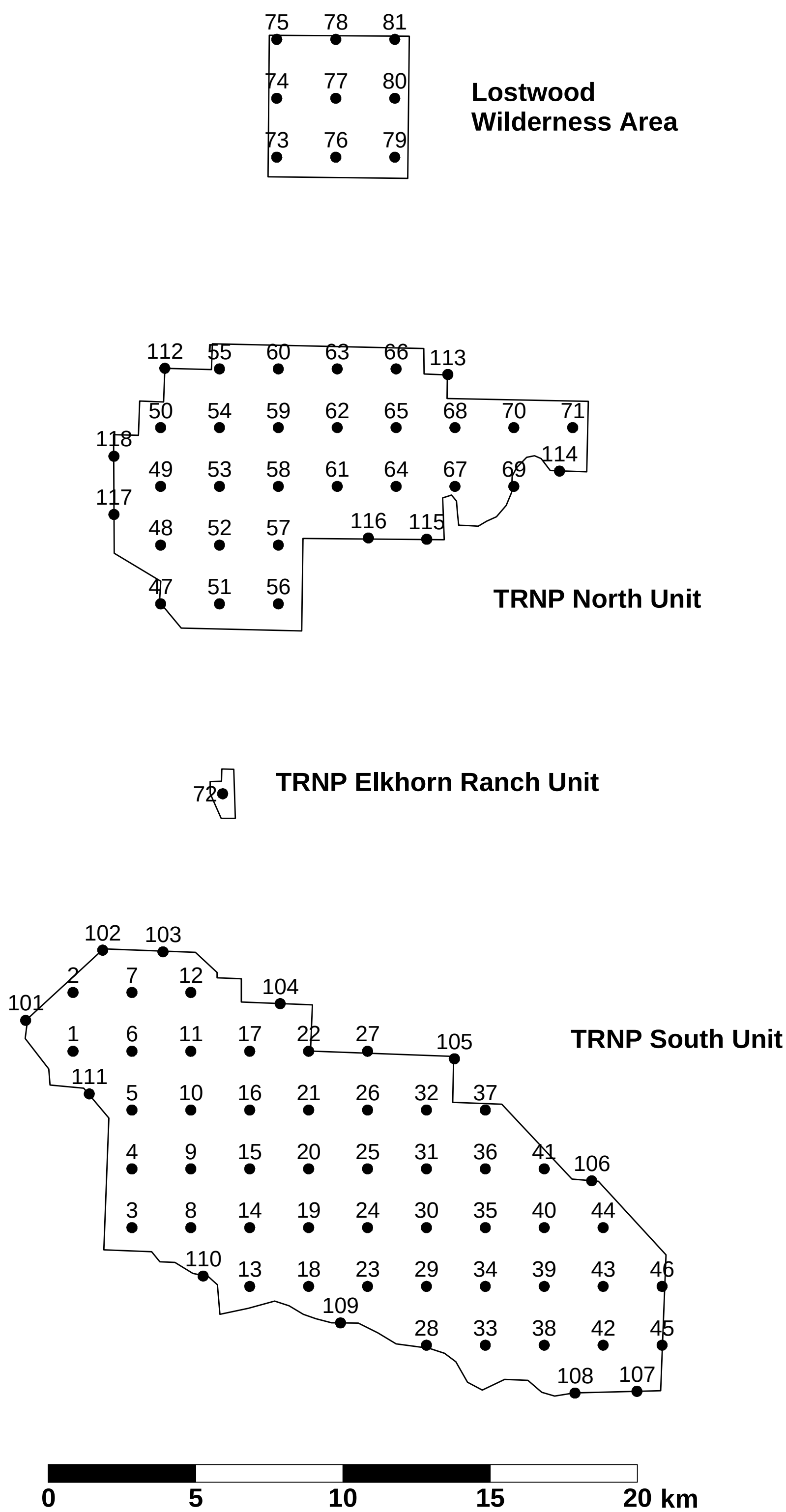
Month	Value (ppb)
Jan	1.22
Feb	1.23
Mar	1.60
Apr	1.94
May	2.29
Jun	1.63
Jul	1.65
Aug	1.69
Sep	0.98
Oct	1.04
Nov	1.37
Dec	1.06

* Data reflect NDDH Beulah monitoring site.

3.2.4 **Receptor Locations**

Receptor locations used by NDDH for PSD Class I area modeling analyses are shown in Figure 3-4. Receptor spacing for all Class I areas is generally 2 kilometers (km). Given the minimum distance of BART-eligible sources from Class I areas in North Dakota (about 100 km), single-source

Figure 3-4: Receptor Locations - North Dakota Class I Areas



concentration gradients (for visibility-related species) in the vicinity of Class I areas are not expected to be significant, and the 2 km receptor grids should be adequate for visibility analyses.

