Calpuff Analysis of Current PSD Class I Increment Consumption in North Dakota and Eastern Montana Using Actual Annual Average SO_2 Emission Rates

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1. Introduction

The North Dakota Department of Health (NDDH) has completed air quality modeling studies to determine the current status of Prevention of Significant Deterioration (PSD) Class I increment consumption for sulfur dioxide (SO_2) in North Dakota and eastern Montana. The purpose of these studies was to determine the current level of PSD Class I increment consumption, based on modeling which includes use of actual emission rates. Completion of these studies satisfies a commitment made to EPA on March 13, 2001[1].

The NDDH conducted initial modeling analyses for Class I increment consumption in 2001-2002. Analyses were conducted based on actual annual average emission rates[2], and based on actual hourly emission rates coupled with concurrent meteorological data[3]. Methodology and emission rates associated with these analyses were subjected to a public comment process which culminated in a hearing in May, 2002.

As a result of input received during the public comment period and hearing[4], and on other more recent information, the NDDH updated its modeling methodology and emission inventory, and completed a final modeling analysis. That updated analysis is the focus of this report. The following changes were incorporated in the updated NDDH analysis:

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[1]NDDH, 2001. March 13 letter from Francis Schwindt, North Dakota Department of Health to Richard Long, EPA Region VIII.

[2]NDDH, 2002. Calpuff Analysis of Current PSD Class I Increment Consumption in North Dakota and Eastern Montana Using Actual Annual Average SO_2 Emission Rates (draft). North Dakota Department of Health, Bismarck, North Dakota 58506.

[3]NDDH, 2002. Calpuff Analysis of Current PSD Class I Increment Consumption in North Dakota and Eastern Montana Using CEM Hourly SO_2 Emission Rates Coupled with Concurrent Meteorology (draft). North Dakota Department of Health, Bismarck, North Dakota 58506.

[4]State of North Dakota, 2002. Findings and Conclusions in the Matter of: Proposed Determination of the Adequacy of the North Dakota State Implementation Plan to Prevent Significant Deterioration. North Dakota Department of Health, Bismarck, North Dakota 58506.

- Meteorological data from the two previous analyses were combined such that the updated analysis incorporates six years of data, i.e., Years 1990 through 1994, and Year 2000 (Section 2).

- Calpuff meteorological/computational grid resolution was improved, with grid cell size decreasing from 10 to 5 km, and number of vertical layers increasing from 8 to 12 (Section 2.1).

- EPA standard Mesoscale Model data sets (MM4/MM5) have been incorporated in Calmet processing, i.e., MM4 data for 1990 and MM5 data for 1992 (Section 2.2.4).

- Values for a limited number of Calmet technical options (TERRAD, R1, R2, IKINE, RMIN2) have been adjusted (Section 2.5).

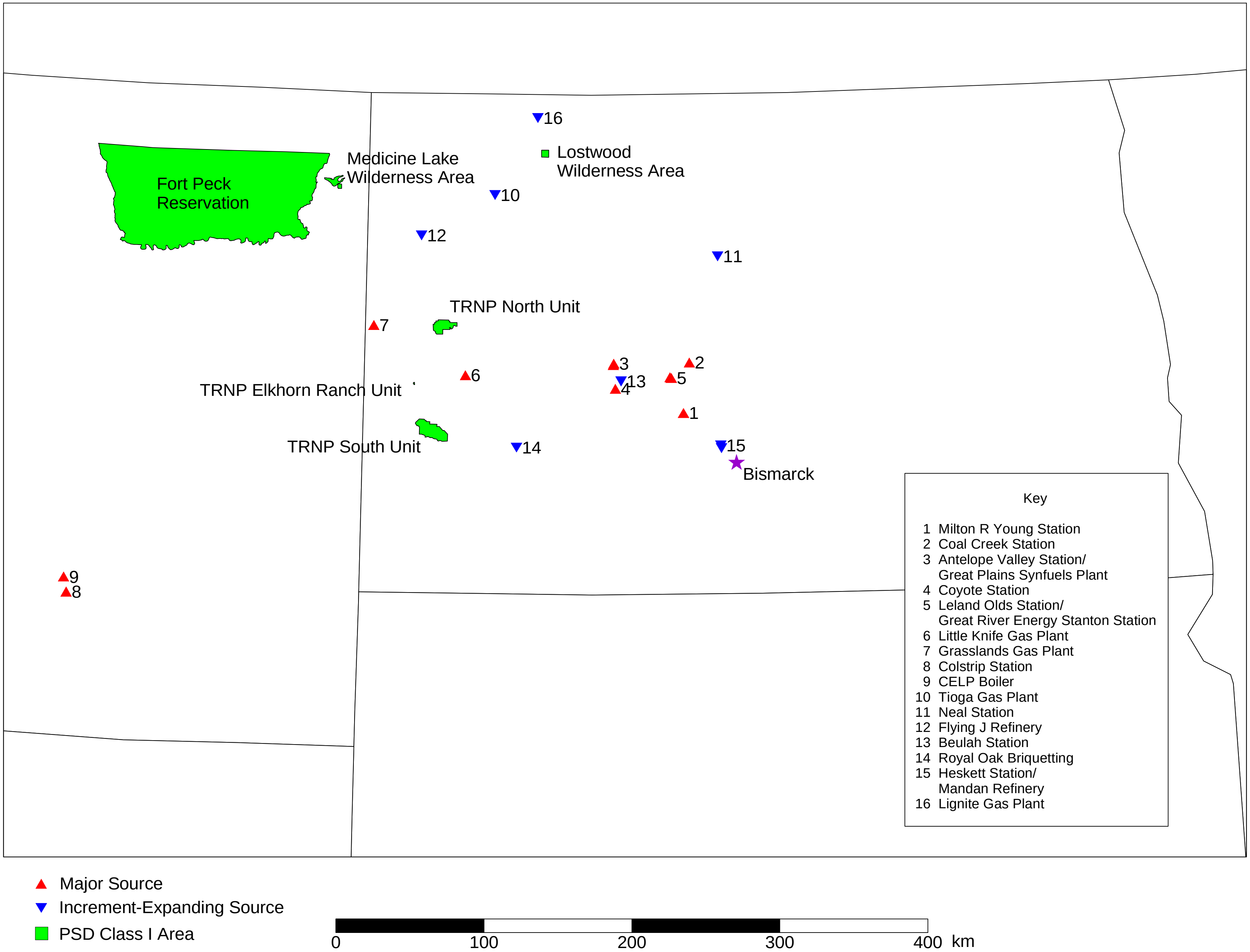
- New Class I area receptor grids employing uniform spacing (2 km) were developed to better accommodate receptor averaging concept (Section 3.3).

- Emissions inventory was revised for both major and minor sources, including adjustments to some emission rates, and elimination of some sources (Section 3.1).

- Based on findings of the 2002 public comment and hearing process, it was concluded that use of annual average emission rates are appropriate for Class I increment modeling; therefore, annual average emission rates (average over hours of operation) are used exclusively in the updated NDDH modeling analysis (Section 3.1).

PSD Class I areas in North Dakota and eastern Montana are depicted in Figure 1-1. These include Theodore Roosevelt National Park (TRNP) and Lostwood Wilderness Area in North Dakota, and the Medicine Lake Wilderness Area and Fort Peck Indian Reservation in Montana. The TRNP is divided into three geographically separated units: North Unit, South Unit, and Elkhorn Ranch Unit. All of these Class I areas were addressed in the NDDH modeling analysis.

Figure 1-1: Class I Areas and Increment-Affecting Source Locations



The NDDH emission inventory for PSD Class I increment analysis included the actual SO_2 emissions associated with all major SO_2 sources located within 250 km, and all minor SO_2 sources located within 50 km of subject Class I areas. Source locations are also shown in Figure 1-1. To more accurately determine the current status of Class I increment consumption, the NDDH emission inventory was derived from hourly CEM (continuous emission monitor) data, when available.

Consistent with current Interagency Workgroup for Air Quality Modeling (IWAQM) guidance[5], the Calpuff long-range modeling system[6,7] was used for the NDDH analysis. EPA has adopted, effective April 15, 2004, Calpuff in the Guideline on Air Quality Models[8] as a refined modeling technique for general use in evaluating long-range transport of pollutants. The Guideline was revised, to include Calpuff, in a Federal Register notice published April 15, 2003. The Calpuff modeling system has been widely applied by States, EPA, and the National Park Service (NPS) to evaluate PSD increments and Air Quality Related Values (AQRV's) in PSD Class I areas.

The NDDH implementation of the Calpuff model followed IWAQM guidance, including the recommendation for at least five years of conventional meteorological data (the NDDH used six years). Complete emission inventories for the baseline period and for the current period (2000-2001) were developed. Increment consumption was then determined as a function of the difference in model output for these two inventories. The NDDH approach also incorporated the

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[5]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, North Carolina 27711.

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

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

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

use of receptor averaging. This interpretation of model output is described fully in Section 4.0.

Implementation of the Calpuff modeling system by NDDH included use of the Calmet meteorological model (Version 5.2), the Calpuff dispersion model (Version 5.4), and the Calpost postprocessing program (Version 5.2). 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. To the extent possible, the NDDH used the utilities provided by Earth Tech. Several additional software programs, developed by NDDH, were necessary to accommodate format conversions and substitutions for missing data. None of the programs developed by NDDH affected the integrity of the original data.

To determine the effectiveness of Calpuff in reproducing observed SO_2 concentrations, the NDDH has conducted several model performance evaluations. The most recent of these is included as Appendix B. This performance evaluation has been revised to reflect changes in the updated NDDH modeling approach (i.e., change in grid resolution, and adjustment of TERRAD, R1, R2, IKINE, RMIN2 in Calmet). The performance evaluations also served as the basis to “tune” a limited number of model input (control file) settings in order to provide optimal agreement between predictions and observations. With control file settings optimized, the model performed reasonably well. All predicted-to-observed ratios fell within the factor-of-two criteria suggested by EPA, and no systematic overprediction or underprediction bias was noted. As a result of the evaluation and tuning process, a limited number of input settings utilized by NDDH differ from those recommended by IWAQM.

This report is organized into three additional sections and four appendices. Section 2 describes the preparation and processing of meteorological data using Calmet and supporting software. Section 3 describes the preparation of input data for Calpuff. Application of Calpuff, and model results are discussed in Section 4. Appendix A documents NDDH code changes to Calmet. The NDDH report on Calpuff performance evaluation is included as Appendix B. The complete list of IWAQM-recommended settings for Calmet input control file is provided in Appendix C, and the complete list of IWAQM-recommended settings for Calpuff control file is provided in Appendix D.

2. **Meteorological Data Processing - Calmet**

Execution of the Calmet meteorological model requires establishment of the modeling domain (meteorological grid), preprocessing and quality assuring meteorological and geophysical input data, and determination of appropriate control file settings. Meteorological input data include surface, upper-air, and precipitation data. Geophysical input data include terrain and land-use data. Meteorological data were obtained from the National Climatic Data Center (NCDC), and geophysical data were acquired from the United States Geological Survey (USGS).

The NDDH processed six years of conventional meteorological data to use with Calpuff. The six-year record of meteorological data includes years 1990 through 1994, and year 2000. EPA standard Mesoscale Model (MM4/MM5) data sets have been incorporated in NDDH Calmet processing, i.e., MM4 data for 1990 and MM5 data for 1992 (Section 2.2.4).

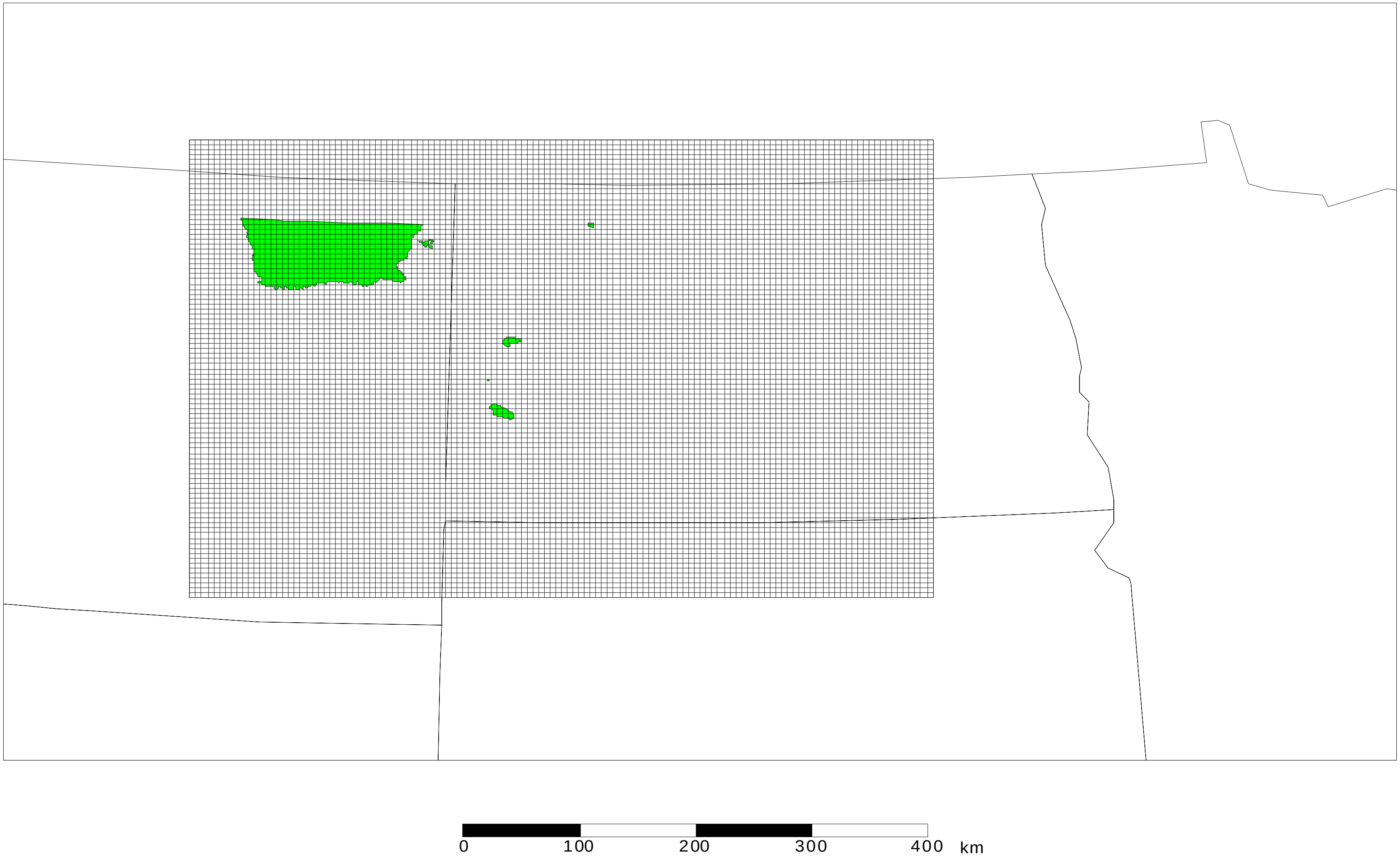
Due to differences in surface/upper-air meteorological data format and availability for 1990-1994 versus 2000, NDDH processing methodology differs for these two time periods. Therefore, surface data processing (Section 2.2.1) and upper-air data processing (Section 2.2.2) for years 1990-1994, and for year 2000, are discussed separately.

2.1 Modeling Domain

The NDDH meteorological grid was designed to provide a modeling domain which would encompass all SO_2 sources located up to 250 km from any North Dakota Class I area. The dimensions of the grid are 640 km east-west by 460 km north-south. The extent of NDDH Calmet grid, with respect to PSD Class I areas, is illustrated in Figure 2-1.

Selection of grid cell size (and number of vertical layers) reflects a compromise between the desire to define meteorological and geophysical variations on a very small scale, and the computer time and resources necessary to do so. Sensitivity testing conducted by the NDDH for grid cell sizes of 3, 5, and 10 km, and

Figure 2-1: Location of Meteorological Grid and Class I Areas



8 versus 12 vertical layers, suggests that grid resolution has very little effect on Calpuff predictions[9] (i.e., for the North Dakota domain). For the updated analysis, nevertheless, grid cell size was set to 5 km; the grid cell size in previous NDDH analyses was 10km. Given the gently rolling nature of North Dakota terrain, relatively uniform land-use characteristics, and the general lack of terrain features or water bodies large enough to cause persistent, strong local-scale flows, the NDDH believes the 5 km resolution is reasonable. Grid cell size is also depicted in Figure 2-1.

In the vertical, the NDDH meteorological grid is defined by twelve vertical layers. Cell face heights are set at 20, 40, 80, 120, 180, 260, 400, 600, 800, 1200, 2000, and 4000 meters above-ground level (AGL). Again, the use of twelve layers reflects an improvement over previous NDDH analyses, where eight layers were utilized.

Because the NDDH Calmet domain is large, the grid system, meteorological data, and geophysical data were fit to Lambert conformal mapping to account for the earth's curvature.

2.2 Meteorological Data

2.2.1 Surface Meteorological Data

2.2.1.1 Years 1990-1994

Surface meteorological data for the five-year period 1990-1994 were obtained in CD-144 format from the National Climatic Data Center (NCDC). Data were obtained for 25 stations (National Weather Service, Federal Aviation Administration, U.S. Military, Environment Canada) located within or near the NDDH Calmet grid. Location of these stations is shown in Figure 2-2.

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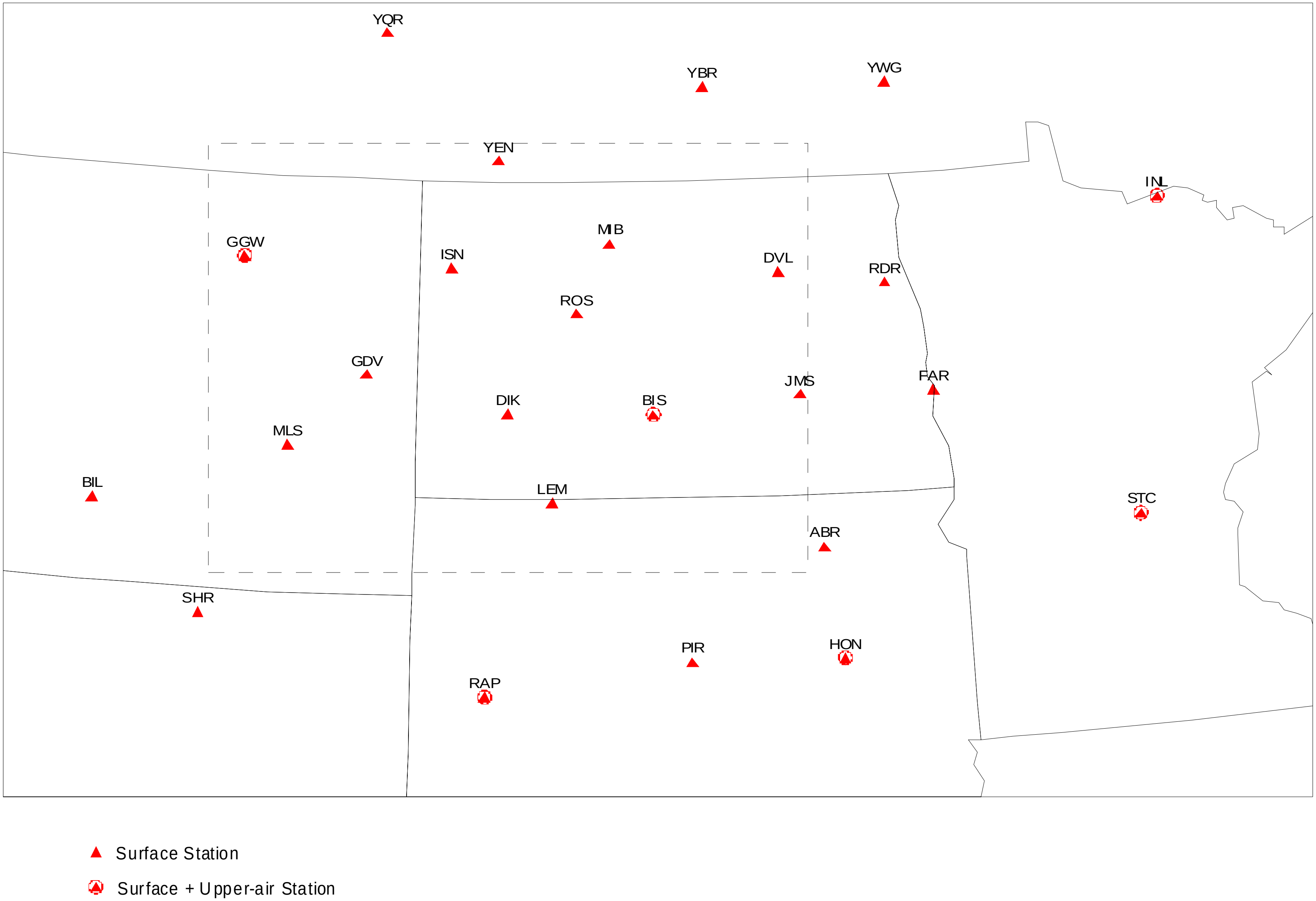
[9]NDDH, 2002. Sensitivity Testing of Calpuff/Calmet Grid Resolution. Memorandum from Steve Weber to Interested Parties. North Dakota Department of Health, Bismarck, North Dakota 58506

Figure 2-2: Surface / Upper-air Meteorological Stations 1990-1994



Some adjustments to the surface data files were required before Earth Tech programs METSCAN and SMERGE could be applied. Stations other than first-order National Weather Service (NWS) were missing opaque cloud cover for the entire five-year period. Based on a comparison of total and opaque cloud cover in the first-order NWS data sets, the NDDH developed an objective scheme to extrapolate opaque from total cloud cover. This scheme was coded into a computer program (TOT2OPQ) and applied to all surface data sets with missing opaque cloud cover.

