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USER'S REFERENCE GUIDE FOR NOISE ASSESSMENT PREDICTION SYSTEM (NAPS)

July 1992

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ATMOSPHERIC SCIENCES LABORATORY
White Sands Missile Range, NM 88002-5501

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13. ABSTRACT *(Maximum 200 words)*

The noise assessment and prediction system (NAPS) model provides an estimate of the surface peak noise intensity in all directions surrounding a blast source using a personal computer. An essential feature of the model is its ability to account for meteorological and topographical variations in the calculation of blast sound propagation. In performing noise intensity estimates, acoustic ray traces are generated over a sufficient range of azimuth and elevation angles to define the focusing and shadow regions in the area surrounding the airblast. The acoustics of the model include the effects of spherical acoustic spreading, absorption, focusing, shadow zones, reflection of rays from water, interference of multiple rays arriving at the same location, and the directional asymmetry of a blastwave. The NAPS model has been implemented at Aberdeen Proving Ground, Maryland, using acoustic sounder, upper air, and surface station data to provide on-line meteorological input. Plots of ray trace trajectories and sound intensity contour levels on a background map of the Aberdeen area, along with tabular data, are included as model features. This user's reference guide describes the procedures for running the NAPS model. It also includes examples of the required input data files and examples of the graphic outputs generated by the model.

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The research and the accompanying documentation were conducted under Army Contract DAAD0789-C-0209 with the Atmospheric Sciences Laboratory. Mr. Robert Olsen served as the contracting officer's technical representative.

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1. INTRODUCTION

1.1 Purpose

The purpose of this manual is to introduce the user to the operation of the noise assessment and prediction system (NAPS), version 4.6 for a personal computer (PC), released in October 1991. The NAPS model provides an estimate of peak noise intensity in all directions from a blast source located at or near ground level. This manual is intended for those familiar with the effects of terrain and meteorological conditions on the behavior of noise propagation. It is meant as a guide for running the NAPS model and is not to be considered a technical treatment of the model. For a complete discussion of the basic principles of sound propagation, acoustics, and mathematical models utilized in the development of NAPS, refer to the Technical Reference Guide For Noise Assessment Prediction System, UDR-TR-91-87.

1.2 NAPS Program Development

The research and development of the NAPS program was conducted under Army Contract DAAD07-89-C-0209 with the U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico. A method was needed to provide a reliable estimate of the noise level in the areas surrounding the testing sites at Aberdeen Proving Grounds (APG), Maryland, thus affording APG the option to perform weapon testing at the most opportune times.

The NAPS model was evaluated by running several validation tests with data provided by APG [1]. The evaluation indicated that NAPS performs well in predicting the propagation of sound around a blast site, if the blast data, terrain parameters, and the meteorological conditions at the time of the blast are adequately defined. It is especially important to utilize detailed and accurate meteorological profiles that are representative at the blast site location.

1.3 NAPS Program Overview

The NAPS model generates sound intensity contours surrounding a blast source based upon the meteorological conditions that influence the speed of sound. The model uses a ray trace approach that takes into account spherical spreading, absorption, and refraction. A ray is assumed to be absorbed when it impacts with the ground, but is totally reflected when it impacts a water surface. Diffraction in shadow zone regions is estimated by using empirical equations. The model also utilizes acoustical propagation principles that should provide accurate predictions of noise focusing regions of high sound intensity. Accurate meteorological wind and temperature profiles are essential to provide accurate sound estimates.

An essential feature of the model is its ability to account for meteorological and topographical variations in the calculation of blast sound propagation. The NAPS model has been implemented at APG by using an acoustic sounder, upper air, and surface station data to provide online meteorological input. A profile generating program (BLDPROF2) processes this data to produce a met profile suitable for input into the NAPS model. Elevation and ground attribute data files define the terrain in the testing area.

The software is user friendly, providing interactive input and graphics output options. The user, starting with meteorological vertical profiles of temperature, relative humidity, windspeed and direction, may manually edit the profiles or may use the integrated planetary boundary layer model (IPBL) to produce a forecasted version of the profiles. The IPBL model is one-dimensional and requires soil, moisture, and radiation parameters to forecast the time-dependent evolution of boundary layer profiles. A primary use of the model, with NAPS, is to forecast the influence of the dissipation of the natural temperature inversion on sound propagation.

Run-time options allow the user to choose the run conditions and any of the numerous output graphics displays. The met profile data versus altitude plots give a clear picture of the various met conditions. Plots of (a) ray trace trajectories, (b) sound intensity contour levels on a background map of the testing area, (c) topographical mapping of the testing area, and (d) attenuation versus range for given azimuths are display options available to the user. A color hard copy can be made of any of these graphic outputs, and a tabular summary of the calculations is produced for each run.

2. PROGRAM ENVIRONMENT

2.1 Hardware Requirements

The NAPS program was developed to run on an IBM compatible PC that has an EGA or a VGA graphics adapter and MS-DOS 3.3 (or higher) operating system. Due to the complexity of the calculations and the size of the files, it is recommended that the computer also have a 287 or 387 math coprocessor, minimum 40 Mg hard drive, and at least a 20 MHz clock. To get the full benefit of the graphics displays, a color monitor is recommended.

Printer types are optional, but a color printer is best for copying the color output displays. APG is using an additional screen dump facility (GRAFPLUS) to give better control for formatting the output, but this is not required.

The operation of personal computers and printers is described within the appropriate manual provided with each computer system. It is assumed that the user has an elementary knowledge of MS-DOS, directory and file structure, and the execution of programs.