The BART guideline focuses on receptors at the nearest Class I area, only. Because all four Class I areas in North Dakota are located at relatively equal distances from BART-eligible sources, however, it is recommended that receptors for all Class I areas be accounted for in all BART-related visibility analyses. Class I area receptor coordinates and elevation, as implemented by NDDH, are provided in Appendix A. Receptor coordinates/elevation are also found in the example CALPUFF control file discussed in Section 3.2.5.

Note that receptor coordinates are provided in the same Lambert map projection as is used for source locations (Table 3-3). If needed, the NDDH can provide a utility (MAPCONI) to convert UTM or geographic coordinates to the North Dakota Lambert system.

3.2.5 **CALPUFF Control File Settings**

CALPUFF control file settings recommended for BART-related visibility analyses are generally consistent with IWAQM guidance.[10] IWAQM recommendations for CALPUFF control file settings fall into two categories. IWAQM-defined variables are those for which IWAQM provides a default value as a general recommendation for all analyses. User-defined variables are those where IWAQM recognizes the input value will need to be tailored for a given application, and default values are therefore not provided.

For BART-related visibility analyses, the NDDH has established appropriate settings for user-defined variables, and has determined the need to adjust a limited number of IWAQM-defined variables from recommended values, as discussed below. The CALPUFF control file user-defined settings, as well as the IWAQM-defined settings which have been adjusted by NDDH, are summarized in Table 3-5. IWAQM-defined settings adjusted by NDDH have a highlighted background in the table.

Most of the user-defined settings recommended by NDDH are intuitive, involving variables related to defining the meteorological/computational grid, variables related to the Lambert map projection, and the use of default values for dry and wet deposition parameterization. The variable IRESPLIT is set such that puffs are eligible for splitting on any hour of the day.

NDDH settings for IWAQM-defined variables are equivalent to IWAQM recommendations, with exception of settings for a limited number of variables related to puff splitting, dispersion, and mixing height. Variable MSPLIT is set to allow puff splitting, as this option is generally recommended when modeling source-receptor distances of 200 km or more. Based on performance testing of the CALPUFF model for PSD Class I increment modeling,[3] the NDDH uses adjusted settings for dispersion-related variables MDISP and MPDF, and for variables IVEG and ROLDMAX, as these adjustments provide better model performance. NDDH settings for MDISP and MPDF, reflecting the use of micro meteorological variables in calculating dispersion, are also more consistent with dispersion treatment in the local-scale model AERMOD. Values for background ozone and ammonia (variables BCKO3 and BCKNH3, respectively) are set to be

Table 3-5
User-Defined and Non-IWAQM Settings
for CALPUFF Control File

Variable	Description	Value
IBTZ	Base time zone	7
NSPEC	Number of chemical species	7
NSE	Number of chemical species emitted	4
MSPLIT	Allow puff splitting (1=yes)	1
MDISP	Method used to compute dispersion coefficients	2
MPDF	PDF used for dispersion under convective conditions (1=yes)	1
PMAP	Map projection (LCC=Lambert Conformal Conic)	LCC
FEAST	False easting at origin	0.0
FNORTH	False northing at origin	0.0
RLAT0	Origin latitude of projection	44.0N
RLON0	Central meridian of projection	102.0W
XLAT1	Latitude of 1st standard parallel for projection	46.0N
XLAT2	Latitude of 2nd standard parallel for projection	48.5N
DATUM	Datum-region for output coordinates	NWS-27
NX	No. of X grid cells	213
NY	No. of Y grid cells	153
NZ	No. vertical layers	12
DGRIDM	Grid spacing (km)	3.0
ZFACE	Cell face heights (m)	0.,20.,50.,90.,140.,200.,270.,370.,500.,1000.,1700.,2500.,4200.
XORIGKM	Southwest grid cell X coordinate	-380
YORIGKM	Southwest grid cell Y coordinate	140

Variable	Description	Value
IBCOMP	Southwest X-index of computational grid	20
JBCOMP	Southwest Y-index of computational grid	6
IECOMP	Northeast X-index of computational grid	213
JECOMP	Northeast Y-index of computational grid	153
Dry Gas Dep.	Chemical parameters of gaseous deposition species	Model defaults
Dry Part. Dep.	Chemical parameters of particulate deposition species	Model defaults
IVEG	Vegetative state in unirrigated areas (2=active and stressed vegetation)	2
Wet Dep.	Wet deposition parameters	Model defaults
BCKO3	Monthly ozone background concentration (ppb)	30.0*
BCKNH3	Monthly ammonia background concentration (ppb)	Table 3-4
XMAXZI	Maximum mixing height	4000.
IRESPLIT	Hours when puff is eligible for vertical split	hours 1-24
ROLDMAX	Vertical puff split allowed only when the ratio of last hour's mixing height to max. mixing height experienced by the puff is smaller than this value	0.33
NSPLITH	Number of puffs that result when a puff is split horizontally	5
SYSPLITH	Minimum sigma-y (grid cell units) of puff before it may split horizontally	1.0
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr) due to wind shear, before it may split horizontally	2.0
CNSPLITH	Minimum concentration (g/m^3) in puff before it may split horizontally	1.0E-07
NREC	Number of discrete receptors	99

*Use same value for each month.

consistent with local monitoring data. Maximum mixing height (XMAXZI) is set to 4000 meters for consistency with CALMET settings.