EPA recommendations were followed to substitute for other missing data[10,11] (i.e., ceiling height, wind, pressure, temperature, relative humidity). The EPA substitution scheme was coded into a computer program (SUB144) and applied to all surface data sets. Substitutions were made if data elements were missing for one or two consecutive hours. Except for opaque cloud cover, substitutions were not made for longer missing periods (Calmet ignores stations with missing data). This is not an issue, because Calmet accommodates missing hourly surface data. Stations with missing data are simply ignored in the Calmet gridding of surface data elements for that hour.

Earth Tech program METSCAN was next applied to scan each data set for missing or unreasonable values. A few very minor changes were resultantly applied. Lastly, Earth Tech program SMERGE was applied to merge individual station data sets into a single input file (SURF.DAT) compatible with Calmet.

The occurrence of missing data elements in the CD-144 data sets was generally very limited, and within the tolerances suggested by EPA. Note that none of the missing data substitution procedures applied by NDDH affected the integrity of the original, raw data.

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

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

2.2.1.2 Year 2000

Surface meteorological data in the conventional CD-144 format required by the Calmet system were no longer available from the National Climatic Data Center (NCDC) for Year 2000 processing. Thus, NDDH obtained surface data in the alternative TD-9956 (surface hourly) format from NCDC, and prepared utility software to convert the TD-9956 format data to CD-144. Data were obtained for Year 2000 for 32 stations (National Weather Service, Federal Aviation Administration, U.S. Air Force Base, Environment Canada) located within or near the NDDH Calmet/Calpuff grid. Location of these stations is shown in Figure 2-3.

Data for most of the 32 surface locations reflect observations from automated stations equipped with Automated Surface Observing Systems (ASOS). The relatively new ASOS data has well-documented limitations (compared to earlier manual data collection) including lack of cloud data (ceiling height / sky cover) above 12,000 feet. To compensate for these limitations in the TD-9956 format data, the NDDH also obtained concurrent GOES ASOS satellite data for all ASOS surface stations (i.e., not available for Air Force Base or Canadian stations) from NCDC. The satellite hourly observations include cloud amount (sky cover) to the nearest one percent, and include cloud height data from which ceiling height can be derived. The satellite entries for sky cover and ceiling height extend above 12,000 feet, and therefore do not share the limitations of the TD-9956 data.

The general procedure followed by NDDH to prepare surface data for Calmet included tasks to merge satellite observations for sky cover and ceiling height with TD-9956 data, convert the resultant TD-9956 data sets to CD-144 format, provide substitutions for missing data elements in the CD-144 data sets, and merge the resultant CD-144 data sets for individual stations into a single file compatible with Calmet. These tasks were accomplished using utility software provided by Earth Tech, and supplemental software programs developed by NDDH. The NDDH procedure for preparation of year 2000 surface meteorological data is depicted schematically in Figure 2-4. The function of individual programs identified in Figure 2-4 is described below.

Figure 2-3: Surface / Upper-air Meteorological Stations 2000

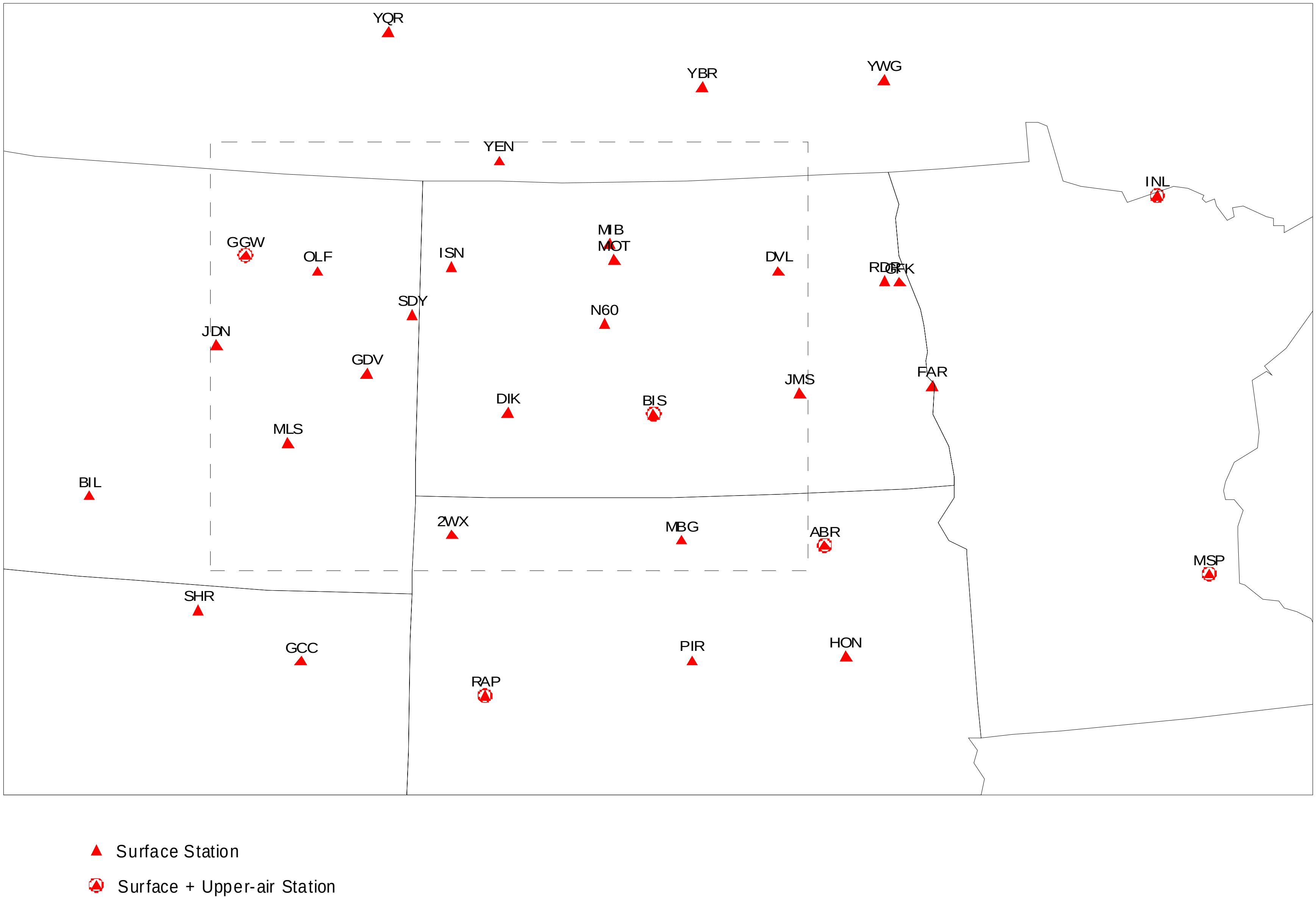
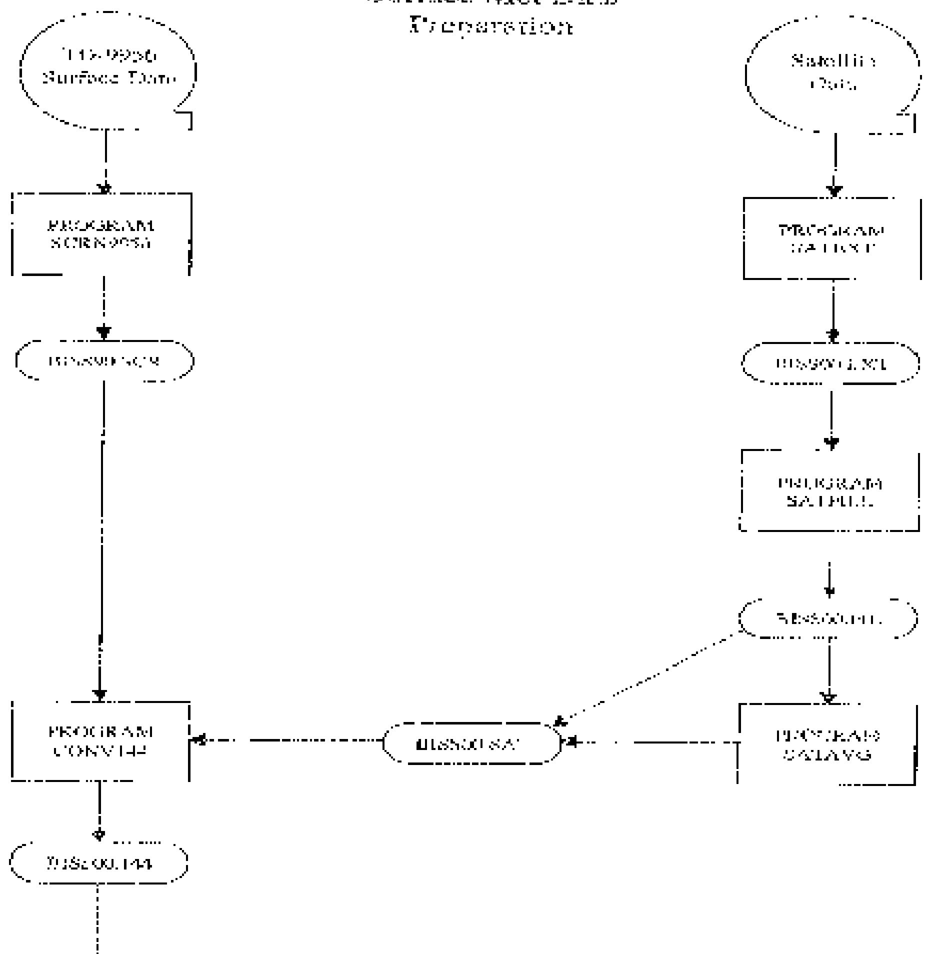


Figure 2.4
Surface Met Data
Preparation



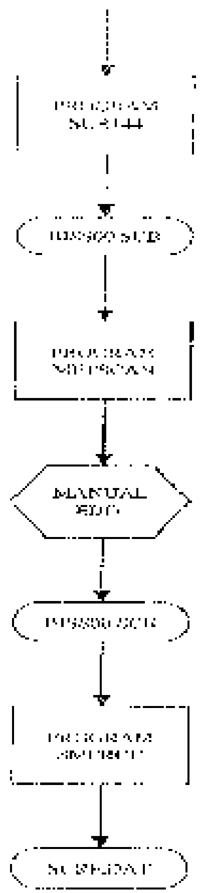


Figure 2-4
Surface Met Data
Preparation
(cont.)

SCRN9956 (NDDH) - Because the TD-9956 data set includes multiple observations during some hours, this program was developed to extract a single observation for each hour, as required by Calmet (and CD-144 compatibility). The record (observation) closest to on-the-hour is selected. Missing elements in the selected record are substituted from other available records for the hour, starting with the next-closest record to on-the-hour. SCRN9956 completes the data set by inserting a blank record for each hour containing no observations.

SATEXT (NDDH) - NCDC provides satellite data in contiguous, satellite-specific data sets only. One data set is available for the GOES-8 Satellite (eastern half of the U.S.) and one for the GOES-10 Satellite (western half fo the U.S.). The NDDH Calmet/Calpuff grid lies in the coverage area for both satellites (i.e., GOES-8 covers eastern part of grid and GOES-10 covers western part). SATEXT extracts the necessary hourly information (cloud height and cloud cover) for each TD-9956 (ASOS) station from these contiguous data sets, and creates a separate satellite data file for each station.

SATFILL (NDDH) - This program completes the individual station satellite files by inserting a blank record for each hour with no data.

SATAVG (NDDH) - Because overlapping of the GOES-8 and GOES-10 coverage areas occurs, some of the meteorological stations used by NDDH are covered by both satellites, and duplicate satellite files for these stations were produced by SATEXT. Since cloud data in the duplicate files was somewhat different, it was concluded that averaging the hourly data in the two files would be the best solution for developing a single data set. This task was accomplished with SATAVG.

CONV144 (NDDH) - This program merges the satellite file cloud data with the TD-9956 data (for each station), and converts the resultant data set to CD-144 format.

SUB144 (NDDH) - SUB144 provides substitutions for remaining missing elements in the CD-144 format data sets (i.e., missing winds, pressure, temperature, relative humidity, ceiling height, sky cover). Substitutions follow EPA recommendations[10,11]. Substitutions are made by SUB144 if the data element is missing for one or two consecutive hours, only. Consistent with the EPA guidance, substitutions are not provided for longer missing periods. This is not a problem, because Calmet accommodates missing hourly surface data. Stations with missing data are simply ignored in the Calmet gridding of surface data elements for that hour.

METSCAN (Earth Tech) - Program provides a final scan of each station data set to flag missing or unreasonable values, and achieves a final quality assurance review. Given the robustness of NDDH screening and substitution procedures prior to this step, METSCAN produced very few messages. To accommodate the METSCAN flags, a few very minor manual edits were resultantly applied to some station data sets.

SMERGE (Earth Tech) - SMERGE combines individual station CD-144 data sets into the single, contiguous file required by Calmet (SURF.DAT).

The occurrence of missing data elements in the TD-9956 and satellite data sets was generally very limited, and within the tolerances suggested by EPA. Note that none of the format conversion or missing data substitution procedures applied by NDDH affected the integrity of the original, raw data.

2.2.2 Upper-Air Meteorological Data

Upper-air meteorological data for 1990 through 1994 were obtained in TD-6201 format from NCDC. Upper-air meteorological data for Year 2000 were obtained from the Forecast Systems Laboratory (FSL) in Boulder, Colorado, one of the NOAA Research Laboratories. Files of upper-air soundings were downloaded from the FSL website (www.fsl.noaa.gov). The FSL sounding data were in the original FSL format, which is accepted for Calmet input as the option “NDCD CD-ROM”. For each time period, data were obtained for six upper-air stations located within or near the NDDH Calmet grid. The locations of these stations are shown in Figures 2-2 and 2-3 for 1990-94 and 2000, respectively.

Near the end of 1994, the NWS replaced the upper-air observing station at Huron, South Dakota, with one at Aberdeen, South Dakota, to the north of Huron. Likewise, between 1994 and 2000, the NWS replaced the upper-air station at St. Cloud, Minnesota, with one near Minneapolis, Minnesota, to the south of St. Cloud. For processing of 1990-94 meteorological data, considering the locations of Huron and St. Cloud relative to the Calmet grid, it was determined that both station's data contributed to the model calculations at the southeast corner of the Calmet grid. However, in processing the 2000 data, Aberdeen is much closer to the grid than is Huron, and Minneapolis is much farther from the grid than is St. Cloud. Given the relative locations of Aberdeen and Minneapolis to the Calmet grid, it was determined that Aberdeen and International Falls, Minnesota were sufficient to model the southeast corner of the grid, and Minneapolis would not add much to the calculations there because of its greater distance from the grid. Therefore, for processing year 2000 upper-air data, Minneapolis data were only used for filling in missing data at International Falls, not for the rest of the year.

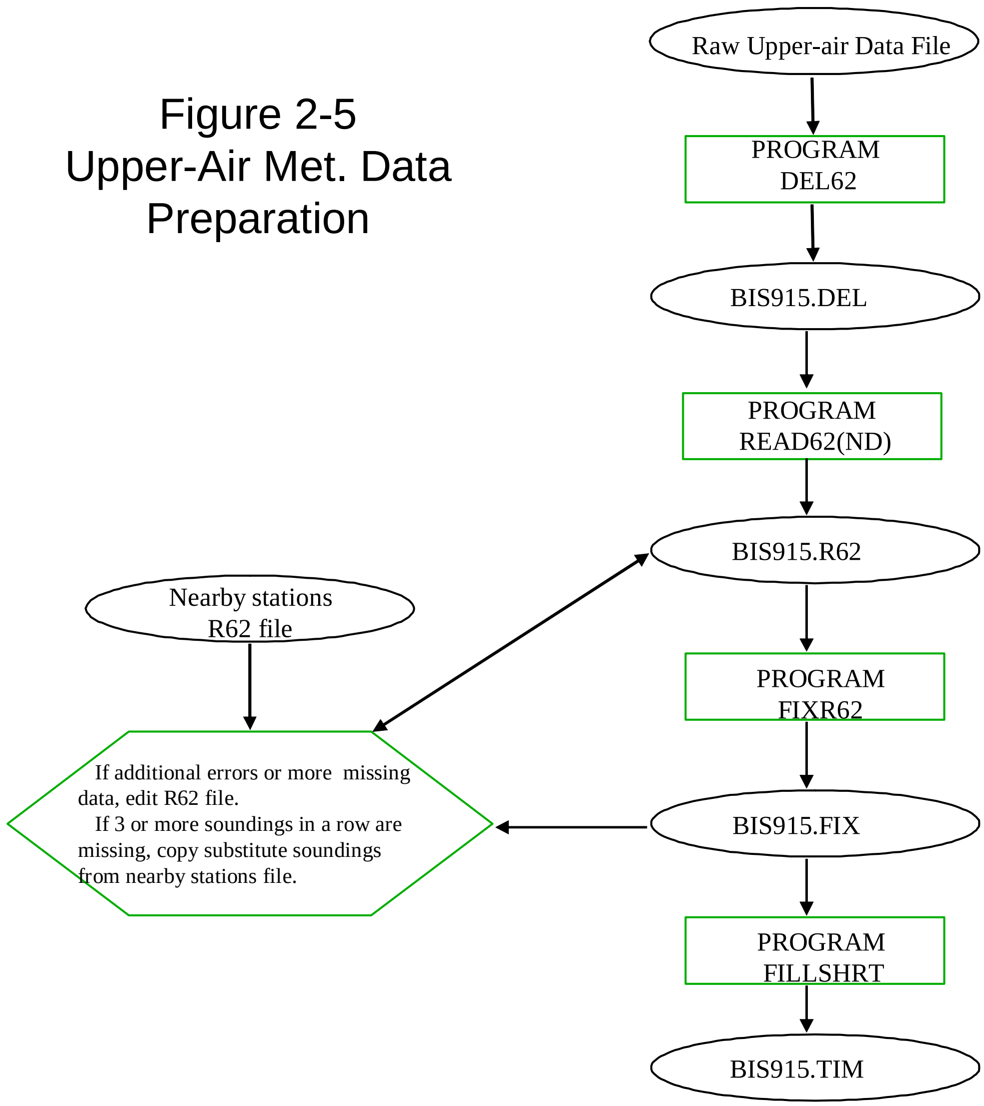
Because of Calmet's fairly strict requirements on the completeness of upper-air data records and the frequency of missing upper-air data, it was desirable to automate the upper-air data processing with computer programs as much as possible. Since Earth Tech's program READ62 did not correct errors or fill in for missing data, much of the upper-air data processing was accomplished by running programs written by NDDH staff, along with manual file editing. The procedure consisted of preparing the upper-air data file for Earth Tech's program READ62, execution of READ62, manual editing to correct infrequent or complex data problems or to fill in for extended missing periods, and execution of two NDDH programs to fill in more frequent, common occurrences of missing data.