2.2 Software Support

The NAPS is written in standard FORTRAN-77 and is linked to a small, standard GKS graphics library written for this system. In NAPS version 4.6, the data files are all standard ASCII formatted files. These files are described in section 3. All interactive screen input and output options are menu driven. Appendices A, B, and C contain explanations and examples of the command file, input file, and output file needed to support the program.

The NAPS is supplemented by the met profile generating program, BLDPROF2, which is written in Quick Basic. BLDPROF2 can be used as a stereotype program for other sites that wish to use the NAPS model. Appendix D contains the code and further discussion of this program.

Another supplement to the NAPS model is the program IPBL, which can be used to generate a set of forecasted met profiles. This program is written in FORTRAN. The code and a further discussion of this program can be found in appendix E. The user may employ any forecasting program of his choice, but the resulting met profile must meet the NAPS input requirements described in section 3.1 and appendix B.

2.3 Program Configuration

The main program, NAPS, consists of eight modules of FORTRAN code. The FORTRAN program was compiled in MS-FORTRAN 5.0 and linked to the graphics library, GRAFLIB.LIB. Command files and definitions of the options used for compiling and linking the program can be found in appendix A.

An operating configuration can be designed for individual sites, but the following discussion is for the scenario at APG. The various data collecting devices at APG store meteorological data files in the C:**RAWMET** directory. These are the input files for the profile generating program BLDPROF2. All data files defining the physical features of the area are in the directory, C:**NAPS\DATA**.

Once the met profile has been generated it is then written to the C:**MET\DATA** directory. The program source codes can be housed in any directory convenient for the user since they are necessary only if a change in the operation of the program is required. The APG configuration places all the executable codes in the directory **C:\NAPS**. Figure 1 presents a system diagram of the NAPS model, showing the data flow and the directories used to store the data.

The graphics package written for this program requires two files, GRAFLIB.LIB and the file of print fonts, FONT01.DAT. The program expects these files to be in the C:**LIB** directory. If the NAPS program aborts while in the graphics mode, the utility program, EXGR.EXE, will restore the terminal to the text mode. This program is in the C:**NAPS** directory.

3. INPUT DATA FILES

The input data to this model is divided into two major categories: meteorological (met) and physical. As noted in section 2.3, the MET profile data files are stored in the C:\MET\DATA directory and the files defining the physical features of the area are in the C:\NAPS\DATA directory.

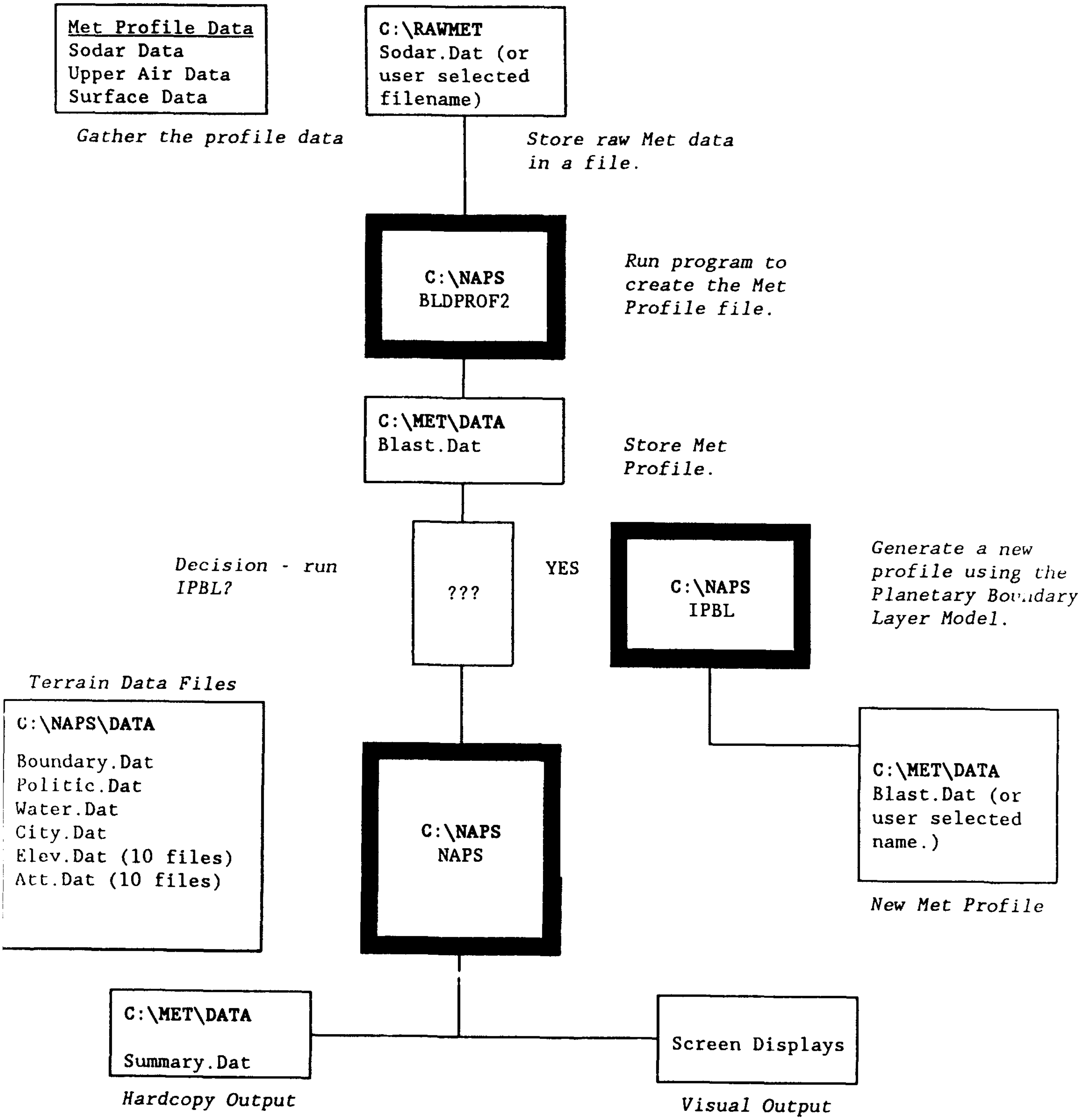

Figure 1. System diagram of NAPS model.