Settings as discussed above are incorporated in the CALPUFF control file developed by NDDH for BART-related visibility analyses. A sample file with NDDH settings will be provided upon request.

3.3 **POSTUTIL Input**

The POSTUTIL processor provides repartitioning of total nitrate to adjust for possible double (or multiple) counting of ammonia in the CALPUFF chemistry. According to Escoffier-Czaja and Scire[12],

> *"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*

[12]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.

on receptor concentrations of total sulfate and total nitrate (HNO_3 + NO_3), not on a puff-by-puff basis."

Input required by POSTUTIL includes an input control file and the hourly concentration output file from CALPUFF. Primary settings for the POSTUTIL control file include the ammonia background concentrations and a variable (MNITRATE) related to recomputing the nitrate partition. The monthly ammonia background concentrations are equivalent to the values used in CALPUFF (Table 3-4), and the appropriate setting for MNITRATE in BART-related visibility analyses is '1'. Species processing information (POSTUTIL Input Group 2) for BART-related visibility analyses is specified as shown in Figure 3-5, with PMC representing the name used in CALPUFF for coarse particulate, and PMF representing the name used for fine particulate. Note that entries are not necessary for Subgroups 2.c and 2.d. All other POSTUTIL settings are intuitive, with some simply repeated from the CALPUFF control file.

Settings as discussed above are incorporated in the POSTUTIL control file developed by NDDH for BART-related visibility analyses. A sample file with NDDH settings will be provided upon request.

3.4 **CALPOST Input**

CALPOST produces summary 24-hour average visibility results (in delta-deciviews) which are compared to the BART-related thresholds (Section 2.1). Required input for CALPOST includes an input control file and the hourly concentration output file from either CALPUFF or POSTUTIL.

Figure 3-5: POSTUTIL Control Input File: Input Group 2

```
 INPUT GROUP: 2 -- Species Processing Information
--------------

-------------
Subgroup (2a)
-------------

  The following NSPECINP species will be processed:

! ASPECI =          SO2 !         !END!
! ASPECI =          SO4 !         !END!
! ASPECI =          NOX !         !END!
! ASPECI =         HNO3 !         !END!
! ASPECI =          NO3 !         !END!
! ASPECI =          PMF !         !END!
! ASPECI =          PMC !         !END!


-------------
Subgroup (2b)
-------------

  The following NSPECOUT species will be written:

! ASPECO =          SO2 !         !END!
! ASPECO =          SO4 !         !END!
! ASPECO =          NOX !         !END!
! ASPECO =         HNO3 !         !END!
! ASPECO =          NO3 !         !END!
! ASPECO =          PMF !         !END!
! ASPECO =          PMC !         !END!
```

CALPOST control file settings recommended by NDDH for BART-related visibility analyses are summarized in Table 3-6. The BART guideline specifies that daily (24-hour) visibility values should be calculated for each receptor as the change in deciviews (delta-deciview) compared against natural background visibility conditions. More specifically, the preamble to the final BART rule specifies use of natural background for the 20 percent best visibility days. The guideline also provides for the use of monthly average relative humidity (RH) values for BART-related visibility analyses. The preference for monthly average relative humidity implies the use of CALPOST visibility Method 6 (MVISBK = 6).

In order to develop background conditions for visibility Method 6, CALPOST requires monthly background concentrations of ammonium sulfate, ammonium nitrate, coarse particulate mass, organic carbon, soil, and elemental carbon. Annual averages reflective of natural background conditions for these species are found in EPA's "Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program" (2003)[13]. For each Class I area, this guidance document provides separate deciview values representative of annual average natural background, and natural background for the 20 percent best days.

The EPA natural visibility guidance document does not provide speciated background concentrations (above) representative of the 20 percent best days, as would be needed for implementation of

[13]EPA, 2003. Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program. Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

Table 3-5
CALPOST Control File Settings

Variable	Description	Value
ASPEC	Species to process	VISIB
ILAYER	Enter “1" to process concentrations in CALPUFF hourly file	1
A	Scaling factor	0.0
B	Scaling factor	0.0
LBACK	Add hourly background concentration	F
RHMAX	Maximum relative humidity	95.0
LBSO4	Include modeled sulfate?	T
LVNO3	Include modeled nitrate?	T
LVOC	Include modeled organic carbon	F
LVPMC	Include modeled coarse particles	T
LVPMF	Included modeled fine particles	T
LVEC	Include modeled elemental carbon	F
LVBK	Include background in output tables	F
EEPMC	Extinction efficiency for PM coarse	0.6
EEPMF	Extinction efficiency for PM fine	1.0
EEPMCBK	Extinction efficiency for background PM coarse	0.6
EESO4	Extinction efficiency for ammonium sulfate	3.0
EENO3	Extinction efficiency for ammonium nitrate	3.0
EEOC	Extinction efficiency for organic carbon	4.0
EESOIL	Extinction efficiency for soil	1.0
EEEC	Extinction efficiency for elemental carbon	10.0
MVISBK	Visibility calculation method	6