The NDDH procedure for preparation of upper-air meteorological data is depicted schematically in Figure 2-5. The first step in processing the upper-air data was to set the hours of the standard

12-hourly observing times consistently at 00Z and 12Z (hours GMT or UTC) for the entire year for each station. For processing the 1990-94 upper-air data in TD-6201 format, the NDDH executed program DEL62 to make the observing times consistent at 00Z and 12Z. Program DEL62 also passed along only the first line of data (lowest 79 sounding levels) for each sounding and ignored the higher levels of data, which weren’t needed. For processing the one year of data in FSL format, for year 2000, the standard observing times were set at 00Z and 12Z using a manual text editing program.

Next, program READ62 was executed to input the upper-air sounding data for one station for one year, to convert the upper-air data to

Figure 2-5
Upper-Air Met. Data
Preparation



the format Calmet requires, and to output only the desired variables pressure, height above mean sea level (MSL), temperature, and wind at sounding levels up to the top level desired, 500 mb. Calmet requires sounding data at levels up to the calculated mixing height for all hours processed. It was necessary to extract data up to 500 mb to accommodate mixing heights up to approximately 4000 meters above ground level (AGL) at stations as high as Rapid City, South Dakota (elevation 966 meters MSL).

The NDDH encountered numerous problems in using Earth Tech’s Program READ62. Solving these data processing problems necessitated modifying READ62, modifying its output, or running additional programs to correct the problems. The procedures used were somewhat different for processing the 2000 FSL data than what was done for the 1990-94 TD-6201 data. Consequently, the rest of the description of the procedure for processing upper-air data was separated into two subsections, the first for processing the 1990-94 TD-6201 data and the second for processing the 2000 FSL data.

2.2.2.1 1990-94 TD-6201 Data

Since program READ62 only flags missing soundings but does not fill in any missing data, the rest of the data preparation and missing data substitution is left up to the user. In addition, READ62 (version available in 1996-97) created some problems that were corrected in later NDDH programs or by modifying READ62. READ62 rejected some surface data records because they were coded as having been substituted for missing data by NCDC. Since surface data must be complete (in upper-air data files) and the NCDC substitutions looked reasonable, READ62 was modified to accept this type of data. Also, READ62 overlooked some occurrences of two consecutive missing soundings and did not code missing temperatures correctly for Calmet input, which were remedied in a later NDDH program. Most of these READ62 problems were corrected by Earth Tech in a more recent version, but these NDDH modifications were necessary because preprocessing of raw data was performed in 1997.

Two NDDH programs (FIXR62 and FILLSHRT) performed much of the remaining upper-air data preprocessing. The first program copied soundings at the beginning and end of the year, when necessary, to ensure that upper-air data bracketed the entire calendar year of surface data, as required by Calmet. Since Calmet requires the surface level and top level to be present and complete for all soundings, the program either filled in the missing data or output informative messages indicating where manual substitution was required. Following EPA guidance[10,11], missing data at the top or surface level were interpolated in time from the same station's data for one or two consecutive missing observations and were substituted from a nearby station's data at the same time for three or more consecutive missing observations.

Unlike the requirements for surface meteorological data, Calmet requires soundings to be present for every standard 12-hour observation time. Since no soundings may be left missing, periods with completely missing soundings were filled in either by execution of the NDDH program FILLSHRT or manual substitution. For periods with one or two consecutive missing soundings, the program filled in the missing soundings from adjacent soundings in time for the same station. The substitutions were designed to retain appropriate representative diurnal variations in the substituted soundings. For periods with three or more consecutive missing soundings, the missing soundings were substituted by copying soundings from a representative nearby station for the same times using a text editor. Some editing of the substituted soundings was required to adjust the new soundings to the new station and its different elevation. Program FIXR62 also found missing temperatures, which were converted incorrectly in READ62, and replaced them with the correct missing code (in the correct units). The result was a file for each upper-air station and year containing sounding data in Calmet-ready format for every 12-hour observation.

2.2.2.2 2000 FSL Data

Program READ62 was updated and corrected since 1995 (by Earth Tech) to correct some errors and problems, some of which were discovered and reported by the NDDH. Nevertheless, the most recent version of READ62 available at the time the 2000 FSL data were processed (1999 version) still contained a few errors or problems to be dealt with by the NDDH. The 1999 version of READ62 had a Year 2000 problem

(Y2K) in data input which was handled by inputting artificial dates and times into READ62 to force it to output all days of data. Also, READ62 did not correctly read a station’s longitude if it was 100°W or greater (westward). This error caused READ62 to misread the station’s ground elevation, which didn’t match the first sounding’s base elevation and caused the program to abort. The NDDH solved this problem by making a small correction to the formatting of the one line in READ62 to correctly read longitudes west of 100°W. The only station affected by this problem was Glasgow, Montana. The slightly modified, corrected version of READ62 was executed for Glasgow 2000 data. The standard Earth Tech version of READ62 was used for all other stations for year 2000.

The first three days of FSL upper-air data in 2000 were missing or contained missing or erroneous pressures and heights for all stations. Pressure and height are the vertical coordinate (elevation) in meteorological models and are essential data for input to a model. Since there were no valid data at any nearby stations for substitution, the first three days of 2000 would have to be skipped. The NDDH executed READ62 by directing the program to eliminate sounding levels with bad or missing pressure or height (standard application), which caused READ62 to skip the first three days of 2000, as desired.

Since program READ62 only flags missing soundings but does not fill in any missing data, the rest of the data preparation and missing data substitution is left up to the user. READ62 outputs error messages for any errors detected in addition to outputting soundings in Calmet format. The 1999 version of READ62 checks the data for more types of errors and outputs more error messages than did older versions. Errors or problems that occurred infrequently were corrected by manually editing the READ62 output file with a text editing program. Occasionally, pressure levels were out of order in the FSL data, which required manual correction. READ62 error messages indicated where data were missing at the top level or surface level of a sounding. Since Calmet requires the surface level and top level to be present and complete for all soundings, it was necessary to fill in for missing data or entirely missing levels for the surface and top levels. Following EPA guidance[10], missing data at the top or surface level were interpolated in time from the same station’s data for one or two consecutive missing observations. Because missing data at one or two consecutive surface-level observations were quite infrequent, missing surface data were interpolated and edited into the file manually. Missing data at the top level, 500 mb, were generally filled in using an NDDH program, which is described later.

Unlike the requirements for surface meteorological data, Calmet requires soundings to be present for every standard 12-hour observation time. Since no soundings may be left missing, periods with completely missing soundings were filled in either by manual substitution or by using another NDDH program. Extended periods of missing soundings (three or more consecutive missing soundings) were filled in manually at this step in the process. The READ62 output indicated where missing soundings occurred and the number of missing soundings to be filled in was determined. According to EPA guidance[10], episodes of three or more missing soundings were filled in by copying soundings for the same observing times from a representative nearby station’s file. The substituted soundings were then edited to match the new station (e.g., station number, elevation). Filling in data for one or two missing soundings was accomplished in a later program.

Two NDDH programs, FIXR62 (version 3.1) and FILLSHRT (version 2), performed most of the remaining upper-air data preprocessing. The two programs were executed in sequence on the modified, partially corrected READ62 output file already processed. The first program was intended to fix problems left by READ62 (which have been corrected in the latest version), fill in some of the missing data, and check for any remaining missing or bad data. The first program copied soundings at the beginning and end of the year, when necessary, to ensure that upper-air data bracketed the entire calendar year of surface data, as required by Calmet. The first program also filled in for missing data or an entirely missing level at the top level, 500 mb, when one or two consecutive observations were missing, by interpolating in time between earlier and later observations at the same station.

The only remaining task in processing upper-air data was substituting data for periods with one or two missing soundings.

Episodes with three or more missing soundings were substituted manually in an earlier step. Episodes with one or two consecutive missing soundings were filled in by execution of NDDH program FILLSHRT. The program filled in the missing soundings from adjacent soundings in time for the same station. The substitutions were designed to retain appropriate representative diurnal variations in the substituted soundings. The 1999 version of READ62 was designed to allow for soundings at times other than the standard 00Z and 12Z observing times. Extra soundings at nonstandard times were carried along in the processing as long as the top and bottom levels were complete. The result of all this upper-air data processing was a file for each upper-air station for the year 2000 (except for the first three days) containing sounding data in Calmet-ready format for at least every standard 12-hour observation.

2.2.3 Precipitation Data

Hourly precipitation data for the five-year period 1990-1994 were obtained from Earth Info, Incorporated (Boulder, CO). Data were included for 96 stations located in North Dakota, eastern Montana, northern South Dakota, and western Minnesota. Location of these stations is shown in Figure 2-6.

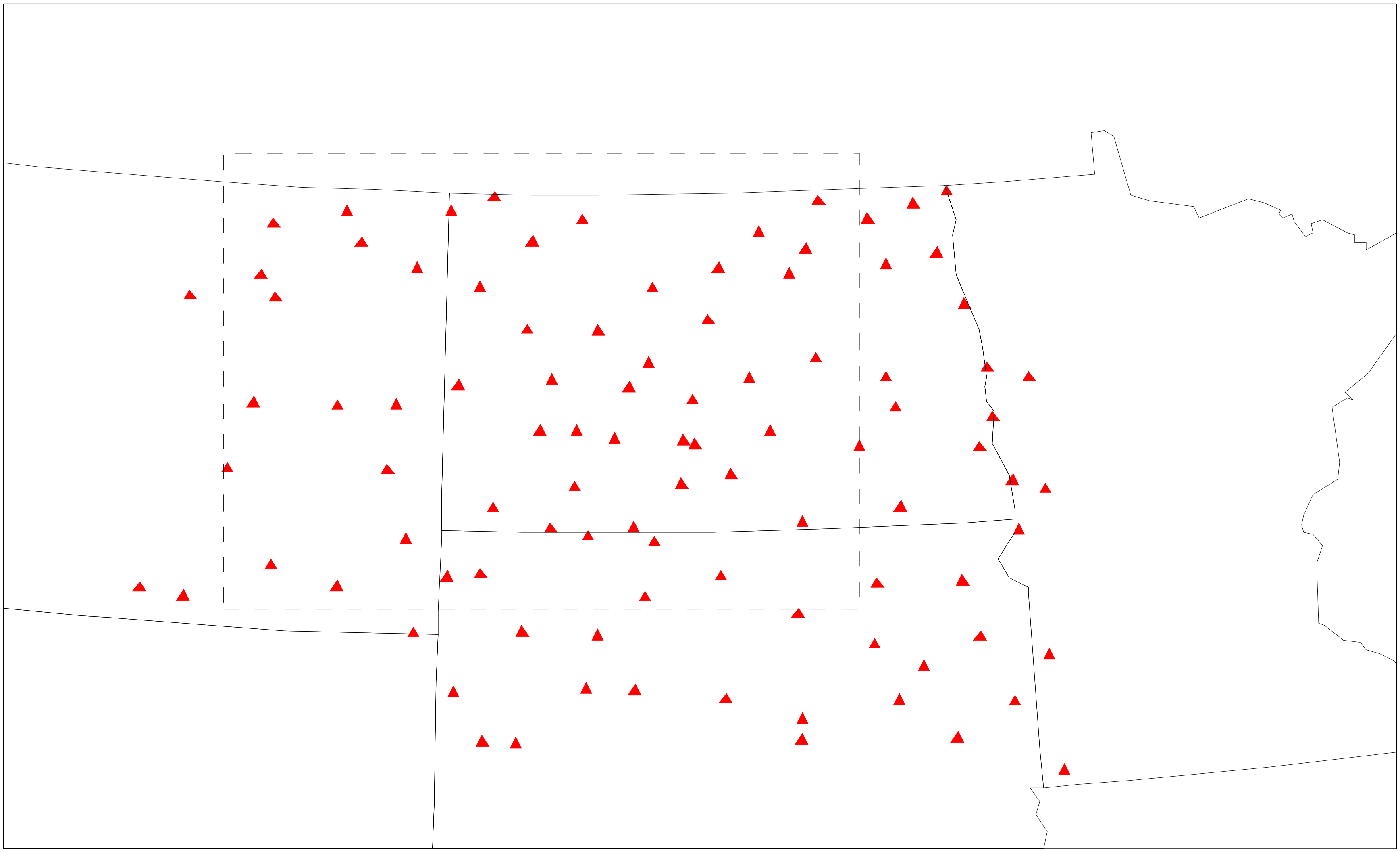
Software provided with the Earth Info distribution allowed extraction of hourly precipitation data in TD-3240 variable record length format. The Earth Tech program for processing precipitation data (PXTRACT) requires data in TD-3240 fixed record length format. Therefore, the NDDH prepared a program (CONV3240) to convert precipitation files from variable to fixed record length format.

Hourly precipitation data for Year 2000 were obtained from NCDC in the TD-3240 format required by the Earth Tech utility software. Data were included for 89 hourly recording stations located within or near the NDDH Calmet/Calpuff grid. Location of these stations is shown in Figure 2-7.

The NDDH noted that the format of the data measurement flag in the Year 2000, TD-3240 data files differed from earlier (1990-1994) files, and was therefore not compatible with the Earth Tech software. NDDH thus developed and executed software (FIX3240) to convert the Year 2000 flags to the earlier format.

Earth Tech program PXTRACT was executed to extract individual station precipitation data from the TD-3240 files (1990-1994 and 2000), and PMERGE was executed to consolidate individual station data into the single file 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 (Figures 2-6, 2-7).

Figure 2-6: Precipitation Stations 1990-1994



2.2.4 MM4/MM5 Data

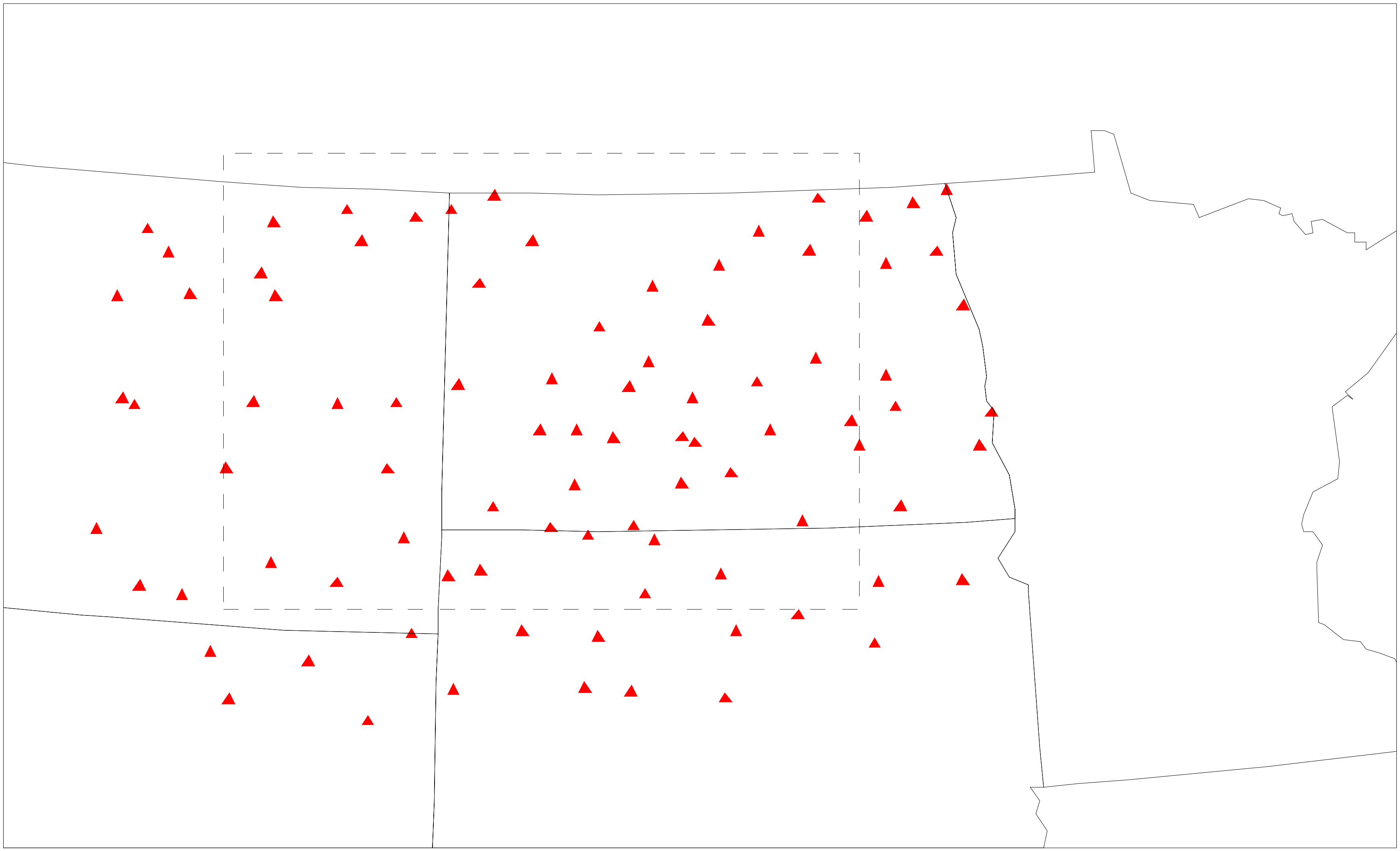
As part of the “Findings and Conclusions” of the May 2002 hearing and public comment process[4], the NDDH was instructed to “explore the potential benefits and potential implementation of the use of MM5 data with the Calpuff air modeling system.” MM4 and MM5 meteorological data sets are produced using the Penn State University / NCAR Mesoscale Model (MM) Version 4 and Version 5, respectively. Version 5 is the more recent iteration of the Penn State / NCAR model. Because the Penn State / NCAR MM is a prognostic meteorological model, use of the output data sets with Calmet theoretically improve the hour-to-hour progression of the generated wind field compared to the default use of Calmet with raw hourly observations in a diagnostic mode. EPA has approved the use of MM data sets to supplement NWS (National Weather Service) observations in the execution of Calmet[8].

The EPA 1990 MM4 and 1992 MM5 data sets are well documented and have been applied extensively for PSD Class I modeling analyses throughout the United States. Thus, it is a relatively simple matter to supplement the NDDH analysis for these two years, (1990 and 1992) with the familiar MM data.

At the May 2002 hearing, Basin Electric/ENSR submitted Class I increment modeling analysis based on a MM5 data set for year 2000. The NDDH reviewed this analysis with the intent of determining the viability of the MM5 data set. During the review, several input errors were noted in the analysis, which were subsequently corrected by ENSR. In an updated analysis which was submitted to the NDDH[12]. The NDDH is currently reviewing the updated ENSR’s MM5 analysis. Based on its initial review, the NDDH notes the following:

[12]ENSR, 2003. Revised Calpuff Analysis with Year 2000 MM5 Meteorological Data: PSD Increment Consumption in Class I Areas in North Dakota and Eastern Montana. ENSR Corporation Document Number 3496-010-100.

Figure 2-7: Precipitation Stations 2000



- The ENSR MM5 data set is extrapolated from National Weather Service RUC2 model output, as modified by another meteorological model (ADAS).

- The ENSR data and RUC2 model input does incorporate a considerably large volume of meteorological observations including NEXRAD wind data and satellite cloud data.

- The ENSR MM5 data set reflects RUC2 output based on initial analyses for every hour. Whether a smooth prognostic progression of air flow/weather patterns, characteristic of conventional prognostic MM5 analyses will occur, is unknown.

The NDDH incorporated the ENSR RUC/MM5 data set in Calpuff test analyses for year 2000 meteorological data. Using the year 2000 RUC/MM5 data with equivalent model inputs, the NDDH found Calpuff results consistent with other meteorological scenarios modeled (i.e., years 1990-1994, and year 2000 without MM5 data). Although the NDDH did not incorporate the 2000 RUC/MM5 data in its updated analysis, it continues to evaluate this data set.

The NDDH is also aware that EPA Region 8 has developed an MM5 data set for the North Dakota modeling domain for year 1994, but the NDDH does not currently have access to the data. The NDDH also intends to evaluate the use of the 1994 data set when it is made available.