3.1 Meteorological Data (Met Profile)

The BLDPROF2 program generates a met profile by processing a combination of upper air, acoustic sounder, and surface data. The default name for the profile is "Blast.dat," but the user has the option to rename this file if desired. It is advisable to assign meaningful names to these profiles, such as a reference to the date or location. Appendix D describes in detail the procedure for generating met profiles using the BLDPROF2 program. A met profile contains the temperature, relative humidity, wind direction, windspeed and atmospheric pressure interpolated for preassigned altitude levels ranging from 2 m to 3000 m above the surface. If desired, additional levels can be added above 3000 m; the model can currently handle a maximum of 50 altitude levels. The model assumes that the specified profiles are horizontally homogeneous, except where modified by the influence of the terrain. Table 1 is an example of a met profile. The format of this file is discussed in appendix B.

TABLE 1. EXAMPLE MET PROFILE DATA FILE

```
03/16/89   06:37 EST   I-FIELD   @ 26#
SFALT  SFPRES
3.00    1022.
LINE     AGL    TEMP      RH       WSPD    WDDIR  PRESS
  1       0.    5.9      63.0       1.5    350.0  1022.
  2       2.    5.9      62.8       3.1    349.7  1022.
  3      10.    5.9      61.9       3.2    348.6  1020.
  4      50.    5.8      57.3       3.5    343.0  1019.
  5      70.    5.8      55.0       3.7    340.2  1014.
  6     100.    5.7      51.6       3.9    336.0  1008.
  7     150.    5.4      49.5       4.4    330.0  1002.
  8     200.    4.9      49.4       5.0    325.4   996.
  9     300.    4.0      51.5       6.2    318.7   983.
 10     400.    3.1      53.6       7.2    316.6   971.
 11     500.    2.2      55.8       8.2    316.1   959.
 12     600.    1.3      58.0       9.2    315.7   947.
 13     700.     .3      60.2      10.2    315.2   936.
 14     800.    -.4      60.8      11.1    314.6   924.
 15     900.    -.9      60.5      11.8    314.1   913.
 16    1000.   -1.5      60.3      12.6    313.5   901.
 17    1200.   -1.3      44.1      13.5    308.3   879.
 18    1400.    1.0      22.9      13.7    301.6   857.
 19    1600.    1.4      10.4      13.7    293.3   836.
 20    1800.     .5       3.7      14.2    282.2   816.
 21    2000.    -.6       3.8      15.8    274.0   795.
 22    2200.   -1.8       9.4      18.3    269.0   776.
 23    2400.   -3.0      14.9      20.8    264.1   756.
 24    2600.   -4.1      20.4      23.3    259.1   737.
 25    2800.   -5.3      27.4      26.1    254.9   719.
 26    3000.   -6.6      41.4      31.0    254.1   701.
```

The NAPS model can be run in two modes: as a nowcast model or as a forecast model. Met profiles define the current or nowcast and the forecasted meteorological conditions. When run as a nowcast model, NAPS uses a met profile generated from the observed met data. When run as a forecast model, it uses a met profile forecasted for some future point in time.

3.2 Physical Data

The second major category of input data describes the physical features of the blast area. This category is further divided into two sets: the background map data and the terrain data.

3.2.1 Background Map Data

The background files provide the necessary coordinates to enable the program to draw and label the background of the blast site at APG. These files: "Water.dat," define all the water areas; "City.dat" names and locates each city on the map; "Politic.dat" provides physical features such as the outline of large cities; and "Boundary.dat." outlines and labels the APG area. The data in these files were extracted from the USGS digital maps using a map reading and processing program provided by the agency. These files and their formats are discussed further in appendix B.

3.2.2 Terrain Data

There are 10 established blast sites at APG, and each has an elevation file and a land attribute file indicating the surrounding surface (land or water). These files contain data values along azimuths radiating from the blast sites. The blast source location is considered to be the origin, or hub, with "spokes" expanding outward at each 5° increment of azimuth, as shown in figure 2. Along each spoke, at increments of 200 m in range, a spoke's data points are defined. The total range of a spoke is approximately 40 km. Each file contains 72 spokes of data, starting with the azimuth pointing to the east. The files for blast site number 1 are named "Elevl.dat" and "Attl.dat"; the other files are named accordingly. Refer to appendix B for the format and description of these large data files.