Variable	Description	Value
RHFAC	Monthly RH adjustment factor	Table 3-8
BKSO4	Background ammonium sulfate conc.	Table 3-7*
BKNO3	Background ammonium nitrate conc.	Table 3-7*
BKPMC	Background coarse particulate conc.	Table 3-7*
BKOC	Background organic carbon conc.	Table 3-7*
BKSOIL	Background soil conc.	Table 3-7*
BKEC	Background elemental carbon	Table 3-7*
BEXTRAY	Extinction due to Rayleigh scattering	10.0

* Use same value for each month.

CALPOST Method 6 consistent with the BART rule. Upon consultation with EPA and National Park Service/Fish and Wildlife Service representatives[14], it was concluded that the annual concentrations (Table 2-1 in guidance document) should be scaled back, in equal proportion, until they converge to lower concentratons that produce the deciview value specified for the 20 percent best days (guidance document Appendix B) to provide the necessary CALPOST input. The scaling procedure would be conducted separately for each Class I area.

The scaling procedure as applied by NDDH is illustrated here for Theodore Roosevelt National Park (TRNP). From Appendix B in the natural visibility guidance document, the deciview value for annual average natural conditions at TRNP is 4.75, and the deciview value for the 20 percent best days is 2.19. Note that the TRNP annual average deciview value reflects natural background components for the US west region. To obtain the speciated background concentrations representative of the 20 percent best days at TRNP, the deciview value (2.19) must first be converted to light extinction. The relationship between deciviews and light extinction is expressed,

$$dv = 10 \ln (b_{ext}/10)$$

or

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

where

dv represents deciviews,
b_{ext} represents total light extinction expressed in inverse megameters (Mm^{-1}).

---

[14]NDDH, 2005. Electronic message summarizing BART modeling-related conference-call discussion with representatives of EPA, National Park Service, and Fish and Wildlife Service, August 31, 2005.

Using this relationship with a deciview value of 2.19, one obtains a light extinction value of 12.45 Mm^{-1}. Next, the natural visibility guidance document background concentrations for annual average (Table 2-1, west) are adjusted in order to provide the extinction value just determined (12.45 Mm^{-1}). The relationship between light extinction and background concentrations is:

$$b_{ext} = (3)\ f\ (RH)\ [\text{ammonium sulfate}] + (3)\ f\ (RH)\ [\text{ammonium nitrate}] + (0.6)\ [\text{coarse mass}] + (4)\ [\text{organic carbon}] + (1)\ [\text{soil}] + (10)\ [\text{elemental carbon}] + b_{ray}$$

where

bracketed quantities represent background concentrations in $\mu g/m^3$,
values in parenthesis represent scattering efficiencies,
f (RH) is the relative humidity adjustment factor (applied to hygroscopic species only),
b_{ray} is light extinction due to Rayleigh scattering (10 Mm^{-1} used for all Class I areas).

Substituting the annual average natural background values and TRNP f (RH) from the natural visibility guidance document, and including the coefficient for scaling, one obtains

$$12.45 = (3)\ (2.56)\ [0.12]\ X + (3)\ (2.56)\ [0.1]\ X + (0.6)\ [3.0]\ X + (4)\ [0.47]\ X + (1)\ [0.5]\ X + (10)\ [0.02]\ X + 10$$

where

X represents scaling factor to convert annual average natural background concentrations to values representative of 20 percent best days.

Solving for X provides a value of 0.403. This scaling factor was applied to the annual average natural background components in the natural visibility guidance document (Table 2-1, west region) to obtain background components for the 20 percent best days for TRNP. The scaling procedure was repeated for Lostwood Wilderness Area.

Results of the scaling procedure are shown in Table 3-7, which includes speciated natural background concentrations representative of annual average visibility, 20 percent best days for Theodore Roosevelt National Park, and 20 percent best days for Lostwood Wilderness Area. Note that west region natural conditions are assumed for North Dakota Class I areas. The Table 3-7

Table 3-7
Natural Levels of Aerosol Components
(µg/m^3)

Component	Annual Average West Region *	20% Best Days Theodore Roosevelt NP	20% Best Days Lostwood NWA
Ammonium sulfate	0.12	0.048	0.049
Ammonium nitrate	0.10	0.040	0.041
Organic carbon mass	0.47	0.189	0.190
Elemental carbon	0.02	0.008	0.008
Soil	0.50	0.202	0.203
Coarse mass	3.00	1.209	1.215
Natural deciview**		2.19	2.21

*From “Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program” (EPA, 2003), Table 2-1.
**From “Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program” (EPA, 2003), Appendix B.

values for 20 percent best days should be used for BART-related analyses. The same value is used for each month in the CALPOST control file.