2.3 Geophysical Data

Calmet requires a terrain-elevation value, and parameters related to the land-use profile, for each grid cell. Grid cell terrain elevations were derived from United States Geological Survey (USGS) GTOPO30 data sets for North America central and mountain zones. Land-use profiles for grid cells 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. The Earth Tech TERREL program was first applied to the GTOPO30 data sets to produce an intermediate file of gridded elevations for the Calmet/Calpuff domain. The CTGPROC program was applied to the USGS Global data set to provide an intermediate file of gridded land-use profiles (i.e., distribution of each land-use type within each grid cell) for the modeling domain.

The two intermediate files were merged into the necessary single (GEO.DAT) file using Earth Tech program MAKEGEO. MAKEGEO also converts the gridded land-use types in the intermediate file to the land-use-related parameters required by Calmet and stored in the GEO.DAT file. These parameters include surface roughness length, albedo, Bowen ratio, soil heat flux, and leaf area index. Values for these parameters are related to land-use type as shown in Table 4-45 of the Calmet User's Guide[6]. MAKEGEO uses the distribution of land-use type within each grid cell to calculate composite land-use related parameter values for the cell.

2.4 Calmet Code Revision

Based on a thorough examination of plotted wind fields generated from Calmet processing of 1990-1994 meteorological data sets, the NDDH noted a chronic discontinuity between surface and upper wind levels. To mitigate this problem, the Calmet option to extrapolate surface wind observations to upper layers was deployed, using similarity theory (Option 4) and layer-dependent bias settings. Calmet Version 5.x extrapolates surface winds both for setting the initial guess field, and for introducing observations in the Step 2 wind field procedure. Unfortunately, the model utilizes the bias factors for the initial guess field, only. The Step 2 vertical extrapolation has equal effect through all upper layers. The NDDH considered this unrealistic because resultant upper-layer wind fields reflected localized surface-layer (low-level) perturbations consistently, upward through all upper levels, even in the top layer (4000 m). It was believed that such low-level features should dampen with height and not extend up into the middle troposphere. In other words, the Step 2 vertical extrapolation essentially undid the effective Step 1 (dampened) vertical extrapolation of the wind fields.

To address this problem, the NDDH modified the Calmet code to simply eliminate the vertical extrapolation in the Step 2 wind field procedure, resulting in a more realistic transition from surface to upper layers. This modification was made with concurrence from Joe Scire (Earth Tech) and John Vimont (National Park Service). NDDH changes to Calmet code are documented in Appendix A. The modified Calmet version was used to process all data (1990-1994, 2000).

2.5 Calmet Control File Settings

Calmet control file settings utilized in the processing of 1990-1994 and 2000 data were generally consistent with guidance from the Interagency Workgroup on Air Quality Modeling (IWAQM)[5]. However, extensive testing of Calmet output, with visual feedback (plotted 2-D fields), suggested that adjustment to a limited number of IWAQM settings was required to achieve reasonable representations of wind and mixing height fields. Further, the adjustment of a limited number of additional settings was found to provide better agreement with monitored observations based on a Calmet/Calpuff performance evaluation conducted by NDDH (Appendix B) and such changes were judged to be scientifically consistent.

IWAQM recommendations for Calmet control file settings fall into two categories. Group A (NDDH terminology) includes those variables for which IWAQM provides a default value as a general recommendation for all analyses. Group B includes those variables where IWAQM recognizes the value will need to be tailored for a given application, and default values are therefore not provided.

The Group B settings utilized by NDDH for Calmet processing of 1990-1994 and 2000 data are summarized in Table 2-1. Most of these settings involve straightforward variables, related to the Calmet/Calpuff meteorological grid, which have been previously discussed. The remaining Group B variables (RMAX1, RMAX2, RMAX3, TERRAD, R1, R2) control the influence of station observations and terrain features in development of the final wind field. Initial values for these latter variables were based on guidance from the National Park Service. The NDDH then tuned the initial values to optimum settings using iterative testing with visual feedback.

Additional refinement of settings for Group B variables R1, R2, and TERRAD was based on input received during the May 2002 public comment period and hearing[4].

NDDH settings for Group A variables were based both on the iterative testing process described above, and on a model performance evaluation. Initial iterative testing ensured that Calmet settings provided a reasonable appearance of wind and mixing height fields. Then a model performance evaluation was conducted by NDDH to establish optimum and final Calmet/Calpuff control file settings. The performance evaluation was based on a comparison of observations and model predications at two monitoring sites, one located at the TRNP South Unit. The evaluation proceeded in an iterative manner to determine the effect of adjustments to settings in the Calmet and Calpuff input control files on model skill. The NDDH performance evaluation is described in Appendix B.

As a result of the iterative testing process and performance evaluation, the NDDH elected to modify IWAQM values for a limited number of Calmet Group A control file settings. Non-IWAQM settings utilized by the NDDH for the Calmet control file, and which provided optimum agreement with monitored observations, are listed in Table 2-2. These non-IWAQM Group A settings are discussed below.

BIAS(NZ) - NDDH bias settings were developed through iterative testing with visual feedback. The IWAQM recommendation provides neutral bias (between surface and upper-air data) for all vertical layers. In light of its testing, the NDDH does not believe it is reasonable to assume equal weighting of upper-air wind data with surface data at the lowest level, and to assume equal weighting of surface data with upper-air at top levels.

LVARY - Given the size of the meteorological grid, the NDDH felt it necessary to deploy this option (varying radius of influence) to ensure that at least one station would be available for wind field interpolation.

ZUPWIND(2) - The NDDH was concerned that IWAQM was recommending a value of 1000 m while the model (Earth Tech) default is 2500 m, thus prompting the NDDH compromise value of 2000 m. But regardless of the selected value for this initial guess wind field input, subsequent wind field development should converge to the same result.

MNMDAV/ILEVZI - The NDDH found that IWAQM default values for these parameters, relating to spatial averaging of mixing heights, produced entirely unacceptable results for the mixing height field. Severe gradients (bull's eyes) in mixing height were observed in the immediate vicinity of meteorological stations, and a significant increase in the value of these input parameters was required to mitigate the anomaly. The NDDH notes that because MNMDAV is

Table 2-1

Calmet Control File Settings - Group B

Variable	Description	Value
NX	No. of east-west grid cells	128
NY	No. of north-south grid cells	92
DGRIDKM	Grid spacing (km)	5
XORIGKM	Southwest grid cell X coordinate	-380
YORIGKM	Southwest grid cell Y coordinate	140
LLCONF	Lambert conformal coordinates	T
XLAT1	Latitude of 1st standard parallel	46.0
XLAT2	Latitude of 2nd standard parallel	48.5
RLON0	Reference longitude	102
RLAT0	Origin latitude	44
NZ	No. vertical layers	12
RMAX1	Max surface over-land extrapolation radius (km)	300
RMAX2	Max aloft over-land extrapolation radius (km)	1200
RMAX3	Max over-water extrapolation radius (km)	500
TERRAD	Radius of influence of terrain features (km)	30
R1	Relative weight at surface of Step 1 field & observation	40
R2	Relative weight aloft of Step 1 field & observation	60
ISURFT	Surface station to use for surface temperature	1*
IUPT	Station for lapse rates	1*

* Represents Bismarck NWS

a function of grid cell size, IWAQM should not specify an absolute default value for this parameter.

ZIMAX/ZIMAXW - Because the NDDH Calmet/Calpuff grid extends into the western part of the upper Great Plains, maximum mixing height was increased to 4000 m to be consistent with maximum mixing heights reported for this region (Holzworth, 1972)[13].

The complete list of IWAQM-recommended settings for the Calmet control file is included as Appendix C.

[13]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.

Table 2-2

Non-IWAQM Group A Settings Used by NDDH in Calmet Control File

Variable	IWAQM	NDDH
BIAS(NZ)	0,0,0,0, 0,0,0,0, 0,0,0,0	-1.0, -0.9, -0.8, -0.4, 0.0, 0.1, 0.5, 0.8, 1.0, 1.0, 1.0, 1.0
LVARY	F	T
ZUPWIND(2)	1000 m	2000 m
MNMDAV	1	8
ILEVZI	1	4
ZIMAX	3000 m	4000 m
ZIMAXW	3000 m	4000 m

3. **Calpuff Input Data**

Along with the Calmet-processed meteorological data, the user must provide an emissions inventory, receptor locations, input control file settings, and (optionally) hourly ozone data before Calpuff can be executed.

3.1 Emission Inventory

To address PSD Class I increment consumption, the NDDH developed a source inventory for current (Year 2000/2001) SO_2 emissions, and another source inventory for baseline SO_2 emissions. Net increment consumption was determined as a function of the difference in model results for these two inventories (i.e., current inventory minus baseline inventory). A few sources (e.g., Colstrip Units 1 and 2, and MDU Sidney) whose emissions remained essentially unchanged from the baseline to Year 2000 were not included in the analysis.

SO_2 increment-affecting sources located in the vicinity of the six subject Class I areas were shown in Figure 1-1. These sources include primarily electrical generating stations, natural gas processing plants, and well-site facilities (not shown in the figure) related to oil and gas production. With the exception of well-site oil and gas facilities, all sources located within 250 km of subject Class I areas were included in the emission inventories (current and baseline). Because well-site oil and gas facilities are numerous and generally have very small SO_2 emissions, their inclusion was limited to a distance of 50 km from Class I areas. These distance limits are consistent with previous NDDH PSD Class I modeling analyses.

Numerous oil and gas production facilities are located in the vicinity of Medicine Lake and Fort Peck Class I areas and emission/stack data for these facilities were not obtainable. Therefore, the local well-site oil and gas facility contribution was not accounted for in Calpuff modeling for Montana Class I areas.

Annual average SO_2 emission rates, expressed as the total actual annual emission divided by the annual hours of operation, were utilized in the NDDH baseline and current emission inventories. Use of the annual average is based on the state's legal review of the Air Pollution Control Rules.[14]

3.1.1 Current Inventory

Annual-average SO_2 emission rates and dynamic stack operating parameters (exit velocity and temperature) for the current inventory were derived from Continuous Emission Monitoring (CEM) hourly data for years 2000 and 2001, where available. The annual average was calculated as the average for all non-zero hours. CEM hourly data for emission rates and flow rates (exit velocity) for electrical generating stations (larger than 25 megawatts) were available and downloaded from the EPA Acid Rain Web Site on the internet. All CEM hourly data for other major sources, as well as the hourly stack exit temperature for electrical generating stations, were obtained directly from the plant operators. Values for fixed stack parameters (stack height and diameter) were obtained from NDDH records/permits. Basically, CEM hourly data were available for all electrical generating stations, and for most natural gas processing plants.

For major sources with no hourly data (Tioga Gas Plant, Mandan Refinery), total annual emissions and operating hours were obtained from Annual Emission Inventory Reports for Year 2000/2001. Stack exit velocity and temperature were obtained from recent stack test data. Stack height and diameter were obtained from NDDH records/permits.

Year 2000 actual emission rates reflecting annual average operation for oil and gas production sources (treaters and flares) were derived from the ND State Industrial Commission's (SIC) Oil and Gas data base. The data base includes information on gas production (flared and lease-use), and the H_2S content of the gas, such that SO_2 emission rates for well-site flares and treaters can be

[14] NDDH, 2002. Summary of Legal Issues Relating to Administration of the Prevention of Significant Deterioration (PSD) Provisions of North Dakota's State Implementation Plan (SIP). North Dakota Department of Health, Bismarck, North Dakota 58506.

calculated. Dynamic stack operating parameters for oil and gas production sources were derived from the calculated heat of combustion using procedures described in the "Williston Basin Regional Air Quality Study"[15], and modified using SCREEN3[16] (EPA screening model) adjustments for effective flare plume height and radiotational heat loss. Flare and treater stack height were obtained directly from the SIC data base.

In summary, the current emissions inventory was grouped into major sources with annual averages derived from CEMs hourly stack data, major sources with annual averages derived from Annual Emission Inventory Reports, and oil and gas sources with annual averages derived from the SIC Oil and Gas data base. In all cases, the annual average SO_2 represents total actual annual emissions divided by hours (or days) of operation. The emission characterization for each current inventory source is provided in Table 3-1.

The Great Plains Synfuels Plant and the Little Knife Gas Processing Plant were not included in the current emissions inventory. Based on the state's legal review, it was concluded that all emissions from these facilities are exempt from the Class I increments and are subject to the alternative Class I increments under 42 U.S.C.§. 7475(d)(2)(C)(iii) and (iv), because Class I variances were granted for major modifications at both facilities.

Some additional changes are noted in the current emissions inventory used in the present analysis compared to what was assumed for the NDDH April 2002 analysis. Minor revisions in SO_2 emission rates for some sources reflect the use of all eight quarters of 2000/2001 CEMS data in the calculation of annual average. The last quarter of 2001 was unavailable and not included in the calculation of emission rates for the April 2002 analysis. Also, the Grasslands and Lignite gas processing plants, which were included in the April 2002 analysis, have been eliminated from the present

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[15]NDDH, 1990. Williston Basin Regional Air Quality Study. North Dakota Department of Health, Bismarck, ND 58506.

[16]EPA, 1995. SCREEN3 Model User's Guide. Publication No. EPA-454/B-95-004, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, 27711.

current-emissions inventory. These two facilities recently began injecting sour gas into the ground, and their air quality permits have been accordingly revised to reflect zero SO_2 emissions.

The complete current-emissions inventory for major sources, including all information required by Calpuff, is provided as Table 3-2. Current inventory information for the numerous oil and gas sources can be provided on computer media if requested. Source locations in Table 3-2, provided in Lambert coordinates, were obtained from NDDH permits. Stack base elevations were derived from USGS digital elevation models (DEM).

Table 3-1
Current Source Inventory

Source	Emission Characterization	Status		Figure 1-1 Loc. Key
		PSD/ Baseline	Inc. Consuming/ Expanding	
Antelope Valley Station	Average - Hrs Operation	PSD	Consuming	3
Coal Creek Station	Average - Hrs Operation	PSD	Consuming	2
Coyote Station	Average - Hrs Operation	PSD	Consuming	4
Colstrip Station (3&4)	Average - Hrs Operation	PSD	Consuming	8
CELP Boiler	Average - Hrs Operation	PSD	Consuming	9
Leland Olds Station	Average - Hrs Operation	Baseline	Consuming	5
Stanton Station	Average - Hrs Operation	Baseline	Consuming	5
Milton R. Young Station	Average - Hrs Operation	Baseline	Both	1
Heskett Station	Average - Hrs Operation	Baseline	Expanding	15
Mandan Refinery	Average - Hrs Operation	Baseline	Expanding	15
Tioga Gas Plant	Average - Hrs Operation	Baseline	Expanding	10
Oil & Gas Related*	Average - Days Operation	Both	Both	-

* All facilities located within 50 km of Class I areas.

3.1.2 Baseline Inventory

The baseline inventory includes sources that were operating at the time of the baseline date. Included are sources which no longer existed as of the time of the current inventory (2000/2001), or which had reduced emissions by 2000/2001, and therefore had the effect of expanding increment.

SO_2 emission rates for baseline sources were computed as total actual emissions for the baseline period, divided by actual hours of operation for the period. The baseline period reflects the two-year period prior to the western North Dakota minor-source baseline date (December 19, 1977), or a different period representative of "normal" operation, as determined by the NDDH.

For electrical generating stations, total emissions for the baseline period were calculated as a function of mine-average sulfur content, actual coal usage, and current emission factor. For natural gas processing plants, total emissions for the baseline period were taken from Annual Emission Inventory Reports, or calculated from raw gas volume and H_2S content. Actual hours of baseline period operation for both electrical generating stations and natural gas processing plants were obtained from Annual Emission Inventory Reports.

Baseline period emissions for well-site oil and gas production sources (treaters and flares) were derived from the State Industrial Commission (SIC) Oil and Gas data base information on gas production and H_2S content. Because the SIC had reservations about the quality and quantity of gas production data contained in the data base for the baseline period (1976-1977), the NDDH elected to extrapolate (in time) production data from the period of the "Williston Basin Regional Air Quality Study" (i.e., the period 1987-1988). According to SIC, this latter period represents the approximate earliest point in the chronology of the data base that consistent confidence can be placed in the completeness and reliability of the gas production data. Days of production were also extrapolated from this period.

Table 3-2
Calpuff Input Data for Current Source Inventory

```
Source       X          Y       Stack    Base      Stack    Exit  Exit     Bldg.  Emission
  No.    Coordinate Coordinate Height Elevation Diameter  Vel.  Temp.    Dwash   Rate
            (km)       (km)      (m)     (m)       (m)    (m/s) (deg. K)          (g/s)
 ------   ---------- ---------- ------  ------   -------- ----- -------- ----- --------

  1 ! SRCNAM = Antelope Valley Station 1 !
  1 ! X =    12.459,  374.908,   182.9,  588.3,     7.0,   19.0,  358.2,   0.,   200.4,  ! !END!
  2 ! SRCNAM = Antelope Valley Station 2 !
  2 ! X =    12.459,  374.908,   182.9,  588.3,     7.0,   19.1,  356.7,   0.,   188.5,  ! !END!
  3 ! SRCNAM = Coal Creek Station 1 !
  3 ! X =    63.487,  375.784,   201.0,  602.0,     6.7,   25.9,  358.5,   0.,   424.4,  ! !END!
  4 ! SRCNAM = Coal Creek Station 2 !
  4 ! X =    63.487,  375.784,   201.0,  602.0,     6.7,   24.9,  354.5,   0.,   374.6,  ! !END!
  5 ! SRCNAM = Coyote Station !
  5 ! X =    13.513,  357.842,   152.0,  556.9,     6.4,   25.4,  370.7,   0.,   498.4,  ! !END!
  6 ! SRCNAM = Grasslands Gas Plant !
  6          Deleted - zero emissions
  7 ! SRCNAM = Colstrip Station 3 !
  7 ! X =  -357.648,  220.211,   210.9,  988.7,     7.3,   26.9,  361.3,   0.,    93.6,  ! !END!
  8 ! SRCNAM = Colstrip Station 4 !
  8 ! X =  -357.648,  220.211,   210.9,  988.7,     7.3,   27.6,  362.7,   0.,    90.6,  ! !END!
  9 ! SRCNAM = CELP Boiler !
  9 ! X =  -359.424,  230.411,    61.0,  945.1,     2.5,   22.6,  433.2,   0.,    52.9,  ! !END!
 10 ! SRCNAM = Leland Olds Station 1 !
 10 ! X =    51.326,  365.208,   106.7,  518.3,     5.3,   19.7,  450.0,   0.,   526.6,  ! !END!
 11 ! SRCNAM = Leland Olds Station 2 !
 11 ! X =    51.326,  365.208,   152.4,  518.3,     6.7,   25.0,  448.6,   0.,  1079.3,  ! !END!
 12 ! SRCNAM = Stanton Station !
 12 ! X =    50.407,  365.773,    77.7,  518.3,     4.6,   19.9,  411.1,   0.,   301.1,  ! !END!
 13 ! SRCNAM = Milton R Young Station 1 !
 13 ! X =    59.519,  341.409,    91.4,  597.4,     5.8,   18.5,  449.1,   0.,   650.3,  ! !END!
 14 ! SRCNAM = Milton R Young Station 2 !
 14 ! X =    59.519,  341.409,   167.6,  597.4,     7.6,   19.2,  361.8,   0.,   548.5,  ! !END!
 15 ! SRCNAM = Heskett Station 1 !
 15 ! X =    84.794,  319.565,   91.44,  514.8,     2.2,  20.67,  461.7,   0.,    31.1,  ! !END!
 16 ! SRCNAM = Heskett Station 2 !
 16 ! X =    84.794,  319.565,   91.44,  514.8,    3.65,  17.37,  419.7,   0.,    77.2,  ! !END!
 17 ! SRCNAM = Mandan Refinery - Boilers !
 17 ! X =    85.215,  317.679,    31.8,  518.3,     1.7,   12.5,  424.7,   0.,    17.8,  ! !END!
 18 ! SRCNAM = MR - FCU/CO !
 18 ! X =    85.215,  317.679,    60.7,  518.3,     3.4,    9.9,  547.0,   0.,   133.2,  ! !END!
 19 ! SRCNAM = MR - Alky Furnace !
 19 ! X =    85.215,  317.679,    53.0,  518.3,     2.0,    6.1,  447.0,   0.,     0.9,  ! !END!
 20 ! SRCNAM = MR - Ultra Furnace !
 20 ! X =    85.215,  317.679,    29.1,  518.3,     1.3,    5.9,  530.8,   0.,     1.9,  ! !END!
 21 ! SRCNAM = MR - SRU !
 21 ! X =    85.215,  317.679,    60.8,  518.3,     0.6,    5.7,  589.0,   0.,     5.3,  ! !END!
 22 ! SRCNAM = Lignite Gas Plant !
 22          Deleted - zero emissions
 23 ! SRCNAM = Tioga Gas Plant !
 23 ! X =   -67.762,  489.627,    50.3,  686.0,    0.91,    7.7,  782.0,   0.,    37.3,  ! !END!
```

Table 3-3
Baseline Source Inventory

Source	Inc. Consuming/Expanding	Figure 1-1 Loc. Key
Leland Olds Station	Consuming	5
Stanton Station	Consuming	5
Milton R. Young Station	Consuming	1
Heskett Station	Expanding	15
Mandan Refinery	Expanding	15
Lignite Gas Plant	Expanding	16
Tioga Gas Plant	Expanding	10
Beulah Station (shut down)	Expanding	13
Neal Station (shut down)	Expanding	11
Flying J Refinery (shut down)	Expanding	12
Royal Oak Briquetting (shut down)	Expanding	14
Oil & Gas Related *	Both	-

* All facilities located within 50 km of Class I areas.