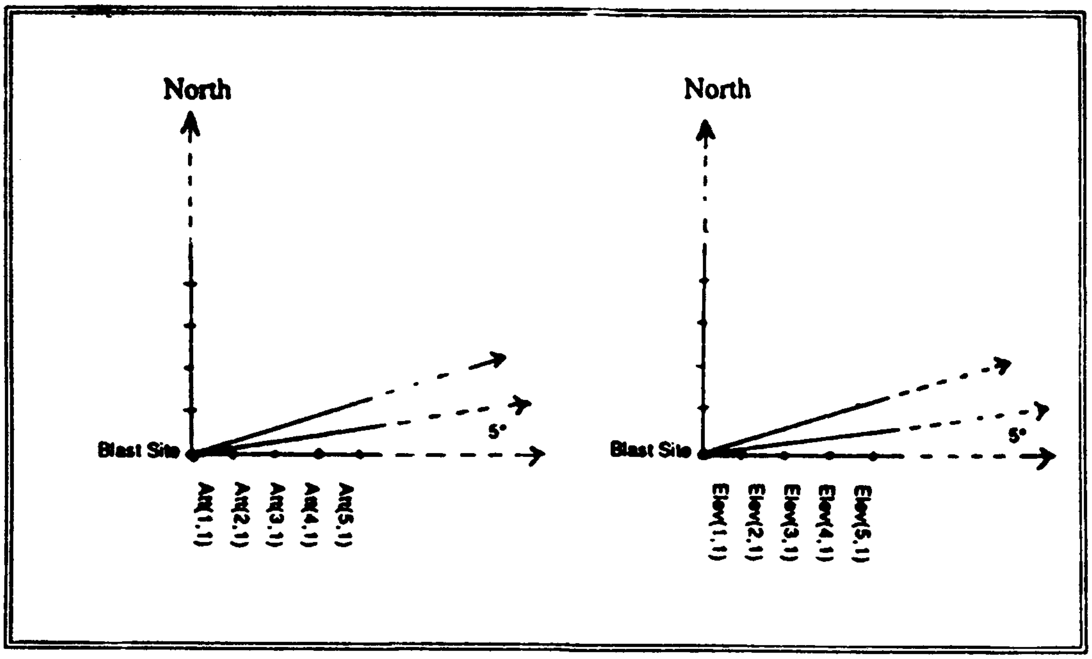

Figure 2. Diagram of attribute and elevation spoke data points.

4. STARTING THE MODEL

A command file can be used to start the model. At APG the user logs into the system and types the name of the command file "NAPS." The program begins and the user responds interactively to pick options and direct the processes desired. The command file first sets the correct directory, runs the BLDPROF2 to build the current met profile, and then queries the user if he/she wants to use the IPBL program to produce a forecasted met profile. At the completion of these three processes a met profile has been approved by the user and written to a file. The command file then runs the NAPS program. The following is an example of this four-step procedure:

1. CD\MET\DATA
   Set the default directory to the met profile directory.

2. \NAPS\BLDPROF2
   Run met profile building program.

3. \NAPS\IPBL
   Run the forecasting program. (Exit this call if a forecasted profile is not wanted.)

4. \NAPS\NAPS
   Run the model.

The user may bypass the initialization and/or the forecasting program and run only the NAPS program anytime there is a met profile available. This allows the user to selectively edit an archived met profile and then rerun the program.

Before beginning the program, the user should check to be sure all files are located in the proper directories. Table 2 list the directories, the subdirectories, and the necessary files. This configuration cannot be changed to individual preferences without program code changes.

TABLE 2. FILES REQUIRED TO RUN NAPS MODEL

Library directory	C:\LIB - GRAFLIB.LIB, FONT01.DAT
Main directory	C:\NAPS - BLDPROF2.EXE, IPBL.EXE, NAPS.EXE, EXGR.EXE
Subdirectory	C:\NAPS\DATA - All ELEV and ATT files (one set for each blast site), WATER.DAT, CITY.DAT, POLITIC.DAT, BOUNDARY.DAT, desired met profile
Subdirectory	C:\MET\DATA - Met profiles

5. RUNNING THE NAPS PROGRAM

The system is ready to operate once the NAPS program has been installed and all input data files have been placed in the appropriate directory. Each time the NAPS model is run an input met profile must be available. This can be an archived profile generated previously, but usually it is a profile generated from the current met data readings, or one forecasted from the current readings.

The program begins by displaying an introductory screen (figure 3).

```
      NN        NN          AAA         PPPPPP         SSSSSS
      NNN       NN         AA AA        PP     PP    SS       S
      NN NN     NN        AA    AA      PP      PP   SS
      NN NN     NN        AA    AA      PP      PP   SS
      NN   NN   NN       AA      AA     PP     PP       SS
      NN   NN   NN       AA      AA     PPPPPP             SS
      NN     NN NN      AAAAAAAAAAA     PP                    SS
      NN     NN NN     AA          AA   PP                    SS
      NN       NNN     AA          AA   PP           S        SS
      NN        NN     AA          AA   PP            SSSSSS

                 NOISE ASSESSMENT PREDICTION SYSTEM

                     VERSION 4.6 OCTOBER 1991

                   MICROSOFT FORTRAN 5.0 VERSION

   Please press return key to continue
```

Figure 3. Introduction screen.

The Main Menu, "Run/Met Display Menu" (figure 4), displays the options available. **Main Menu Option 1 - Run NAPS Model** - executes the model and generates ray trace and sound intensity level data for the area surrounding the blast site. This option is described in detail in section 5.1. **Main Menu Option 2 - Display Meteorological Data** - provides visual displays of any met profile in graphic form. This option does not retain any sound intensity data.

Refer to section 5.2 for discussion of this option. **Main Menu Option 99 - Stop** - terminates the program.