Monthly RH adjustment factors (RHFAC input in CALPOST) for Theodore Roosevelt National Park and Lostwood Wilderness Area BART-related analyses are provided in Table 3-8. These values are also from the EPA guidance document for natural visibility conditions. One other setting needed for CALPOST development of natural background is extinction due to Rayleigh scattering (BEXTRAY), which should be left at the default value of 10.0.

Table 3-8
Monthly RH Adjustment Factors*

Month	Theodore Roosevelt NP	Lostwood NWA
Jan	2.9	3.0
Feb	2.8	2.9
Mar	2.8	2.9
Apr	2.3	2.3
May	2.3	2.3
Jun	2.5	2.6
Jul	2.4	2.7
Aug	2.2	2.4
Sep	2.2	2.3
Oct	2.3	2.4
Nov	3.0	3.2
Dec	3.0	3.2

* From "Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program" (EPA, 2003)

The remainder of CALPOST control file settings are intuitive, and mirror settings in the CALPUFF control file. Settings as discussed above are incorporated in the CALPOST control file developed by the NDDH for BART-related visibility analyses. A sample file with NDDH settings will be provided upon request.

4 Model Execution and Output Interpretation

For BART-related single-source visibility analyses in North Dakota, the CALPUFF modeling system should be executed with input data and settings as described in Section 3. Delta-deciview results necessary for comparison with visibility thresholds are obtained from the "24HR VISIBILITY (deciview)" table in the CALPOST output file.

The BART guideline states that the 98th percentile of 24-hour CALPUFF modeling results should be compared with the contribution threshold established by the State for purposes of determining BART applicability. Upon clarification from EPA and FLM's[14], the context of the 98th percentile 24-hour delta-deciview prediction is with respect to days of the year, and is not receptor specific. A 24-hour prediction greater than 0.5 delta-deciview at any receptor in a Class I area would constitute a day of exceedance, and up to 7 days of exceedance would be allowed per year per Class I area (i.e., the 98th percentile is approximated by the eighth-highest daily prediction).

4.1 BART Screening

To complete the BART screening analysis for North Dakota sources, CALPUFF (and optionally POSTUTIL) is executed for each year of meteorological data processed with CALMET (2000-2002). And for each year of CALPUFF (POSTUTIL) hourly output, CALPOST is executed separately for receptor groups representing each Class I area. Delta-deciview modeling results applicable to BART screening are found in the summary section at the bottom of the "24HR VISIBILITY (deciview)" table in the CALPOST output file. If the number of days with delta-deciview prediction greater than 0.5 is more than 7, for any year of meteorological data for any Class I area, the source is concluded to be BART-applicable. Note that the three units of Theodore Roosevelt National Park are treated as separate Class I areas for BART-related visibility analyses.

4.2 Degree of Visibility Improvement

For analyses to determine the degree of visibility improvement due to BART controls, the modeling system is executed as described above for BART screening. Model execution and results are needed for both pre-BART control and post-BART control scenarios, to allow comparison of CALPOST delta-deciview predictions for both scenarios. The context of this comparison is not specifically defined, leaving it to the State to determine the appropriate metric. The BART guideline states:

> *"Assess the visibility improvement based on the modeled change in visibility impacts for the pre-control and post-control emission scenarios. You have flexibility to assess visibility improvement due to BART controls by one or more methods. You may consider the frequency, magnitude, and duration components of impairment."*

Consistent with the goals stated in the BART guideline, the NDDH recommends the following specific approaches for evaluating the degree of visibility improvement from BART controls:

- Compare the 98th percentile delta-deciview prediction from pre-control and post-control modeling scenarios.
- Compare the number of days of exceedance of the 0.5 delta-deciview threshold for pre-control and post-control scenarios (to address “duration”, the maximum number of consecutive days of exceedance should also be reported for both scenarios).
- For consistency with goals of the Regional Haze program (and WRAP regional-scale modeling), compare the 90th percentile delta-deciview prediction from pre-control and post-control modeling scenarios (i.e., average of the 20 percent worst days).

Again, these comparisons would be made for each Class I area and for each year of meteorological data.

While the above comparisons are proposed in the context of total deciview improvement attributable to BART controls for all species combined, it may be desirable to also test the relative effectiveness of controls for individual species. When evaluating visibility improvement for individual species, the following should be considered.

- To maintain reasonable balance in the CALPUFF chemistry, all four species (SO_2, NO_X, PM coarse, PM fine) should be included in the model input files for pre-control and post-control scenarios. The post-control input file should reflect the BART-control emission rate for the tested species, while the emission rate for other species remains at pre-control levels. Post-control input file stack parameters should reflect post-control values for the tested species.