Table 3-4
Calpuff Input Data for Baseline Source Inventory

```
Source       X          Y       Stack     Base      Stack     Exit  Exit     Bldg.  Emission
 No.     Coordinate Coordinate Height Elevation Diameter  Vel.  Temp.    Dwash   Rate
            (km)       (km)      (m)      (m)       (m)    (m/s) (deg. K)          (g/s)
------   ---------- ---------- ------  ------   -------- ----- -------- ----- --------

 1 ! SRCNAM = Leland Olds Station 1 !
 1 ! X =    51.326,  365.208,   106.7,  518.3,     5.3,   19.7,  450.0,   0.,   502.8,  ! !END!
 2 ! SRCNAM = Leland Olds Station 2 !
 2 ! X =    51.326,  365.208,   152.4,  518.3,     6.7,   25.0,  448.6,   0.,  1021.4,  ! !END!
 3 ! SRCNAM = Stanton Station !
 3 ! X =    50.407,  365.773,    77.7,  518.3,     4.6,   19.9,  411.1,   0.,   313.4,  ! !END!
 4 ! SRCNAM = Milton R Young Station 1 !
 4 ! X =    59.519,  341.409,    91.4,  597.4,     5.8,   18.5,  449.1,   0.,   624.9,  ! !END!
 5 ! SRCNAM = Milton R Young Station 2 !
 5 ! X =    59.519,  341.409,   167.6,  597.4,     7.6,   19.2,  361.8,   0.,   618.1,  ! !END!
 6 ! SRCNAM = Heskett Station 1 !
 6 ! X =    84.794,  319.565,   91.44,  514.8,     2.2,  20.67,  461.7,   0.,    58.7,  ! !END!
 7 ! SRCNAM = Heskett Station 2 !
 7 ! X =    84.794,  319.565,   91.44,  514.8,    3.65,  17.37,  419.7,   0.,   137.0,  ! !END!
 8 ! SRCNAM = Mandan Refinery - Boilers !
 8 ! X =    85.215,  317.679,    31.8,  518.3,     1.7,   12.5,  424.7,   0.,    78.4,  ! !END!
 9 ! SRCNAM = MR - FCU/CO !
 9 ! X =    85.215,  317.679,    60.7,  518.3,     3.4,    9.9,  547.0,   0.,   212.4,  ! !END!
10 ! SRCNAM = MR - Alky Furnace !
10 ! X =    85.215,  317.679,    53.0,  518.3,     2.0,    6.1,  447.0,   0.,    20.2,  ! !END!
11 ! SRCNAM = MR - Ultra Furnace !
11 ! X =    85.215,  317.679,    29.1,  518.3,     1.3,    5.9,  530.8,   0.,     1.9,  ! !END!
12 ! SRCNAM = Lignite Gas Plant !
12 ! X =   -38.885,  541.932,    38.1,  598.0,     0.4,   19.9,  893.0,   0.,    36.0,  ! !END!
13 ! SRCNAM = Tioga Gas Plant !
13 ! X =   -67.762,  489.627,    30.5,  686.0,     1.7,    7.7,  782.0,   0.,   135.3,  ! !END!
14 ! SRCNAM = Beulah Station 1+2 !
14 ! X =    17.404,  362.995,    23.0,  567.0,     1.7,   7.6,    477.0,   0.,   17.27,  ! !END!
15 ! SRCNAM = Beulah Station 3-5 !
15 ! X =    17.404,  362.995,    30.5,  567.0,     2.1,  14.6,    527.0,   0.,   28.29,  ! !END!
16 ! SRCNAM = Neal Station 1+2 !
16 ! X =    82.646,  447.977,    42.4,  488.0,     1.8,  25.0,    470.0,   0.,    44.7,  ! !END!
17 ! SRCNAM = Flying J Refin - Heaters + Boiler 2 !
17 ! X =  -117.411,  462.238,    17.3,  575.0,     0.9,   3.2,    700.0,   0.,    3.19,  ! !END!
18 ! SRCNAM = Flying J Refin - Boiler 1 !
18 ! X =  -117.411,  462.238,    30.2,  575.0,     1.2,   3.4,    464.0,   0.,    1.32,  ! !END!
19 ! SRCNAM = Flying J Refin - Boiler 3 !
19 ! X =  -117.411,  462.238,     9.1,  575.0,     0.8,   6.3,    464.0,   0.,    1.89,  ! !END!
20 ! SRCNAM = Royal Oak - Boilers 1-3 !
20 ! X =   -53.232,  318.050,    19.2,  751.0,     1.4,   9.8,    520.0,   0.,    21.7,  ! !END!
21 ! SRCNAM = Royal Oak - ACC !
21 ! X =   -53.232,  318.050,    26.2,  751.0,    3.35,  9.35,   1172.0,   0.,   200.5,  ! !END!
```

Through the NDDH's work with the SIC, the agencies did find a block of data that was of exceptional quality. This block of data was for the Little Knife oil field and was for the period surrounding the baseline period. For that reason, this data set was used to supplement the Williston Basin study.

A complete description of the NDDH methodology for determining baseline emission rates is contained in "Prevention of Significant Deterioration Sulfur Dioxide Baseline Emission Rates."[17] The extrapolation of oil and gas data from the Williston Basin Study is also discussed.

For electrical generating stations and natural gas processing plants, dynamic stack operating parameters for the baseline inventory were derived from stack test reports. Stack height and diameter were taken from NDDH records/permits. For oil and gas sources, dynamic stack parameters (as well as stack diameter) were derived from calculated heat of combustion, as described in Section 3.1.1. Typical values were assumed for flare and treater stack height (i.e., 5 feet and 22 feet, respectively).

The status of each baseline-inventory source is summarized in Table 3-3. The complete baseline-emission inventory for non oil and gas sources, including all data required by Calpuff, is provided as Table 3-4. Baseline inventory information for oil and gas sources can be provided on computer media, if requested. Source locations in Table 3-4, based on Lambert coordinates, were obtained from NDDH permits. Stack base elevations were derived from USGS digital elevation models (DEM).

Changes in emission rates for generating stations are noted in the present analysis baseline emission inventory when compared to the inventory assumed for the NDDH April 2002 analysis. These changes are a result of revised emission factors, which are discussed in the NDDH report on baseline emission rates[17].

[17] NDDH, 2003. Prevention of Significant Deterioration Sulfur Dioxide Baseline Emission Rates. North Dakota Department of Health, Bismarck, ND 58506

The baseline inventory for oil and gas production sources has also been revised for the present analysis. To supplement the extrapolated data from the Williston Basin Study, the NDDH obtained actual baseline period (1976-77) production data from SIC for wells in the Little Knife field. This is significant because Little Knife is the largest field (by emissions) in the baseline oil and gas inventory. The introduction of actual Little Knife baseline data is discussed in the NDDH report on baseline emission rates[17]. Despite SIC concerns regarding the general quality of gas production data prior to 1987-1988, it considers the Little Knife field data for 1976-1977 reliable.

3.2 Ozone Data

Calpuff requires background ozone values. The NDDH elected to utilize the option of providing an input file of concurrent hourly ozone values, rather than assume the constant default value in Calpuff. Hourly ozone data for 1990-1994 were obtained from a NDDH monitoring site located about 140 km east of TRNP Elkhorn Ranch Unit. This places the site within the corridor of primary plume transport between major generating stations and Theodore Roosevelt National Park.

Year 2000 hourly ozone data were obtained from four NDDH monitoring sites located within the primary plume transport corridor. These monitoring sites are located at Hannover, Beulah, Dunn Center, and TRNP South Unit. Software was prepared to merge and format the 2000 ozone data into the single input file required by Calpuff.

3.3 Receptor Locations

Receptor locations for the present analysis have been updated compared to those used in previous NDDH Class I area analyses. Resolution has been improved with the introduction of uniformly spaced 2 km receptor grids at TRNP South Unit, TRNP North Unit, and Lostwood Wilderness Area.

Updated locations for the Class I Calpuff analysis are shown in Figures 3-1 and 3-2. Figure 3-1 identifies receptor locations for North Dakota Class I areas and Figure 3-2 depicts receptor locations for Montana Class I areas. Numbers in the figures correspond to the receptor numbering convention employed in Calpuff input/output files. Receptor coverage includes 46 receptors (Nos. 1-46) at TRNP South Unit, 25 receptors (Nos. 47-71) at TRNP North Unit, 1 receptor (No. 72) at TRNP Elkhorn Ranch Unit, 9 receptors (Nos. 73-81) at Lostwood Wilderness Area, 1 receptor (No. 82) at Medicine Lake Wilderness Area, and 4 receptors (Nos. 83-86) at Fort Peck Reservation.

Receptor coverage for Medicine Lake and Fort Peck Class I areas was limited because they are relatively distant from largest-contributing sources (concentration gradients not significant), and the local minor-source contribution could not be accounted for (Section 3.1). Most of Fort Peck is located more than 300 km from major North Dakota sources.

3.4 Calpuff Control File Settings

Calpuff control file settings for the NDDH Class I increment analysis were generally consistent with IWAQM guidance. However, the adjustment of a limited number of settings was found to provide better agreement with monitored observations based on a Calmet/Calpuff performance evaluation conducted by NDDH (Appendix B), and such changes were judged to be scientifically viable.

IWAQM recommendations for Calpuff control file settings fall into two categories. Group A (NDDH terminology) includes those variables where IWAQM provides a default value as a general recommendation for all analyses. Group B includes those variables where IWAQM recognizes the value will need to be tailored for a given application, and default values are therefore not provided.

The Group B settings utilized by NDDH are listed in Table 3-5. These settings are straightforward, involving variables related to defining the meteorological and computational grids, and the use of default values for dry and wet deposition parameterization. Note that the computational grid utilized by Calpuff can be designated a subset of the meteorological grid produced by Calmet. But as shown in Table 3-5, NDDH set the computational grid equivalent to the full meteorological grid.

Figure 3-1: Receptor Locations - North Dakota Class I Areas

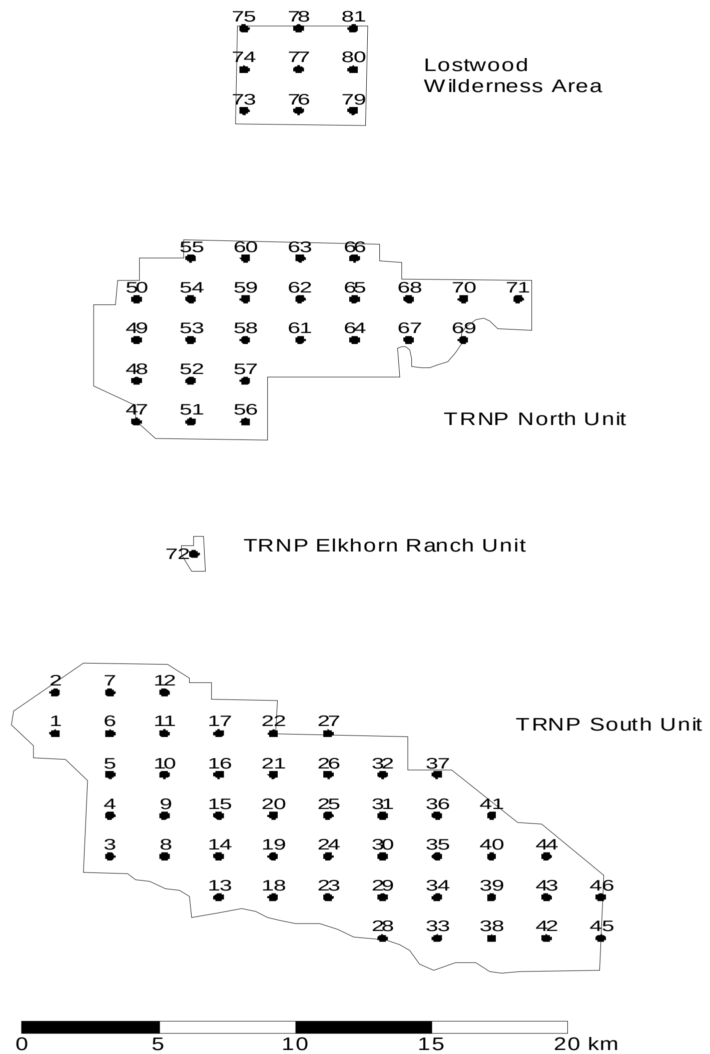
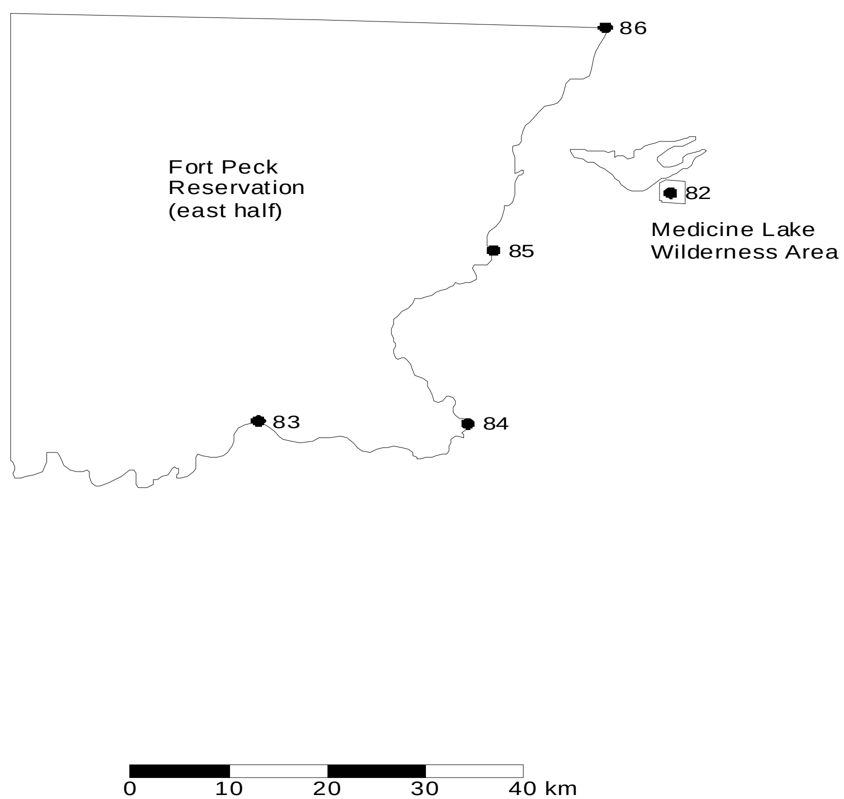


Figure 3-2: Receptor Locations - Montana Class I Areas



NDDH settings for Calpuff Group A variables were largely consistent with IWAQM recommendations, but included adjustments to a limited number of variables based on the model performance evaluation. As discussed in Section 2.5, the performance evaluation was based on a comparison of observations and predictions at two monitoring sites, and proceeded in an iterative manner to determine the effect of adjustments to control file settings on model skill. The NDDH performance evaluation is described in Appendix B.

As a result of the performance evaluation, the NDDH chose to modify a limited number of IWAQM Group A control file settings. Non-IWAQM settings utilized by the NDDH for the Calpuff control file, and which provided optimum agreement with monitored observations, are shown in Table 3-6. These non-IWAQM Group A settings are discussed below.

MSPLIT - The option for puff splitting was recommended by John Irwin (EPA) when modeling source-receptor distances of 200 km or more, because of the tendency for Calpuff to otherwise overpredict at these distances. Deployment of this option also provided better agreement with observations.

MDISP - Use of dispersion coefficient option 2 provided significantly better agreement with observations. The NDDH also believes this selection is more consistent with the “state-of-the-art” in air quality modeling.

BCKO3 - Though the NDDH utilized the hourly file option for ozone background, the BCKO3 value is substituted by Calpuff when hourly data are missing. Based on local monitoring data, NDDH judged the IWAQM value of 80 ppb to be much higher than typical for North Dakota, and therefore reset the value to 30 ppb.

BCKNH3 - The NDDH value of 2 ppb reflects the annual average of local, unbiased monitoring data.

XSAMLEN - The NDDH set this value lower than the IWAQM recommendation, but notes that the only consequence for doing so would be extra computer time due to more puffs on the grid.

The goal was to improve model resolution by increasing the number of puffs and decreasing mass per puff. Again, because this parameter is a function of grid cell size, the NDDH believes IWAQM should not be providing a default value.
XMAXZI - Value was increased to 4000 m for consistency with ZIMAX/ZIMAXW setting in Calmet.

The complete list of IWAQM-recommended settings for the Calpuff control file is included as Appendix D.

4. **Calpuff Application and Results**

4.1 Calpuff Application

Calpuff was executed using meteorological data processed as described in Section 2, and the emission inventories and other input data discussed in Section 3. The model was applied to the current (Year 2000/2001) source inventory (Table 3-2), and then to the baseline source inventory (Table 3-4).

40 C.F.R. § 51.166(a)(4) requires States to review the adequacy of its State Implementation Plan to Prevent Significant Deterioration of air quality "on a periodic basis" and within 60 days of "such time that information becomes available that an applicable increment is being violated." This proceeding and the NDDH's modeling are for the purpose of determining, based on monitoring, emissions trends data and modeling, whether there is a reasonable basis for determining that there has been an exceedance of the increments or significant deterioration requiring action under this section.

When *Alabama Power Co. v. Costle,* 636 F.2d 323, 362 (D.C. Cir. 1980) determined that "enforcement measures beyond preconstruction review" were contemplated under the PSD program, it noted that:

> "EPA assured the court that any such measures ["the relatively severe correctives of a rollback in operations or the application of retrofit air pollution control technology"] would be employed in a reasonable fashion on the basis of a rule of general applicability, or by some reasonable attribution of responsibility for the violation. Any regulations promulgated will be reviewed with such considerations in mind."

Id. at 363.

After 23 years, EPA still has not promulgated any rules or regulations to govern PSD programs outside of preconstruction review. Thus, this is a proceeding for which EPA has adopted no rules or guidelines, for which there is no precedence, and

> for which there are not any prior proceedings conducted in any other Federal or State jurisdiction to which the NDDH can look for guidance. Lacking any such rules or guidance, North Dakota has developed a reasonable method for making the determination required by 40 C.F.R. 51.166, based on the applicable laws and regulations, and consistent with the decisions of the courts.

The purpose of periodic review is to determine whether there has been a significant deterioration of air quality or violation of an increment based on actual conditions and plant operation. 40 C.F.R. § 51.166(a). In contrast to preconstruction review, which deals with worst-case scenarios for a plant or facility that has not yet been built, periodic review looks at actual emissions and actual operations to determine whether the increments are actually being violated. All previous PSD modeling conducted by the NDDH has been done as part of the preconstruction review, not periodic review. The closest analogy under the Clean Air Act is the preconstruction modeling conducted by facilities to determine NAAQS compliance. Again, as the Court noted in *Alabama Power Co. v. Costle,* “the starting point for determining the baseline in a particular clean air region is the existing ambient pollution level in that area at the time of the first application for a permit by a major emitting facility” [footnotes omitted.] Id. at 374.

Congress defined “baseline concentration” as “the *ambient concentration levels* which exist at the time of the first application for a permit in an area subject to this part, based on air quality data available in the Environmental Protection Agency or a State Air Pollution Control Agency and on such monitoring data as the permit applicant is required to submit.” 42 U.S.C. § 7479(4). (Italics provided.)