To activate a Main Menu option, type the number of your choice and press <ENTER>.

```
                    MAIN MENU

               RUN/MET DISPLAY MENU

          1..  RUN NAPS MODEL

          2..  DISPLAY METEOROLOGICAL DATA

         99..  STOP TERMINATE PROGRAM

     ENTER THE NUMBER OF YOUR CHOICE:      1
```

Figure 4. Main menu - run/met display menu.

5.1 Run NAPS Model (Main Menu Option 1)

This option starts the calculation of the sound intensity levels. The user must first interactively define the blast site and blast data.

5.1.1 Interactive Data Input

The "Blast Site Menu 1" options, shown in figure 5, provide a listing of all available blast sites. The user should enter the number of the site conducting the test.

The "Blast Data Input Screen" (figure 6) queries the user for height, weight, and weapon. Enter the height (meters) above the surface at which the blast occurs. These heights depend on the weapon used or the type of testing being conducted. If the blast is at the surface, enter 0 for the height. If a weapon blast occurs, use 2 m as the height. Enter the blast weight in pounds; this also depends on the weapon or type of testing. A typical weight for a weapon blast is 26 lb.

At APG, blast sites 3, 5, and 8 are the most active sites, and the firing directions for these sites have been hard wired into the program. Blasts at all other site locations are assumed to be of uniform intensity in all azimuthal direction. If the site chosen is 3, 5, or 8, the weapon type must be identified; but if other sites are chosen, the "Weapon Type Menu" does not appear on the screen.

Identify the met profile to be used. The default file name given the profile when it was generated was "Blast.dat." If the file has not been renamed, press <ENTER>, but if another name has been assigned to the profile, then type the new file name and press <ENTER>.

```
                    BLAST  SITE  MENU

                       BLAST SITES

                   1. BRIAR POINT
                   2. FUSE RANGE
                   3. H-FIELD
                   4. I-FIELD
                   5. MAIN FRONT
                   6. NEW BOMBING FLD.
                   7. OLD BOMBING FLD.
                   8. PLATE RANGE
                   9. POVERTY ISLAND
                  10. TRENCH WARFARE

        ENTER THE NUMBER OF YOUR CHOICE:   4

    PLEASE WAIT, READING ELEVATION AND LAND USE DATA FILES.
    COMPLETED READING ELEVATION DATA FILE.
```

Figure 5. Blast site menu.

```
                 BLAST DATA INPUT SCREEN

    ENTER BLAST HEIGHT ABOVE SURFACE IN METERS:  2

    ENTER BLAST WEIGHT IN POUNDS:  26

            WEAPON TYPE MENU

        0.. UNIFORM BLAST
        1.. 105 HOWITZER  M102
        2.. 105 TANK  M60
        3.. 8 INCH HOWITZER  M110
        4.. 8 INCH SELF PROPELLED  M110A1
        5.. 120 TANK  (HEAT TPT)
        6.. 120 TANK  (SABOT)

           ENTER THE NUMBER OF YOUR CHOICE:    2

    ENTER MET PROFILE DATA FILE NAME (DEFAULT-> 'BLAST.DAT')
    apg51.dat
```

Figure 6. Blast data input screen.

** Programmer note ** Code in module NAPS1.FOR, Subroutine BLTMENU, at label 200, can be altered to allow weapon type and firing direction for all sites if desired. The directional distribution of sound intensity around the weapons listed in the "Weapon Type Menu" can be found in Module NAPS4.FOR, Subroutine DIRECTDB. The code can be modified to add additional weapon types, change directional distributions, or change line of fire directions.

5.1.2 Ray Trace and Sound Contour Options

All plots generated while running the model are completed at the bell sound. To obtain a hard copy of a plot, press <PRINT SCREEN>. Once a plot has been erased from the screen, it often cannot be recovered during this run. To clear the screen after the completion of a plot, press <ENTER>.

The sound propagation data gathered while the program calculates the ray traces at various azimuths is sorted, stored, and later used to produce the sound contour plot. The "Contour/Ray Trace Display Menu" (figure 7) lists the options available for generating this data.

```
                CONTOUR/RAY TRACE  DISPLAY MENU

    0....GENERATE CONTOUR DATA, RAY TRACES NOT DISPLAYED.
    1....GENERATE CONTOUR DATA, RAY TRACES WITH NO PAUSES.
    2....GENERATE CONTOUR DATA, PAUSE AT RAY TRACES.
    3....DRAW RAY TRACE PLOTS ONLY, NO CONTOURS.
    4....RETURN TO THE MAIN MENU
   99....STOP - TERMINATE PROGRAM
            ENTER THE NUMBER OF YOUR CHOICE:    1
```

Figure 7. Contour/ray trace display menu.

If sound contour mapping is desired, options 0, 1, and 2 generate the sound intensity data for the map, but each option offers different visual displays and run times.

Option 0 - Generate contour data, no ray trace display. This option generates the sound intensity data for the contour, but does not take the time to display each ray trace trajectory as the sound intensity data are calculated. As the program runs, a note is displayed on the screen indicating which azimuth is being processed.

Option 1 - Generate Contour Data, ray trace plots with no pauses. This option generates the sound intensity data and displays the ray trace trajectories as they are generated for the azimuths chosen. The program continues to run and will not pause after each ray trace display has been completed.

Option 2 - Generate Contour Data, pause at ray trace. This option also generates the sound intensity data but does pause at the bell after each ray trace trajectory display. The program waits for the operator to continue the process. This can be an advantage if there are certain ray traces that the user may wish to copy or analyze as the program proceeds.