- Alternatively, to refine the accuracy of single-species testing, the reactive species SO_2 and NO_X may be grouped separately from the non-reactive species PM coarse and PM fine (primary only) in the post-control input file. That is, the BART-applicable source unit would be configured as two virtual co-located sources in the post-control input file. One virtual source would include emission rates for reactive species SO_2 and NO_X, and the other virtual source would include emission rates for non-reactive species PM coarse and PM fine. If the species being tested is reactive, then post-control stack parameters (for the tested species) would be entered for the reactive virtual sources, and pre-control stack parameters would be entered for the non-reactive virtual source. If the species being tested is non-reactive, then post-control stack paramters would be entered for the non-reactive virtual source, and pre-control stack parameters would be assigned for the reactive virtual source.

- If information on particle size distribution is not available for the post-control scenario for primary particulate, the ratio of PM fine to PM coarse for the post-control scenario should be considered equivalent to the PM ratio for the pre-control scenario (Table 3-2).

Whether testing degree of visibility improvement for ensemble species or for one species at a time, testing should be conducted separately for each BART-applicable unit within a facility. When testing for individual species is complete, the overall degree of visibility improvement should be evaluated for each unit. When testing for individual units is complete, the degree of visibility improvement should be evaluated for the entire facility.

It is not the intent of the NDDH to develop specific thresholds for the comparisons of modeled visibility impact recommended above. Rather, the degree of visibility improvement represented by these modeled comparisons (and possibly others) will be evaluated in a qualitative manner, in concert with the review of other prescribed analyses of BART control options (i.e., technology available, cost of compliance, etc.), to establish an appropriate BART control.

4.3 **CALBART Utility**

To expedite recommended comparisons for determining the degree of visibility improvement, the NDDH has developed the CALBART utility software program. CALBART processes the hourly output file from either CALPUFF or POSTUTIL to provide the 24-hr delta-deciview metrics recommended for assessing the degree of visibility improvement due to BART controls. CALBART replaces CALPOST in the sequence of visibility model processing. CALBART produces delta-deciview results equivalent to CALPOST (i.e., when CALPOST input is set as prescribed in Section 3.4), but in a summarized format which includes results for all Class I areas in a single execution.

CALBART requires an input control file which must be named 'CALBART.INP'. The file includes three lines:

Line 1 - Title (up to 80 characters)

Line 2 - File name and path for CALPUFF (POSTUTIL) output file (up to 40 characters)

Line 3 - Beginning year, julian day, and hour for the CALBART run (free format, time must be equal to or later than that specified in the CALPUFF or POSTUTIL input file; also, the hour should always be specified as '0' to ensure that calendar days are simulated)

An example of CALBART output (file CALBART.LST) is provided in Figure 4-1. The CALBART software will be provided upon request.

Figure 4-1: CALBART Output Example

CALBART - Summary of Visibility Results for 24-hr Delta-Deciview

Generic Source for Year 2000 Meteorological Data

Title lines from CALPUFF (POSTUTIL) output file:

Generic Source - BART Protocol - Postutil 1.4
Year 2000 Calmet Met. Data - RUC2d Mesoscale Data - Monthly NH3
BART Protocol Receptors (99)

TRNP SOUTH UNIT

	DELTA-DV	DV(Total)	DV(BKG)	YEAR	DAY	SEQ RECEP	ND RECEP	F(RH)	% of Modeled Extinction by Species %_SO4	%_NO3	%_PMC	%_PMF
Largest Delta-DV	6.416	8.650	2.234	2000	74	48	102	2.80	69.80	30.12	0.05	0.03
98th %tile Delta-DV	1.596	3.872	2.276	2000	316	45	45	3.00	56.96	42.89	0.12	0.03
90th %tile Delta-DV	0.541	2.647	2.106	2000	239	52	106	2.20	84.37	15.45	0.13	0.05

Number of days with Delta-Deciview > 0.50: 39
Number of days with Delta-Deciview > 1.00: 22
Max number of consecutive days with Delta-Deciview > 0.50: 3

TRNP NORTH UNIT

	DELTA-DV	DV(Total)	DV(BKG)	YEAR	DAY	SEQ RECEP	ND RECEP	F(RH)	%_SO4	%_NO3	%_PMC	%_PMF
Largest Delta-DV	5.258	7.492	2.234	2000	36	82	71	2.80	52.58	47.14	0.21	0.07
98th %tile Delta-DV	2.269	4.502	2.234	2000	54	82	71	2.80	71.89	27.91	0.17	0.04
90th %tile Delta-DV	0.446	2.552	2.106	2000	248	71	60	2.20	32.00	66.31	1.29	0.40

Number of days with Delta-Deciview > 0.50: 32
Number of days with Delta-Deciview > 1.00: 17
Max number of consecutive days with Delta-Deciview > 0.50: 2