EPA’s approach for determining air quality deterioration and PSD increment consumption does not determine the baseline concentration or the ambient concentration levels. Instead the Calpuff (hourly) results for the baseline source inventory are subtracted from the results for the current source inventory (hour-by-hour and receptor-by-receptor), and the difference is compared to Class I increments (i.e., 25µg/m^3 for the 3-hour and 5µg/m^3 for the 24-hour average). This was the approach that EPA initially proposed in its 1978 regulations, in which no "baseline concentration" was "formally established." 43 Fed. Reg. 26380, 26400 (June 19, 1978). This approach, however, was rejected in *Alabama Power*. Rather, *Alabama Power* determined that Congress expected EPA and the states "to develop and utilize the most accurate and feasible modeling techniques available," 636 F.2d at 387, and "to use actual air quality data to establish the baseline" which is defined "in terms of existing ambient concentration levels" on the minor source baseline data. Id. at 372. In addition, "Congress intended that monitoring would impose a certain discipline on the use of modeling techniques," through "the development of sophisticated monitoring techniques" by which modeling techniques would be "held to earth by a continual process of confirmation and reassessment, a process that enhances confidence in modeling, as a means for realistic projection of air quality." Id. at 372.

The NDDH has employed an alternative approach for baseline concentration and increment consumption in these proceedings that is consistent with 42 U.S.C.§ 7479(4), the language of *Alabama Power* relating to modeling and monitoring, and the regulations and manual EPA adopted immediately after *Alabama Power* was decided. These regulations redefined how the "baseline concentration" was to be established by the state. 45 Red. Reg. 52675, 52714-715 (August 7, 1980). It also describes how "Increment Consumption" is to be determined through "Use of Actual Emissions." Id. at 52717-719. The manual EPA finalized at that time demonstrates in more detail how this process works. In establishing the emissions inventories, the manual provides:

> At a minimum, the data should be presented in a summary format showing highest and highest, second highest concentrations for pollutants with short-term standards and the appropriate long-term average associated with each standard. These concentrations effectively describe the existing ambient concentrations within the impact area attributable to actual emissions from existing sources.
>
> In many cases, monitoring data may require adjustment to compensate for new emissions permitted in the impact area but

not occurring during the monitoring period. The emissions inventory used for adjusting the monitoring data should be gathered as previously described and should be used to adjust the monitoring data by proper dispersion modeling procedures.

EPA *Prevention of Significant Deterioration Workshop Manual 1* at I-C-23 (October 1980). How these short-term baseline concentrations are used to determine whether there is an increment violation is illustrated in Table C-4, in which the short-term "total possible air quality" is the highest or maximum ambient concentration allowed after the increment is added to the "existing air quality" or baseline concentration to determine whether the maximum allowable ambient concentration is exceeded (i.e., the short-term 3-hour or 24-hour "baseline concentration" plus the relevant 3-hour or 24-hour increment). Id. at I-C-34[18]

The NDDH's approach follows the provisions of 42 U.S.C.§ 7479(4), *Alabama Power,* 636 F.2d at 372, 387, and the 1980 *Prevention of Significant Deterioration Workshop Manual.* It involves determining the baseline concentration for the Class I area by modeling emissions from all the sources that operated during the baseline at normal operation, adding the PSD allowable increment (i.e., 25µg/m^3 for he 3-hour and 5µg/m^3 for the 24-hour average) to the baseline concentration to establish an exceedance threshold known as the Maximum Allowable Ambient Level. Once the MAAL is established, the current source emissions are modeled to determine the current concentration. The current concentration is then compared to the MAAL to determine if any exceedances of the threshold occur. One exceedance of the threshold is allowed. A second exceedance would constitute a violation.

---

[18]EPA's 1990 New Source Review Manual (draft October 1990) has never been finalized like the 1980 manual, and further, its approach is inconsistent with both the language of *Alabama Power* cited above and the definition of "baseline concentration" at 42 U.S.C. 7479(4), which measures deterioration of air quality from "ambient concentration levels" as established in a manner described in the quoted language above from the 1980 *Prevention of Significant Deterioration Workshop Manual*.

The NDDH approach was implemented as follows:

1) Calpuff was applied for the current (Year 2000/2001) source inventory (Table 3-2), and then for the baseline source inventory (Table 3-4). Calpuff was applied separately for each year of meteorological data (1990-94, 2000).
2) Receptor averaging was performed using the Calavg software program developed by NDDH. Calavg was applied to the Calpuff (hourly) output for the baseline-inventory sources, and then to the Calpuff output for the current-inventory sources. All receptors identified in Figures 3-1 and 3-2 were included in the averaging procedure.
3) Calpost (Earth Tech) was applied to the averaged baseline file and then to the averaged current file to provide summary results for 3-hour and 24-hour averages. Calpost provided the high and the second-high prediction (3-hour and 24-hour) for each Class I area.
4) The baseline concentration is determined by using the results from Step 3. The second-high baseline prediction from the averaged baseline file is the baseline concentration. The applicable PSD increment is then added to the baseline concentration to determine the MAAL for each PSD averaging period. MAAL's were determined independently for each year and for each Class I area.
5) The final step compares the second-high prediction for the current source inventory to the applicable MAAL. A violation of the PSD increment occurs if more than one exceedance of the MAAL is predicted.

The MAAL approach is illustrated in Figures 4-1 and 4-2. This illustration indicates application of the procedure to one Class I area for 24-hour averages and one year of meteorological data.

Figure 4-1: Illustration of MAAL Determination for TRNP South Unit

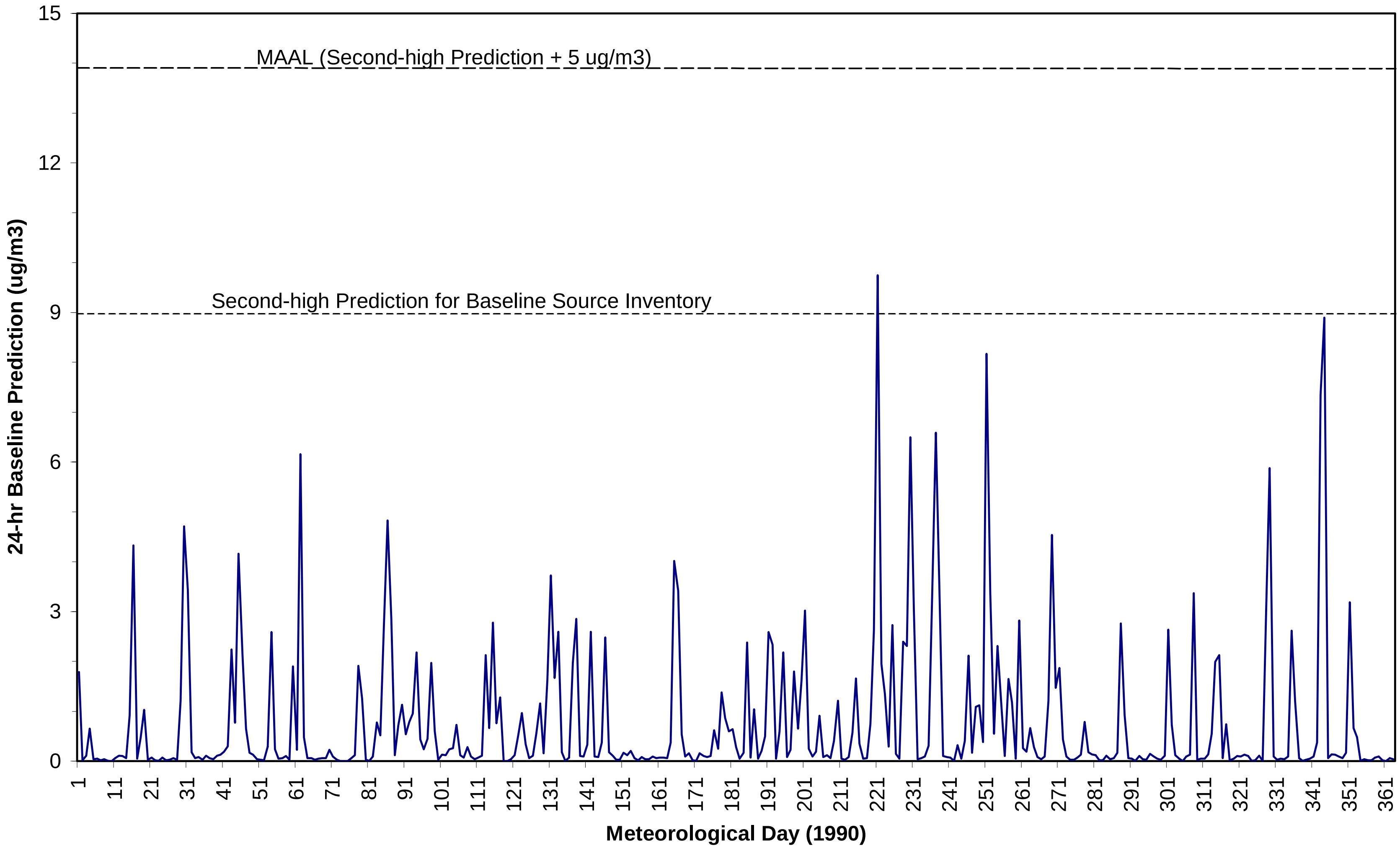
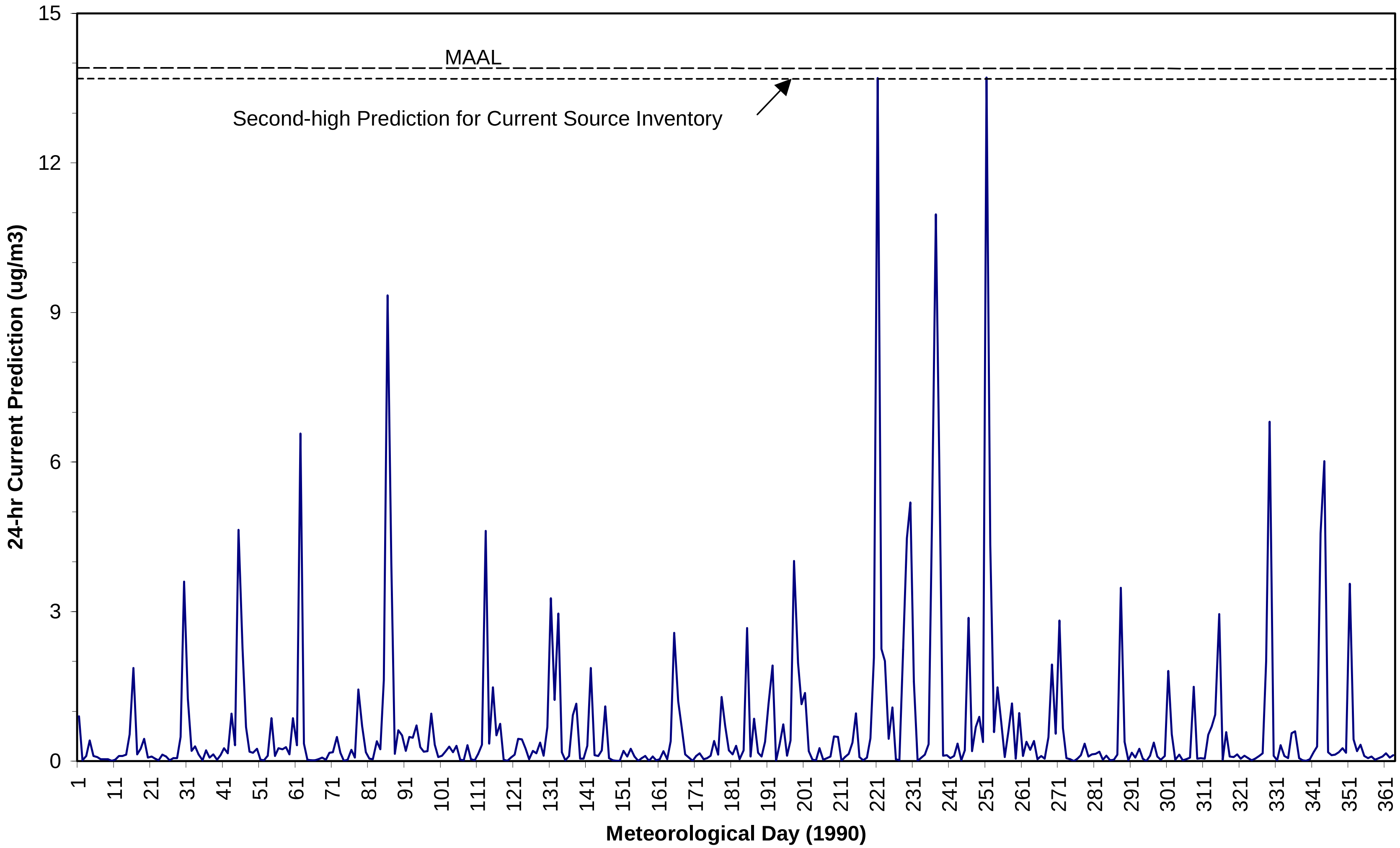


Figure 4-2: Illustration of MAAL Compliance for TRNP South Unit



Determination of the MAAL is illustrated in Figure 4-1. Block 24-hour baseline period predictions are plotted as a function of time for 1990 meteorological data. The second-high prediction of 8.9μg/m^3 is represented by the lower dashed line in the Figure. This second-high prediction is considered the baseline concentration. Upon adding the allowable 24-hour increment of 5μg/m^3 to the second-high prediction the MAAL of 13.9 μg/m^3 is obtained which is represented by the dashed line in the Figure.

Compliance with the MAAL is illustrated in Figure 4-2. Block 24-hour current-inventory predictions are plotted as a function of time for 1990 meteorological data. The previously determined MAAL (13.9μg/m^3) is also represented in Figure 4-2. The second-high prediction of 13.7μg/m^3, represented by the lower dashed line, is less than the MAAL and therefore demonstrates compliance.

In summary, the MAAL does not represent a new air quality standard. It simply measures increment consumption in terms of the “ambient concentration levels” as defined by Congress. EPA’s approach fails to do this and, therefore, fails to measure whether the “ambient concentration levels” are actually better or worse than “baseline concentration” levels.

4.2 Results

Results of the Calpuff SO_2 modeling analysis for Class I increment consumption in North Dakota and Eastern Montana Class I areas are summarized in Tables 4-1 through 4-6. A separate table is provided for each Class I area. The tables identify the modeled baseline concentration for each meteorological year, the PSD allowable increment, the determination of the MAAL, the second-high modeled current prediction and the number of predicted exceedances. It is noted that one exceedance per year is allowed and although a single exceedance did occur in some areas, a second exceedance did not occur and thus, no violations were predicted.

Table 4-1
Calpuff I Increment Results for SO_2
TRNP South Unit
($\mu g/m^3$)

	1990	1991	1992	1993	1994	2000
<u>3-hr Average</u>						
Baseline Concentration	24.3	23.2	23.6	23.5	20.8	26.0
PSD Class I Area Increment	25.0	25.0	25.0	25.0	25.0	25.0
Baseline Concentration + Increment (MAAL)	49.3	48.2	48.6	48.5	45.8	51.0
2nd High Current Prediction	34.4	22.9	23.3	25.9	31.5	39.6
No. of Exceedances of MAAL	1	0	0	0	0	1
<u>24-hour Average</u>						
Baseline Concentration	10.2	9.2	7.4	8.9	7.6	10.4
PSD Class I Area Increment	5.0	5.0	5.0	5.0	5.0	5.0
Baseline Concentration + Increment (MAAL)	15.2	14.2	12.4	13.9	12.6	15.4
2nd High Current Prediction	11.7	11.0	8.6	7.7	9.3	12.9
No. of Exceedances of MAAL	1	1	0	0	0	0

Table 4-2
Calpuff Class I Increment Results for SO_2
TRNP North Unit
($\mu g/m^3$)

	1990	1991	1992	1993	1994	2000
<u>3-hr Average</u>						
Baseline Concentration	44.7	59.3	74.6	69.7	77.0	91.7
PSD Class I Area Increment	25.0	25.0	25.0	25.0	25.0	25.0
Baseline Concentration + Increment (MAAL)	69.7	84.3	99.6	94.7	102.0	116.7
2nd High Current Prediction	26.7	30.0	36.6	26.7	22.2	29.1
No. of Exceedances of MAAL	0	0	0	0	0	0

24-hour Average						
Baseline Concentration	23.9	23.6	20.5	23.5	24.9	25.2
PSD Class I Area Increment	5.0	5.0	5.0	5.0	5.0	5.0
Baseline Concentration + Plus Increment (MAAL)	28.9	28.6	25.5	28.5	29.9	30.2
2nd High Current Prediction	9.5	14.2	15.9	11.0	9.0	12.7
No. of Exceedances of MAAL	0	0	0	0	0	0

Table 4-3

Calpuff Class I Increment Results for SO_2

TRNP Elkhorn Ranch Unit

(μg/m³)

	1990	1991	1992	1993	1994	2000
3-hr Average						
Baseline Concentration	78.6	63.8	54.2	60.4	69.7	101.3
PSD Class I Area Increment	25.0	25.0	25.0	25.0	25.0	25.0
Baseline Concentration + Increment	103.6	88.8	79.2	85.4	94.7	126.3
2nd High Current Prediction	20.1	31.0	23.6	36.6	26.1	46.7
No. of Exceedances of MAAL	0	0	0	0	0	0
24-hour Average						
Baseline Concentration	15.6	22.4	20.8	20.6	23.3	25.3
PSD Class I Area Increment	5.0	5.0	5.0	5.0	5.0	5.0
Baseline Concentration + Increment (MAAL)	20.6	27.4	25.8	25.6	28.3	30.3
2nd High Current Prediction	7.3	13.2	7.0	10.4	11.0	16.5
No. of Exceedances of MAAL	0	0	0	0	0	0

Table 4-4

Calpuff Class I Increment Results for SO_2

Lostwood Wilderness Area

(μg/m³)

	1990	1991	1992	1993	1994	2000

3-hr Average						
Baseline Concentration	24.2	28.8	24.1	25.5	28.8	29.2
PSD Class I Area Increment	25.0	25.0	25.0	25.0	25.0	25.0
Baseline Concentration + Increment	49.2	53.8	49.1	50.5	53.8	54.2
2nd High Current Prediction	27.0	32.8	23.4	23.6	37.3	40.1
No. of Exceedances of MAAL	0	0	0	0	0	0
24-hour Average						
Baseline Concentration	10.2	9.7	9.2	10.6	9.6	13.2
PSD Class I Area Increment	5.0	5.0	5.0	5.0	5.0	5.0
Baseline Concentration + Plus Increment (MAAL)	15.2	14.7	14.2	15.6	14.6	18.2
2nd High Current Prediction	11.5	12.2	9.8	10.4	9.9	12.3
No. of Exceedances of MAAL	0	1	0	0	0	1

Table 4-5
Calpuff Class I Increment Results for SO_2
Medicine Lake Wilderness Area
(μg/m³)

	1990	1991	1992	1993	1994	2000
3-hr Average						
Baseline Concentration	16.1	12.2	18.4	17.9	11.4	15.6
PSD Class I Area Increment	25.0	25.0	25.0	25.0	25.0	25.0
Baseline Concentration + Increment	41.1	37.2	43.4	42.9	36.4	40.6
2nd High Current Prediction	18.9	17.4	21.6	24.9	16.7	22.8
No. of Exceedances of MAAL	0	0	0	0	0	0
24-hour Average						
Baseline Concentration	5.4	4.4	5.3	6.4	5.3	6.7
PSD Class I Area Increment	5.0	5.0	5.0	5.0	5.0	5.0
Baseline Concentration + Increment (MAAL)	10.4	9.4	10.3	11.4	10.3	11.7
2nd High Current Prediction	5.6	5.4	7.1	8.2	6.4	9.1
No. of Exceedances of MAAL	0	0	1	0	0	0

Table 4-6
Calpuff Class I Increment Results for SO_2
Fort Peck Reservation
(μg/m³)

	1990	1991	1992	1993	1994	2000
3-hr Average						
Baseline Concentration	14.0	9.0	17.2	10.2	9.5	15.1
PSD Class I Area Increment	25.0	25.0	25.0	25.0	25.0	25.0
Baseline Concentration + Increment	39.0	34.0	42.2	35.3	34.5	40.1
2nd High Current Prediction	15.3	11.7	23.5	14.2	13.7	20.3
No. of Exceedances of MAAL	0	0	0	0	0	0
24-hour Average						
Baseline Concentration	4.2	3.7	5.1	3.9	4.0	6.1
PSD Class I Area Increment	5.0	5.0	5.0	5.0	5.0	5.0
Baseline Concentration + Plus Increment (MAAL)	9.2	8.7	10.1	8.9	9.0	11.1
2nd High Current Prediction	4.9	4.7	6.5	4.7	5.7	8.6
No. of Exceedances of MAAL	0	0	1	0	0	0

Appendix A
Calmet Code Changes

To defeat vertical extrapolation in Step 2 wind field development (while leaving in for initial guess), the following section of Calmet (Version 5.0, Level 970825) Subroutine DIAGNO was changed from:

```
    52 IF(ICALC.LT.0)  GO TO 850
C
C      EXTRAPOLATE SURFACE WINDS
C      EXTRAPOLATION OPTIONS:
C        1) IF IABS(IEXTRP)=1, THEN DO NOT EXTRAPOLATE FROM SURFACE DATA
C        2) IF IABS(IEXTRP)=2, THEN USE POWER LAW
C        3) IF IABS(IEXTRP)=3, THEN USE FEXTRP MULTIPLIER
C        4) IF       IEXTRP=4, THEN USE SIMILARITY THEORY
C        5) IF IEXTRP<=0, THEN DO NOT USE LEVEL 1 DATA FROM UA WINDS
C
      IF(IABS(IEXTRP).EQ.1) GO TO 91
```

to:

```
    52 IF(ICALC.LT.0)  GO TO 850
C
C      EXTRAPOLATE SURFACE WINDS
C      EXTRAPOLATION OPTIONS:
C        1) IF IABS(IEXTRP)=1, THEN DO NOT EXTRAPOLATE FROM SURFACE DATA
C        2) IF IABS(IEXTRP)=2, THEN USE POWER LAW
C        3) IF IABS(IEXTRP)=3, THEN USE FEXTRP MULTIPLIER
C        4) IF       IEXTRP=4, THEN USE SIMILARITY THEORY
C        5) IF IEXTRP<=0, THEN DO NOT USE LEVEL 1 DATA FROM UA WINDS
C
      go to 91
```

Appendix B
Calpuff Performance Evaluation

Evaluation of

Calpuff Model Performance

Using Year 2000 Data

May 2003

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

Introduction

Performance of the Calpuff model (Version 5.4, Level 000602_1), as implemented by the North Dakota Department of Health (NDDH) for Year 2000 data, was evaluated using SO_2 observations from the NDDH Dunn Center and Theodore Roosevelt National Park (TRNP) South Unit monitoring sites. Meteorological input data for Calpuff were developed using the Calmet meteorological model (Version 5.2, Level 000602a). Source emission rates were based on CEM's hourly data (where available) or annual average emission for Year 2000.