Option 3 - Draws Ray Traces, no contour data. If no sound contour mapping is desired, but the visual presentation of a few ray trace trajectories is desired, option 3 provides a ray trace plot at any chosen azimuth rather than displaying the entire array of azimuth angles.

Option 4 - Return to Main Menu. This option returns the program to the "Run Model/Met Display Menu." At this level the program can be rerun or terminated.

Option 99 - Stop. Terminates the program.

5.1.3 Azimuth Angles

As stated in section 3, the terrain data was gathered along azimuths emanating from the blast source. These azimuths are in increments of 5°. Before sound propagation data can be generated, the azimuth increment desired must be stated. To ensure a resolution fine enough to give a reliable sound contour mapping, it is recommended that the increment not exceed 15°. The azimuths chosen must coincide with those in the terrain data bases, so the user must chose an angle that is a multiple of 5 and a factor of 360 to ensure equal spacing around the blast site. If no sound contours are desired, any azimuth that is a multiple of 5 may be selected. The azimuth notation follows the "met angle" definition; that is, the azimuth pointing north is 0°, east is 90°, south is 180°, and west is 270°.

To facilitate the math calculations the model starts calculating data at the 90° azimuth (to use the Cartesian coordinate convention) and proceeds to calculate counterclockwise. This is not a concern for the user, since all references to azimuth angles are in "met angle" notation. The "Select Azimuth Increment Screen," as shown in figure 8, queries the user for the desired azimuth increment.

```
                 SELECT AZIMUTH INCREMENT

THE AZIMUTH ANGLES ARE MEASURED CLOCKWISE FROM NORTH
INCREMENTS GREATER THAN 15 WILL NOT GENERATE A
RELIABLE CONTOUR PLOT.

THE INCREMENTS MUST BE A MULTIPLE OF 5 AND A FACTOR OF 360.
ENTER YOUR CHOICE OF AZIMUTH ANGLE INCREMENT  10

THE RAY TRACE PLOTS WILL BEGIN AT 90 DEGREES (EAST),
AND WILL OCCUR EVERY  10. DEGREES
COUNTERCLOCKWISE FROM EAST.

PLEASE PRESS THE RETURN KEY TO CONTINUE.
```

Figure 8. Azimuth selection screen.

5.1.4 Ray Trace Plot Options

If the user opts to run only ray traces and the azimuth angle increment has been declared, the program displays a "Ray Trace Plot Menu" (figure 9). This menu allows the user to choose which azimuth ray traces are to be plotted.

```
                    RAY TRACE  PLOT  MENU

        Azimuth angles are measured clockwise from NORTH.

        The Ray trace plots will begin at 90 degrees and
        continue counter clockwise.

        The CURRENT azimuth angle is       90

                      PLOT  OPTIONS

         1 - PLOT RAY TRACES for current azimuth angle.

         2 - DO NOT plot ray trace for current azimuth.
             Increment to the next azimuth.

         3 - NO FURTHER  Ray trace plots are desired.

             Please enter number of your choice.    1
```

Figure 9. Ray trace plot menu.

Ray Trace Option 1 displays the ray trace for the current azimuth. The current azimuth is stated in line 5 of the menu and is incremented on each pass through the cycle.

Ray Trace Option 2 allows the user to skip the current azimuth and increment to the next azimuth.

Ray Trace Option 3 terminates this cycle of ray traces and returns to the "Run Model/Met Display Menu" from which the program can be rerun or terminated.

Section 6.2 contains examples and a thorough discussion of the ray trace trajectory displays.

5.1.5 Main Plot Options Menu

When the sound propagation data has been generated it is stored in the data file, "Decibel.dat." This file stores the sound intensity and the range from the blast site. The program then displays the "Plot Options Menu" (figure 10), affording the user a variety of plot options.

5.1.5.1 Plot Options 1 and 99 - Exit Plot Menu. If for some reason no plots are desired, option 1 exits this menu and returns to the "Run Model/Met Display Menu" or option 99 will terminate the program.

```
                    PLOT OPTIONS MENU

         1... RETURN TO MAIN MENU

         2... DRAW BACKGROUND MAP

         3... DISPLAY SOUND PROPAGATION CONTOUR DATA

         4... DRAW SOUND ATTENUATION VS. RANGE

         5... DRAW ELEVATION CONTOUR

        99... STOP TERMINATE PROGRAM


              ENTER THE NUMBER OF YOUR CHOICE:     3
```

Figure 10. Plot options menu.

5.1.5.2 Plot Options 2 and 5 - Physical Features of the Area. Option 2 draws a background map of the blast area showing the land and water areas and other features of the area, such as the major cities and the state line between Maryland and Delaware. Section 6.4 , "Elevation and Background Plots," contains an example of the background map.

Option 5 draws the elevation contour of the area. An example of this plot is shown in section 6.4. The user can indicate the number of elevation contour levels desired and the height (in meters) for each level. The program uses the data in the elevation data file for the indicated blast site.

5.1.5.3 Plot Option 3 - Display Sound Propagation Contour Data. Option 3 draws the sound intensity contour map surrounding the blast site. The data file "Dblevel.dat" stores the contour decibel levels used in the previous program plot. These values are retrieved and can be used for this run or new decibel levels can be declared. If new levels are desired, first, enter the number of levels and then the decibel values in ascending order. These new levels are then rewritten to the storage file. If no storage file exists, the program will initiate a file, ask the user for the desired decibel values, and then store them in the "Dblevel.dat" file (figure 11).