TRNP ELKHORN RANCH

	DELTA-DV	DV(Total)	DV(BKG)	YEAR	DAY	SEQ RECEP	ND RECEP	F(RH)	%_SO4	%_NO3	%_PMC	%_PMF
Largest Delta-DV	6.347	8.581	2.234	2000	74	90	72	2.80	71.19	28.74	0.05	0.03
98th %tile Delta-DV	1.414	3.647	2.234	2000	66	90	72	2.80	64.45	35.42	0.09	0.04
90th %tile Delta-DV	0.400	2.527	2.127	2000	98	90	72	2.30	62.60	37.25	0.11	0.04

Number of days with Delta-Deciview > 0.50: 26
Number of days with Delta-Deciview > 1.00: 11
Max number of consecutive days with Delta-Deciview > 0.50: 2

LOSTWOOD NWA

	DELTA-DV	DV(Total)	DV(BKG)	YEAR	DAY	SEQ RECEP	ND RECEP	F(RH)	%_SO4	%_NO3	%_PMC	%_PMF
Largest Delta-DV	6.661	8.937	2.275	2000	47	97	79	2.90	92.31	7.54	0.11	0.04
98th %tile Delta-DV	2.121	4.289	2.167	2000	216	95	77	2.40	69.11	30.68	0.18	0.03
90th %tile Delta-DV	0.792	2.959	2.167	2000	215	91	73	2.40	73.19	26.21	0.44	0.16

Number of days with Delta-Deciview > 0.50: 52
Number of days with Delta-Deciview > 1.00: 31
Max number of consecutive days with Delta-Deciview > 0.50: 5

Appendix A

NDDH PSD Class I
Area Receptors

NON-GRIDDED (DISCRETE) RECEPTOR DATA

Receptor No.		X UTM Coordinate (km)	Y UTM Coordinate (km)	Ground Elevation (m)	Height Above Ground (m)	
TRNP South Unit Receptors:						
1	! X =	-120.0,	334.0,	801.5,	0.000!	!END!
2	! X =	-120.0,	336.0,	743.4,	0.000!	!END!
3	! X =	-118.0,	328.0,	737.9,	0.000!	!END!
4	! X =	-118.0,	330.0,	793.8,	0.000!	!END!
5	! X =	-118.0,	332.0,	757.7,	0.000!	!END!
6	! X =	-118.0,	334.0,	817.3,	0.000!	!END!
7	! X =	-118.0,	336.0,	782.7,	0.000!	!END!
8	! X =	-116.0,	328.0,	719.7,	0.000!	!END!
9	! X =	-116.0,	330.0,	715.9,	0.000!	!END!
10	! X =	-116.0,	332.0,	745.1,	0.000!	!END!
11	! X =	-116.0,	334.0,	764.1,	0.000!	!END!
12	! X =	-116.0,	336.0,	686.7,	0.000!	!END!
13	! X =	-114.0,	326.0,	767.7,	0.000!	!END!
14	! X =	-114.0,	328.0,	735.0,	0.000!	!END!
15	! X =	-114.0,	330.0,	683.9,	0.000!	!END!
16	! X =	-114.0,	332.0,	746.0,	0.000!	!END!
17	! X =	-114.0,	334.0,	685.3,	0.000!	!END!
18	! X =	-112.0,	326.0,	749.2,	0.000!	!END!
19	! X =	-112.0,	328.0,	728.1,	0.000!	!END!
20	! X =	-112.0,	330.0,	725.0,	0.000!	!END!
21	! X =	-112.0,	332.0,	707.9,	0.000!	!END!
22	! X =	-112.0,	334.0,	736.5,	0.000!	!END!
23	! X =	-110.0,	326.0,	794.3,	0.000!	!END!
24	! X =	-110.0,	328.0,	731.1,	0.000!	!END!
25	! X =	-110.0,	330.0,	758.7,	0.000!	!END!
26	! X =	-110.0,	332.0,	742.3,	0.000!	!END!
27	! X =	-110.0,	334.0,	767.4,	0.000!	!END!
28	! X =	-108.0,	324.0,	818.4,	0.000!	!END!
29	! X =	-108.0,	326.0,	740.2,	0.000!	!END!
30	! X =	-108.0,	328.0,	728.2,	0.000!	!END!
31	! X =	-108.0,	330.0,	760.7,	0.000!	!END!
32	! X =	-108.0,	332.0,	755.4,	0.000!	!END!
33	! X =	-106.0,	324.0,	790.0,	0.000!	!END!
34	! X =	-106.0,	326.0,	762.8,	0.000!	!END!
35	! X =	-106.0,	328.0,	733.4,	0.000!	!END!
36	! X =	-106.0,	330.0,	825.7,	0.000!	!END!
37	! X =	-106.0,	332.0,	772.3,	0.000!	!END!
38	! X =	-104.0,	324.0,	756 ,	0.000!	!END!
39	! X =	-104.0,	326.0,	761.3,	0.000!	!END!
40	! X =	-104.0,	328.0,	758.2,	0.000!	!END!
41	! X =	-104.0,	330.0,	771.0,	0.000!	!END!
42	! X =	-102.0,	324.0,	796.2,	0.000!	!END!
43	! X =	-102.0,	326.0,	774.3,	0.000!	!END!
44	! X =	-102.0,	328.0,	819.0,	0.000!	!END!
45	! X =	-100.0,	324.0,	839.3,	0.000!	!END!
46	! X =	-100.0,	326.0,	836.4,	0.000!	!END!