This performance evaluation (dated May 2003) reflects changes to the NDDH modeling methodology as described in "Calpuff Analysis of Current PSD Class I Increment Consumption in North Dakota and Eastern Montana Using Actual Annual Average SO_2 Emission Rates," May 2003. These changes include improvements in meteorological grid resolution (grid cell size reduced to 5 km, number of vertical layers increased to 12), and adjustments to a limited number of Calmet technical options (Terrad, R1, R2, IKINE, and RMIN2). A single Calpuff receptor was included for each monitoring site.

Results of the performance evaluation yielded very good agreement between predictions and observations. All of the predicted/observed ratios fell within the factor-of-two criteria suggested by EPA.

Source Inventory

The evaluation analysis accounted for all SO_2 sources located within a reasonable distance of the two monitoring sites, and which operated during Year 2000. The inventory included all significant SO_2 sources within 250 km of the sites. Oil and gas production sources (i.e., treaters and flares) were also included. But because of their greater number and smaller size, the modeled inventory of oil and gas sources was limited to those located within 50 km of each monitoring site.

SO_2 sources included in the evaluation analysis are identified in Table 1. Source locations with respect to monitoring sites are depicted in Figure 1 (oil and gas source locations not shown).

SO_2 emission rates and stack operating parameters (i.e., exit velocity and temperature) were based on CEM's hourly data for Year 2000 where available. For significant sources with no CEM's data, constant emission rates and operating parameters reflecting annual average operation for Year 2000 were utilized. Annual average stack data for oil and gas production sources were derived from monthly production data for Year 2000. The emission characterization for each source is indicated in Table 1. As shown in Table 1, hourly emissions data were available for a majority of significant sources, and for most of the largest sources.

Emission rates for oil and gas production sources were derived from the ND State Industrial Commission's Oil and Gas data base. The oil and gas sources were screened to eliminate those with zero or minimal emissions. Stack operating parameters for oil and gas production sources were derived using procedures described in the "Williston Basin Regional Air Quality Study" (1990), and modified using SCREEN3 (EPA screening model) adjustments for effective flare plume height and radiotational heat loss.

To complete the source inventory, the NDDH considered use of a fixed background concentration to account for the impact of natural or very distant sources not explicitly modeled. For a performance evaluation, the background concentration must be a long-term average (equal probability that the actual value would be higher or lower than the value assumed for each modeled period), and it must not be biased from the impact of sources explicitly modeled. The NDDH obtained raw (un-rounded) monitoring data from TRNP South Unit monitoring site for Year 2000. The manufacturer suggests a minimum detectable limit of 0.5 ppb for the SO_2 analyzer. To filter impact of sources modeled, the NDDH considered monitor data only for hours with wind directions between 130 and 230 degrees (see Figure 1). Long-term averaging of these data produced results that were relatively small, and the NDDH elected not to add a specific background to model results.

Calmet Input Data

The location of the 5 km meteorological/computational grid utilized by the NDDH for the Year 2000 analysis is represented in Figure 1. The grid is defined by twelve vertical layers. Meteorological input data for Calmet was based on 32 surface stations, 5 upper-air stations, and 89 precipitation stations located in or near the meteorological grid. GOES ASOS satellite data were used to supplement surface observations for ceiling height and sky cover. All meteorological data were obtained from the National Climatic Data Center (surface and precipitation data), or Forecast Systems Laboratory (upper-air data). Geophysical data were developed using the USGS GTOPO30 data set for terrain elevations and the USGS Global data set for land use.

Processing of meteorological data relied on Earth Tech software, as well as supplemental software developed by NDDH for format conversions and missing data substitution. Methodology for meteorological data preparation is consistent with that described for Year 2000 in “Calpuff Analysis of Current PSD Class I Increment Consumption in North Dakota and Eastern Montana Using Actual Annual Average SO_2 Emission Rates” (draft), May 2003. Note that the possibility/effect of alternative approaches to meteorological data preparation was not considered in the performance evaluation.

Calmet/Calpuff Control File Settings

For the most part, Calmet and Calpuff input control file settings, as implemented by the NDDH, were consistent with IWAQM recommendations. However, extensive testing of Calmet output, with visual feedback (plotted data), suggested that adjustment to a limited number of IWQAM settings was required to achieve reasonable results for wind and mixing height fields. Further, the adjustment of a limited number of additional settings was found to provide better agreement with observations in previous performance evaluations, and such changes were judged to be scientifically consistent.

Non-IWAQM settings utilized by the NDDH for Calmet and Calpuff control files, and which provided optimum agreement with monitored observations, are listed in Table 2. These Non-IWAQM settings are discussed below.

Calmet

BIAS(NZ) - NDDH bias settings were developed through significant testing with visual feedback. The IWAQM recommendation provides neutral bias (between surface and upper-air data) for all vertical layers. In light of its testing, the NDDH does not believe it is reasonable to assume equal weighting of upper-air wind data with surface data at the lowest level, and to assume equal weighting of surface data with upper-air data at top levels.

LVARY - The NDDH felt it necessary to deploy this option to ensure that at least one station would always be available.

ZUPWND(2) - The NDDH was concerned that IWAQM was recommending a value of 1000 m while the model (Earth Tech) default is 2500 m, thus prompting the NDDH compromise value of 2000 m. But regardless of the selected value for this initial guess wind field input, subsequent wind field development should converge to the same result.

MNMDAV/ILEVZI - The NDDH found that IWAQM default values for these parameters, relating to spatial averaging of mixing heights, produced entirely unacceptable results for the mixing height field. Severe gradients (bull's eyes) in mixing height were observed in the immediate vicinity of meteorological stations, and a significant increase in the value of these input parameters was required to mitigate the anomaly. The NDDH notes that because MNMDAV is a function of grid cell size, IWAQM should specify "User Defines" for this parameter.

ZIMAX/ZIMAXW - Because the NDDH Calmet/Calpuff grid extends into the western part of the upper Great Plains, maximum mixing height was increased to 4000 m to be consistent with maximum mixing heights reported for this region (Holzworth, 1972).

Calpuff

MSPLIT - The option for puff splitting was recommended by John Irwin (EPA) when modeling source-receptor distances of 200 km or more, because of the tendency for Calpuff to otherwise overpredict at these distances. Deployment of this option also provided better agreement with observations.

MDISP - Use of dispersion coefficient option 2 provided significantly better agreement with observations. The NDDH also believes this selection is more consistent with the "state-of-the-art" in air quality modeling.

BCKO3 - Though the NDDH is utilizing the hourly file option for ozone background, the BCKO3 value is substituted by Calpuff when hourly data are missing. Based on local monitoring data, NDDH judged the IWQAM value of 80 ppb to be much higher than typical for North Dakota, and therefore reset the value to 30 ppb.

BCKNH3 - The NDDH value of 2 ppb reflects the annual average of local, unbiased monitoring data.

XSAMLEN - The NDDH set this value lower than the IWAQM recommendation, but notes that the only consequence for doing so would be extra computer time due to more puffs on the grid. The goal was to improve model resolution by increasing the number of puffs and decreasing mass per puff. Again, because this parameter is a function of grid cell size, the NDDH believes the recommended XSAMLEN value should be "User Defined".

XMAXZI - Value was increased to 4000 m for consistency with ZIMAX/ZIMAXW setting in Calmet.

Some other deviations from IWAQM guidance, which had no consequence for model predictions, were also involved in the NDDH implementation. These related to printed output options and parameters for the Lambert conformal map projection used by the NDDH.

Results

Results of the performance evaluation are summarized in Table 3 and Figure 2. The 3-hour and 24-hour block predictions and observations (year 2000) were ranked high to low for both monitoring sites. The fifty highest predictions were paired with the fifty highest observations, and the ratio predicted-to-observed was calculated for each pair. The average for these 50 ratios is reported in Table 3. Figure 2 provides quantile-quantile plots of the highest 50 predictions and observations for 24-hour averages for both monitoring sites. The plots include “factor-of-two” curves for assessing performance.

As shown in Table 3, the Calpuff modeling system, as implemented by NDDH, performs very well. The 24-hour predictions exhibit essentially zero bias when compared to observations. This is particularly significant because the 24-hour averaging period tends to be the most constraining in regulatory Class I modeling studies for North Dakota. The 3-hour predictions exhibit a slight overpredictions bias when compared to observations.

predicted-to-observed ratios fall within the factor-of-two criteria suggested by EPA, and in most cases are much better.

One caveat regarding these results in that TRNP South Unit monitoring data for Year 2000 included extensive missing periods (about 700 hours total). Therefore, maximum observations may be under-represented in the comparative analysis, moving the bias more toward underprediction, particularly for 24-hour averages.

Conclusions

The evaluation of Calpuff performance for Year 2000 data at Dunn Center and TRNP South Unit monitoring sites indicates the modeling system performs well, when implemented using IWAQM control file settings as modified by NDDH (Table 2), and meteorological data as processed by NDDH. Predicted-to-observed ratios for the fifty highest predicted/observed concentrations fell within the factor-of-two criteria suggested by EPA, and did not exhibit systematic bias toward underprediction or overprediction. Therefore, the NDDH implementation of the Calpuff modeling system, using currently processed meteorological/geophysical data and IWAQM control file settings as modified by NDDH, should be acceptable for regulatory Class I area modeling in North Dakota.

The NDDH recognizes that minor improvement in model performance is still possible. But the implication of these performance evaluation results is that caution must attend any suggested changes to input or methodology. Changing all control file settings to IWAQM-recommended values, for example, would likely move some predicted-to-observed ratios outside of the factor-of-two window.

Table 1
Source Inventory (SO_2)

Source	Emission Characterization	Figure 1 Loc. Key
Coal Creek Station	Actual Hourly	1
Antelope Valley Station	Actual Hourly	2
Coyote Station	Actual Hourly	3
Leland Olds Station	Actual Hourly	4
Milton R. Young Station	Actual Hourly	5
Heskett Station	Actual Hourly	6
Stanton Station	Actual Hourly	4
Great Plains Synfuels Plant	Actual Hourly*	2
Little Knife Gas Plant	Actual Hourly	7
Grasslands Gas Plant	Actual Hourly	8
Tioga Gas Plant	Annual Average	9
Lignite Gas Plant	Annual Average	10
Mandan Refinery	Annual Average	6
Boundary Dam Station	Annual Average	11
Shand Station	Annual Average	12
Colstrip Station	Actual Hourly	13
CELP Boiler	Annual Average	14
Sidney Station	Annual Average	15
Oil & Gas Related**	Annual Average	—

* Hourly CEM's data were available for GPSP main stack only. Annual average emission assumed for other three units.

** All facilities located within 50 km of monitoring sites.

Table 2
Non-IWAQM Settings Used by NDDH
in Calmet/Calpuff Control Files

Parameter	IWAQM	NDDH
Calmet		
BIAS(NZ)	0,0,0,0, 0,0,0,0, 0,0,0,0	-1.0, -0.9, -0.8,-0.4, 0.0, 0.1, 0.5, 0.8 1.0, 1.0, 1.0, 1.0
LVARY	F	T
ZUPWND(2)	1000 m	2000 m
MNMDAV	1	8
ILEVZI	1	4
ZIMAX	3000 m	4000 m
ZIMAXW	3000 m	4000 m
Calpuff		
MSPLIT*	0	1
MDISP	3	2
BCKO3	80 ppb	30 ppb
BCKNH3	10 ppb	2 ppb
XSAMLEN	1.0	0.5
XMAXZI	3000 m	4000 m

* Puff splitting was not deployed in Calpuff control file for oil and gas sources. This concession to computer resource requirements is reasonable, because puffs would not grow very large given the maximum 50 km source-receptor distance.

Table 3
Ratio of Calpuff Predicted to Observed
Average for 50 Highest Predictions and Observations

Averaging Period	**Dunn Center**	**TRNP South**
3-hour	1.30	1.42
24-hour	0.97	1.00

Figure 1: Monitor and Source Locations

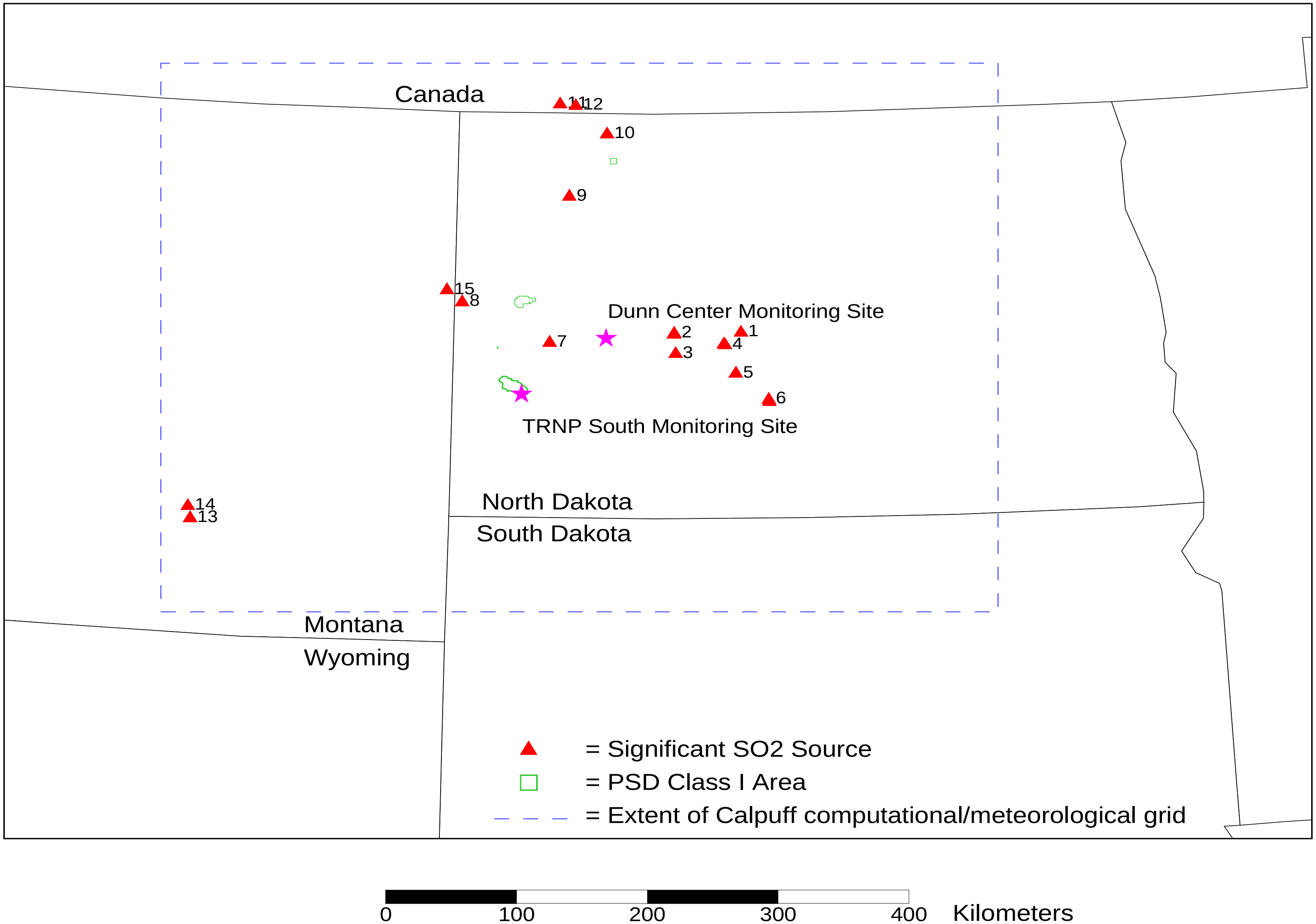
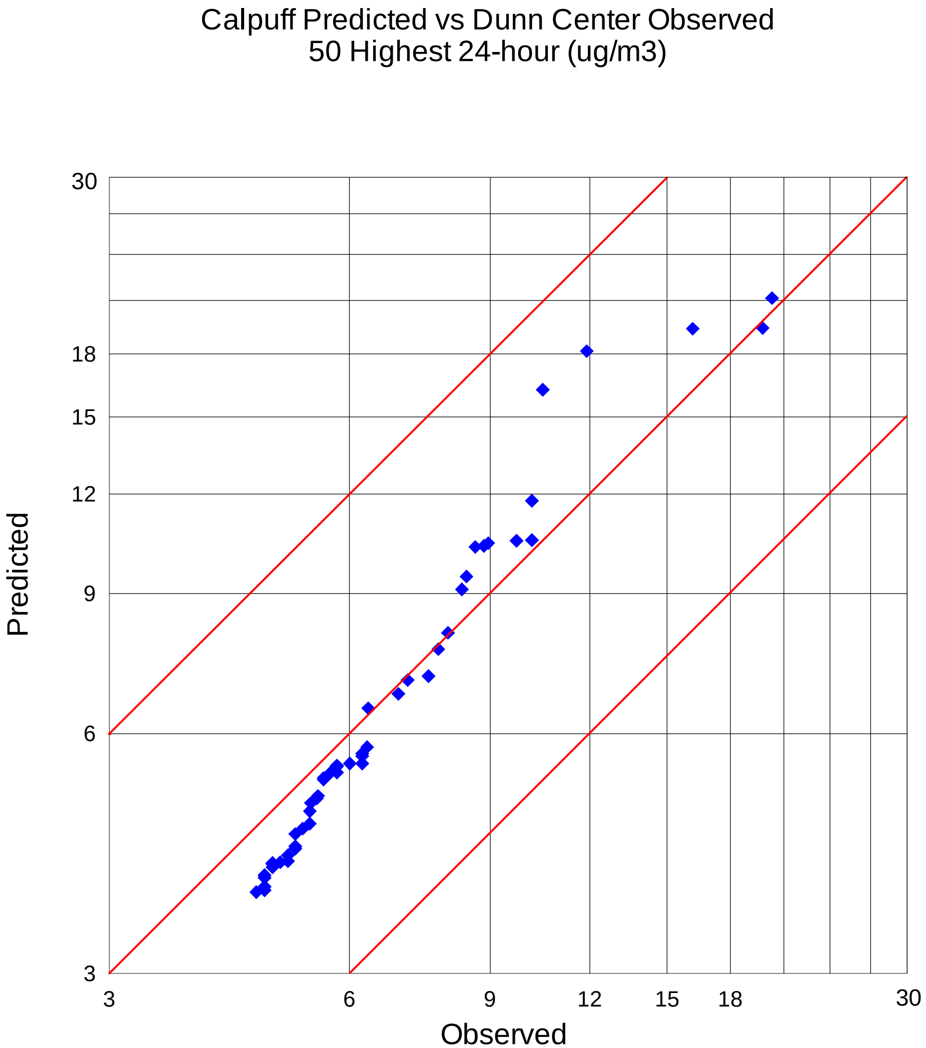
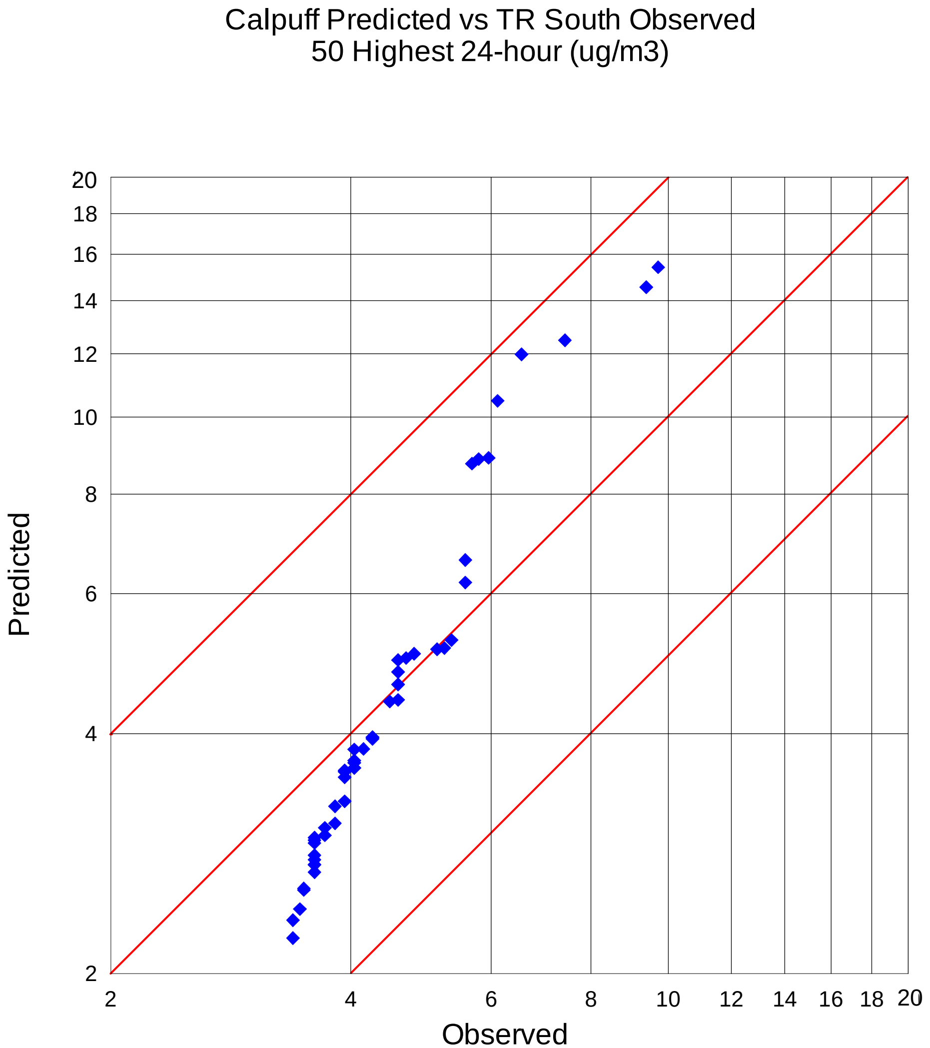