Several examples and an explanation of the display of the sound intensity contour can be found in section 6.3. The contour levels appear in the legend at the lower right corner of the map. The blast data taken from the title line of the met profile and the interactive input entries appear in the upper right corner of the map. The contour levels are color coded on the screen (not evident in this black and white reproduction).

```
                 SELECT CONTOUR DECIBEL LEVELS

THE PROGRAM PLOTS A DB CONTOUR MAP OF THE BLAST.
YOU MAY USE DEFAULT DB LEVELS OR ASSIGN NEW DB LEVELS.
THE PRESENT DEFAULT LEVELS ARE:
                110.0  115.0  125.0  135.0

1... USE DEFAULT LEVELS
2... ASSIGN NEW LEVELS FOR THE CONTOUR PLOT.

   PLEASE ENTER YOUR CHOICE. (1 OR 2)   2


ENTER THE NUMBER OF CONTOUR LEVELS (MIN = 3 and MAX = 10)   4
ENTER THE CONTOUR LEVELS, SEPARATED BY COMMAS.
ENTER VALUES IN ASCENDING ORDER.
 108,  115,   125,  137
```

Figure 11. Select contour dB levels.

5.1.5.4 Plot Option 4 - Draw Sound Attenuation versus Range. Option 4 draws the sound attenuation plots. The menu for selecting the azimuth for the plot is shown in figure 12. Two curves are plotted on the graph. First, the attenuation due to refraction and reflection, and then another curve showing the attenuation including atmospheric absorption. Section 6.5 discusses these plots.

```
THE SOUND ATTENUATION WILL BE PLOTTED ALONG
THE AZIMUTH OF YOUR CHOICE.
PLEASE SELECT AN AZIMUTH ANGLE (MET ANGLE)
FROM THE FOLLOWING SET:

  90        75        60        45        30        15

   0       345       330       315       300       285

 270       255       240       225       210       195

 180       165       150       135       120       105


  45
```

Figure 12. Select azimuth for sound attenuation.

5.2 Display Meteorological Data (Main Menu Option 2)

There are occasions when it is advisable to look at the meteorological data before or after running the NAPS model to better understand the results produced by the model. Main menu option 2 provides the means by which the user can visually look at the various met profile parameters. The "Met Data Display Menu" (figure 13) provides a menu for selecting profile plots.

```
                         MET DATA DISPLAY MENU

     0.....RETURN TO THE MAIN MENU

     1.....TEMPERATURE               - ALTITUDE

     2.....RELATIVE HUMIDITY         - ALTITUDE

     3.....WIND SPEED                - ALTITUDE

     4.....WIND DIRECTION            - ALTITUDE

     5.....SPEED OF SOUND            - ALTITUDE  (GIVEN AZIMUTH)

          PLEASE ENTER THE NUMBER OF YOUR CHOICE:     3
```

Figure 13. Met display options menu.

Option 0 - Exits this menu and returns to the main menu, run model/met display menu.

Option 1 - Temperature versus altitude.

Option 2 - Relative humidity versus altitude.

Option 3 - Wind speed versus altitude.

Option 4 - Wind direction versus altitude. The wind direction is a circular entity and the two-dimensional flat plane representation can be misleading. If the wind direction passes from 360° to 0°, the curve will exit the right side of the plot and reappear on the left side.

Option 5 - Speed of sound versus altitude. This option requires the user to indicate for which azimuth the speed of sound is to be plotted. Once again, the azimuth choice must be a multiple of 5°. Figure 14 shows the menu for selecting the azimuth for speed of sound plot.

6. OUTPUT DATA: PLOTS AND FILES

Section 5 explained the various options the user has for selecting output displays while running NAPS. This section (6) and appendix C present several examples and explanations of the output displays. A hard copy of any screen display can be produced by pressing <PRINT SCREEN>.

```
                    MET DATA DISPLAY MENU

0.....RETURN TO THE MAIN MENU

1.....TEMPERATURE               - ALTITUDE

2.....RELATIVE HUMIDITY         - ALTITUDE

3.....WIND SPEED                - ALTITUDE

4.....WIND DIRECTION            - ALTITUDE

5.....SPEED OF SOUND            - ALTITUDE  (GIVEN AZIMUTH)

        PLEASE ENTER THE NUMBER OF YOUR CHOICE:      5

AZIMUTH ANGLES ARE MEASURED CLOCKWISE FROM NORTH.
ENTER YOUR CHOICE OF AZIMUTH ANGLE FOR THIS PLOT:  45
```

Figure 14. Select azimuth for speed of sound Plot.

6.1 Met Profile Plots

Figures 15 through 20 are examples of the plots of the various met profile data. Each plot display is the same physical size, which enables overlaying of the various curves for comparisons. The y-axis is dimensioned from 0 to 3200 m for all curves. The x-axis is subject to the max and min values of the data, thus the range may differ with each profile. As noted previously, the wind direction is circular, and the flat plane representation of this may be misleading. If the wind direction passes from 360° to 0°, the curve will exit the right side of the graph and reenter on the left side. (See figure 21.)

6.2 Ray Trace Plots

A screen plot of ray trace trajectories along each specified azimuth provides the user with a pictorial view of the regions with downward versus upward refracting sound rays.

All ray trace plots have fixed dimensions and are the same physical size. The height (y-axis) ranges from -200 to 1600 m and the range (x-axis) is from 0 to 32 km. The actual ray trace calculations can extend to a height of 3000 m (or max altitude) and a range of 40 km.

The surface terrain is drawn in green. It displays the surface elevation (resolution 200 m) and takes into account the curvature of the earth. The dotted line (blue curve) superimposed on the plot is the speed of sound for this azimuth. It has no absolute magnitude displayed, but is a good reference to help explain the behavior of the ray trace trajectories.