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101 ! X =    -121.608,    335.052,     777.3,        0.000!    !END!
102 ! X =    -118.992,    337.441,     771.4,        0.000!    !END!
103 ! X =    -116.945,    337.384,     734.8,        0.000!    !END!
104 ! X =    -112.965,    335.621,     728.7,        0.000!    !END!
105 ! X =    -107.051,    333.744,     746.3,        0.000!    !END!
106 ! X =    -102.388,    329.593,     770.0,        0.000!    !END!
107 ! X =    -100.852,    322.428,     853.9,        0.000!    !END!
108 ! X =    -102.956,    322.371,     850.2,        0.000!    !END!
109 ! X =    -110.918,    324.760,     750.5,        0.000!    !END!
110 ! X =    -115.581,    326.352,     752.8,        0.000!    !END!
111 ! X =    -119.447,    332.550,     765.9,        0.000!    !END!
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TRNP North Unit Receptors:

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 47 ! X =    -108.0,      396.0,       608.7,        0.000!    !END!
 48 ! X =    -108.0,      398.0,       604.3,        0.000!    !END!
 49 ! X =    -108.0,      400.0,       614.6,        0.000!    !END!
 50 ! X =    -108.0,      402.0,       684.0,        0.000!    !END!
 51 ! X =    -106.0,      396.0,       621.5,        0.000!    !END!
 52 ! X =    -106.0,      398.0,       774.0,        0.000!    !END!
 53 ! X =    -106.0,      400.0,       598.2,        0.000!    !END!
 54 ! X =    -106.0,      402.0,       736.4,        0.000!    !END!
 55 ! X =    -106.0,      404.0,       690.9,        0.000!    !END!
 56 ! X =    -104.0,      396.0,       648.7,        0.000!    !END!
 57 ! X =    -104.0,      398.0,       768.0,        0.000!    !END!
 58 ! X =    -104.0,      400.0,       615.3,        0.000!    !END!
 59 ! X =    -104.0,      402.0,       622.0,        0.000!    !END!
 60 ! X =    -104.0,      404.0,       763.1,        0.000!    !END!
 61 ! X =    -102.0,      400.0,       671.9,        0.000!    !END!
 62 ! X =    -102.0,      402.0,       719.8,        0.000!    !END!
 63 ! X =    -102.0,      404.0,       629.9,        0.000!    !END!
 64 ! X =    -100.0,      400.0,       594.8,        0.000!    !END!
 65 ! X =    -100.0,      402.0,       624.6,        0.000!    !END!
 66 ! X =    -100.0,      404.0,       651.3,        0.000!    !END!
 67 ! X =     -98.0,      400.0,       593.7,        0.000!    !END!
 68 ! X =     -98.0,      402.0,       725.3,        0.000!    !END!
 69 ! X =     -96.0,      400.0,       591.2,        0.000!    !END!
 70 ! X =     -96.0,      402.0,       692.3,        0.000!    !END!
 71 ! X =     -94.0,      402.0,       677.4,        0.000!    !END!
112 ! X =    -107.858,    404.020,     771.2,        0.000!    !END!
113 ! X =     -98.243,    403.809,     687.9,        0.000!    !END!
114 ! X =     -94.447,    400.520,     594.6,        0.000!    !END!
115 ! X =     -98.960,    398.200,     712.1,        0.000!    !END!
116 ! X =    -100.942,    398.243,     674.5,        0.000!    !END!
117 ! X =    -109.587,    399.044,     677.7,        0.000!    !END!
118 ! X =    -109.587,    401.026,     749.2,        0.000!    !END!
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TRNP Elkhorn Ranch Receptor:

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 72 ! X =    -122.581,    361.580,     647.7,        0.000!    !END!
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Lostwood NWA Receptors:

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 73 ! X =     -36.0,      516.0,       724.9,        0.000!    !END!
 74 ! X =     -36.0,      518.0,       724.4,        0.000!    !END!
 75 ! X =     -36.0,      520.0,       740.4,        0.000!    !END!
 76 ! X =     -34.0,      516.0,       725.0,        0.000!    !END!
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77 ! X =     -34.0,      518.0,       728.2,       0.000!   !END!
78 ! X =     -34.0,      520.0,       729.6,       0.000!   !END!
79 ! X =     -32.0,      516.0,       726.9,       0.000!   !END!
80 ! X =     -32.0,      518.0,       718.8,       0.000!   !END!
81 ! X =     -32.0,      520.0,       719.5,       0.000!   !END!
```