Figure 2



Calpuff Predicted vs Dunn Center Observed
50 Highest 24-hour (ug/m3)
Predicted
Observed
30
18
15
12
9
6
3
3
6
9
12
15
18
30



Calpuff Predicted vs TR South Observed
50 Highest 24-hour (ug/m3)
Predicted
Observed
20
18
16
14
12
10
8
6
4
2
2
4
6
8
10
12
14
16
18
20

Appendix C

IWAQM Recommendations

for Calmet Control File

Variable	Description	Value
GEO.DAT	Name of Geophysical data file	GEO.DAT
SURF.DAT	Name of Surface data file	SURF.DAT
PRECIP.DAT	Name of Precipitation data file	PRECIP.DAT
NUSTA	Number of upper air data sites	User Defined
UPn.DAT	Names of NUSTA upper air data files	UPn.DAT
IBYR	Beginning year	User Defines
IBMO	Beginning month	User Defines
IBDY	Beginning day	User Defines
IBHR	Beginning hour	User Defines
IBTZ	Base time zone	User Defines
IRLG	Number of hours to simulate	User Defines
IRTYPE	Output file type to create (must be 1 for CALPUFF)	1
LCALGRD	Are w-components and temperature needed?	T
NX	Number of east-west grid cells	**User Defines**
NY	Number of north-south grid cells	**User Defines**
DGRIDKM	Grid spacing	**User Defines**
XORIGKM	Southwest grid cell X coordinate	User Defines
YORIGKM	Southwest grid cell Y coordinate	User Defines
XLAT0	Southwest grid cell latitude	User Defines
YLON0	Southwest grid cell longitude	User Defines
IUTMZN	UTM Zone	User Defines
LLCONF	When using Lambert Conformal map coordinates, rotate winds from true north to map north?	F
XLAT1	Latitude of 1st standard parallel	**30**
XLAT2	Latitude of 2nd standard parallel	**60**

Variable	Description	Value
RLON0	Longitude used if LLCONF = T	**90**
RLAT0	Latitude used if LLCONF = T	**40**
NZ	Number of vertical layers	**User Defines**
ZFACE	Vertical cell face heights (NZ+1 values)	**User Defines**
LSAVE	Save met. data fields in an unformatted file?	T
IFORMO	Format of unformatted file (1 for CALPUFF)	1
NSSTA	Number of stations in SURF.DAT file	User Defines
NPSTA	Number of stations in PRECIP.DAT	User Defines
ICLOUD	Is cloud data to be input as gridded fields? (0 = No)	0
IFORMS	Format of surface data (2 = formatted)	2
IFORMP	Format of precipitation data (2 = formatted)	2
IFORMC	Format of cloud data (2 = formatted)	2
IWFCOD	Generate winds by diagnostic wind module? (1 = Yes)	1
IFRADJ	Adjust winds using Froude number effects? (1 = Yes)	1
IKINE	Adjust winds using kinematic effects? (1 = Yes)	0
IOBR	Use O'Brien procedure for vertical winds? (0 = No)	0
ISLOPE	Compute slope flows? (1 = Yes)	1
IEXTRP	Extrapolate surface winds to upper layers? (-4 = use similarity theory and ignore layer 1 of upper air station data)	-4
ICALM	Extrapolate surface calms to upper layers? (0 = No)	0
BIAS	Surface/upper-air weighting factors (NZ values)	NZ*0

Variable	Description	Value
IPROG	Using prognostic or MM-FDDA data? (0 = No)	0
LVARY	Use varying radius to develop surface winds?	**F**
RMAX1	Max surface over-land extrapolation radius (km)	**User Defines**
RMAX2	Max aloft over-land extrapolation radius (km)	**User Defines**
RMAX3	Maximum over-water extrapolation radius (km)	**User Defines**
RMIN	Minimum extrapolation radius (km)	0.1
RMIN2	Distance (km) around an upper air site where vertical extrapolation is excluded (Set to -1 if IEXTRP = ±4)	4
TERRAD	Radius of influence of terrain features (km)	**User Defined**
R1	Relative weight at surface of Step 1 field and obs	**User Defines**
R2	Relative weight aloft of Step 1 field and obs	**User Defines**
DIVLIM	Maximum acceptable divergence	5.E-6
NITER	Max number of passes in divergence minimization	50
NSMTH	Number of passes in smoothing (NZ values)	2, 4*(NZ-1)
NINTR2	Max number of stations for interpolations (NA values)	**99**
CRITFN	Critical Froude number	1
ALPHA	Empirical factor triggering kinematic effects	0.1
IDIOPT1	Compute temperatures from observations (0 = True)	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	**User Defines**
IDIOPT2	Compute domain-average lapse rates? (0 = True)	0
IUPT	Station for lapse rates (between 1 and NUSTA)	**User Defines**
ZUPT	Depth of domain-average lapse rate (m)	200

Variable	Description	Value
IDIOPT3	Compute internally inital guess winds? (0 = True)	0
IUPWND	Upper air station for domain winds (-1 = 1/r**2 interpolation of all stations)	-1
ZUPWND	Bottom and top of layer for 1st guess winds (m)	1, 1000
IDIOPT4	Read surface winds from SURF.DAT? (0 = True)	0
IDIOPT5	Read aloft winds from UPn.DAT? (0 = True)	0
CONSTB	Neutral mixing height B constant	1.41
CONSTE	Convective mixing height E constant	0.15
CONSTN	Stable mixing height N constant	2400
CONSTW	Over-water mixing height W constant	0.16
FCORIOL	Absolute value of Coriolis parameter	1.E-4
IAVEXZI	Spatial averaging of mixing heights? (1 = True)	1
MNMDAV	Max averaging radius (number of grid cells)	1
HAFANG	Half-angle for looking upwind (degrees)	30
ILEVZI	Layer to use in upwind averaging (between 1 and NZ)	1
DPTMIN	Minimum capping potential temperature lapse rate	0.001
DZZI	Depth for computing capping lapse rate (m)	200
ZIMIN	Minimum over-land mixing height (m)	50
ZIMAX	Maximum over-land mixing height (m)	3000
ZIMINW	Minimum over-water mixing height (m)	50
ZIMAXW	Maximum over-water mixing heigh (m)	3000
IRAD	Form of temperature interpolation (1 = 1/r)	1
TRADKM	Radius of temperature interpolation (km)	500

Variable	Description	Value
NUMTS	Max number of stations in temperature interpolations	5
IAVET	Conduct spatial averaging of temperature? (1 = True)	1
TGDEFB	Default over-water mixed layer lapse rate (K/m)	-0.0098
TGDEFA	Default over-water capping lapse rate (K/m)	-0.0045
JWAT1	Beginning landuse type defining water	999
JWAT2	Ending landuse type defining water	999
NFLAGP	Method for precipitation interpolation (2 = 1/r**2)	2
SIGMAP	Precip radius for interpolations (km)	100
CUTP	Minimum cut off precip rate (mm/hr)	0.01
SSn	NSSTA input records for surface stations	User Defines
USn	NUSTA input records for upper-air stations	User Defines
PSn	NPSTA input records for precipitation stations	User Defines

Appendix D

IWAQM Recommendations

for Calpuff Control File

Variable	Description	Value
METDAT	CALMET input data filename	CALMET.DAT
PUFLST	Filename for general output from CALPUFF	CALPUFF.LST
CONDAT	Filename for output concentration data	CONC.DAT
DFDAT	Filename for output dry deposition fluxes	DFLX.DAT
WFDAT	Filename for output wet deposition fluxes	WFLX.DAT
VISDAT	Filename for output relative humidities (for visibility)	VISB.DAT
METRUN	Do we run all periods (1) or a subset (0)?	0
IBYR	Beginning year	User Defined
IBMO	Beginning month	User Defined
IBDY	Beginning day	User Defined
IBHR	Beginning hour	User Defined
IRLG	Length of run (hours)	User Defined
NSPEC	Number of species modeled (for MESOPUFF II chemistry)	5
NSE	Number of species emitted	3
MRESTART	Restart options (0 = no restart), allows splitting runs into smaller segments	**0**
METFM	Format of input meteorology (1 = CALMET)	1
AVET	Averaging time lateral dispersion parameters (minutes)	60
MGAUSS	Near-field vertical distribution (1 = Gaussian)	1
MCTADJ	Terrain adjustments to plume path (3 = Plume path)	**3**
MCTSG	Do we have subgrid hills? (0 = No), allows CTDM-like treatment for subgrid scale hills	**0**
MSLUG	Near-field puff treatment (0 = No slugs)	0

Variable	Description	Value
MTRANS	Model transitional plume rise? (1 = Yes)	1
MTIP	Treat stack tip downwash? (1 = Yes)	1
MSHEAR	Treat vertical wind shear? (0 = No)	0
MSPLIT	Allow puffs to split? (0 = No)	**0**
MCHEM	MESOPUFF-II Chemistry? (1 = Yes)	1
MWET	Model wet deposition? (1 = Yes)	1
MDRY	Model dry deposition? (1 = Yes)	1
MDISP	Method for dispersion coefficients (3 = PG & MP)	3
MTURBVW	Turbulence characterization? (Only if MDISP = 1 or 5)	3
MDISP2	Backup coefficients (Only if MDISP = 1 or 5)	3
MROUGH	Adjust PG for surface roughness? (0 = No)	0
MPARTL	Model partial plume penetration? (0 = No)	1
MTINV	Elevated inversion strength (0 = compute from data)	0
MPDF	Use PDF for convective dispersion? (0 = No)	0
MSGTIBL	Use TIBL module? (0 = No) allows treatment of subgrid scale coastal areas	0
MREG	Regulatory default checks? (1 = Yes)	1
CSPECn	Names of species modeled (for MESOPUFF II, must be SO2, SO4, NOX, HNO3, NO3)	**User Defined**
Specie Names	Manner species will be modeled	**User Defined**
Specie Groups	Grouping of species, if any.	**User Defined**
NX	Number of east-west grids of input meteorology	User Defined
NY	Number of north-south grids of input meteorology	User Defined
NZ	Number of vertical layers of input meteorology	User Defined

Variable	Description	Value
DGRIDKM	Meteorology grid spacing (km)	User Defined
ZFACE	Vertical cell face heights of input meteorology	User Defined
XORIGKM	Southwest corner (east-west) of input meteorology	User Defined
YORIGIM	Southwest corner (north-south) of input meteorology	User Defined
IUTMZN	UTM zone	User Defined
XLAT	Latitude of center of meteorology domain	User Defined
XLONG	Longitude of center of meteorology domain	User Defined
XTZ	Base time zone of input meteorology	User Defined
IBCOMP	Southwest X-index of computational domain	**User Defined**
JBCOMP	Southwest Y-index of computational domain	**User Defined**
IECOMP	Northeast X-index of computational domain	**User Defined**
JECOMP	Northeast Y-index of computational domain	**User Defined**
LSAMP	Use gridded receptors? (T = Yes)	F
IBSAMP	Southwest X-index of receptor grid	User Defined
JBSAMP	Southwest Y-index of receptor grid	User Defined
IESAMP	Northeast X-index of receptor grid	User Defined
JESAMP	Northeast Y-index of receptor grid	User Defined
MESHDN	Gridded recpetor spacing = DGRIDKM/MESHDN	1
ICON	Output concentrations? (1 = Yes)	1
IDRY	Output dry deposition flux? (1 = Yes)	1
IWET	Output west deposition flux? (1 = Yes)	1
IVIS	Output RH for visibility calculations (1 = Yes)	1
LCOMPRS	Use compression option in output? (T = Yes)	T

Variable	Description	Value
ICPRT	Print concentrations? (0 = No)	0
IDPRT	Print dry deposition fluxes (0 = No)	0
IWPRT	Print wet deposition fluxes (0 = No)	0
ICFRQ	Concentration print interval (1 = hourly)	1
IDFRQ	Dry deposition flux print interval (1 = hourly)	1
IWFRQ	West deposition flux print interval (1 = hourly)	1
IPRTU	Print output units (1 = g/m**3; g/m**2/s)	1
IMESG	Status messages to screen? (1 = Yes)	1
Output Species	Where to output various species	**User Defined**
LDEBUG	Turn on debug tracking? (F = No)	F
Dry Gas Dep	Chemical parameters of gaseous deposition species	**User Defined**
Dry Part. Dep	Chemical parameters of particulate deposition species	**User Defined**
RCUTR	Reference cuticle resistance (s/cm)	30.
RGR	Reference ground resistance (s/cm)	10.
REACTR	Reference reactivity	8
NINT	Number of particle-size intervals	9
IVEG	Vegetative state (1 = active and unstressed)	1
Wet Dep	Wet deposition parameters	**User Defined**
MOZ	Ozone background? (1 = read from ozone.dat)	1
BCKO3	Ozone default (ppb) (Use only for missing data)	**80**
BCKNH3	Ammonia background (ppb)	**10**
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2

Variable	Description	Value
SYTDEP	Horizontal size (m) to switch to time dependence	550.
MHFTSE	Use Heffter for vertical dispersion? (0 = No)	0
JSUP	PG Stability class above mixed layer	5
CONK1	Stable dispersion constant (Eq 2.7-3)	0.01
CONK2	Neutral dispersion constant (Eq 2.7-4)	0.1
TBD	Transition for downwash algorithms (0.5 = ISC)	0.5
IURB1	Beginning urban landuse type	10
IURB2	Ending urban landuse type	19
Use Following Only For Single-Point Meteorological Input (CALPUFF Screen)		
ILANDUIN	Land use type (20 = Unirrigated agricultural land)	20
ZOIN	Roughness length (m)	0.25
XLAIIN	Leaf area index	3
ELEVIN	Met. Station elevation (m above MSL)	0
XLATIN	Met. Station North latitude (degrees)	**User Defined**
XLONIN	Met. Station West longitude (degrees)	**User Defined**
ANEMHT	Anemometer height of ISC meteorological data (m)	10.0
ISIGMAV	Lateral turbulence (Not used with ISC meteorology)	1
IMIXCTDM	Mixing heights (Not used with ISC meteorology)	0
End of Single Point Meteorology Input Variables		
XMXLEN	Maximum slug length in units of DGRIDKM	1
XSAMLEN	Maximum puff travel distance per sampling step (units of DGRIDKM)	1

Variable	Description	Value
MXNEW	Maximum number of puffs per hour	99
MXSAM	Maximum sampling steps per hour	99
SL2PF	Maximum Sy/puff length	10
PLX0	Wind speed power-law exponents	0.07,0.07,0.10,0.15,0.35,0.55
WSCAT	Upper bounds 1st 5 wind speed classes (m/s)	1.54,3.09,5.14,8.23.10.8
PGGO	Potential temperature gradients PG E and F (deg/km)	0.020, 0.035
SYMIN	Minimum lateral dispersion of new puff (m)	1.0
SZMIN	Minimum vertical dispersion of new puff (m)	1.0
SVMIN	Array of minimum lateral turbulence (m/s)	6*0.50
SWMIN	Array of minimum vertical turbulence (m/s)	0.20, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz (1/s)	0.01
WSCALM	Minimum non-calm wind speed (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
PPC	Plume path coefficients (only if MCTADJ = 3)	0.5,0.5,0.5,0.5,0.35,0.35
NSPLIT	Number of puffs when puffs split	3
IRESPLIT	Hours when puff are eligible to split	**User Defined**
ZISPLIT	Previous hour's mixing height (minimum), (m)	100
ROLDMAX	Previous Max mixing height/current mixing height ratio, must be less then this value to allow puff split	0.25

Variable	Description	Value
EPSSLUG	Convergence criterion for slug sampling integration	1.0E-04
PESAREA	Convergence criterion for area source integration	1.0E-06
NPT1	Number of point sources	User Defined
IPTU	Units of emission rates (1 = g/s)	1
NSPT1	Number of point source-species combinations	0
NPT2	Number of point sources with fully variable emission rates	0
Point Sources	Point sources characteristics	User Defined
Area Sources	Area sources characteristics	User Defined
Line Sources	Buoyant lines source characteristics	User Defined
Volume Sources	Volume sources characteristics	User Defined
NREC	Number of user defined receptors	User Defined
Receptor Data	Location and elevation (MSL) of receptors	User Defined