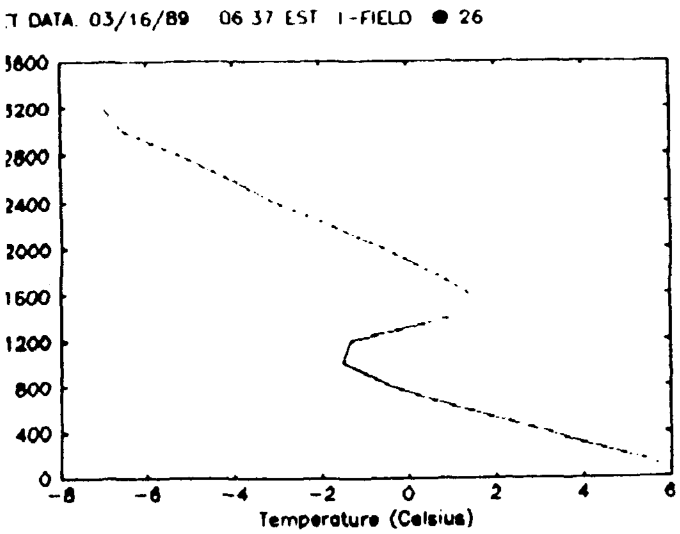

Figure 15. Altitude vs temperature.

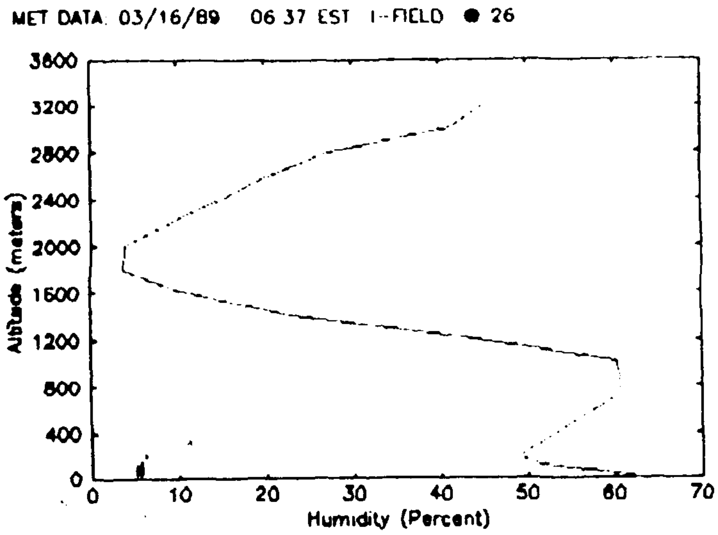

Figure 16. Altitude vs relative humidity.

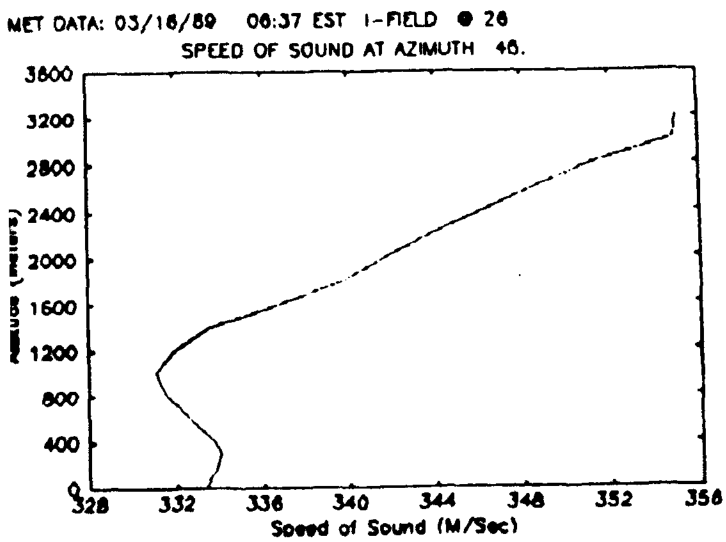

Figure 17. Altitude vs speed of sound - azimuth 45.

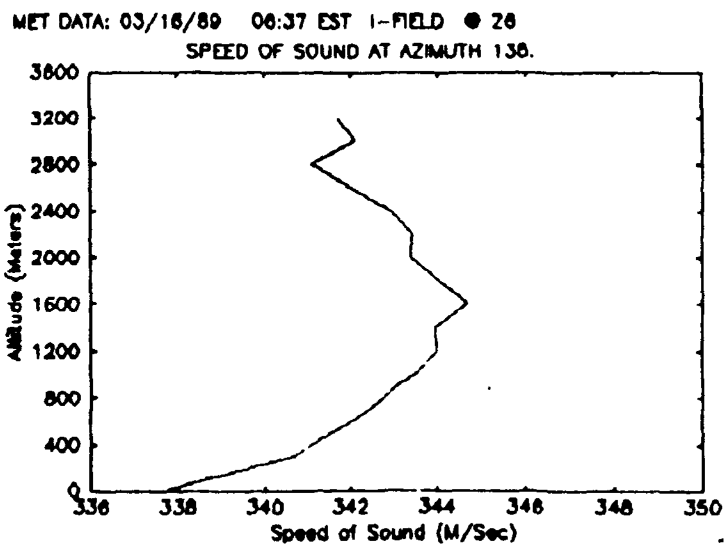

Figure 18. Altitude vs speed of sound - azimuth 135.

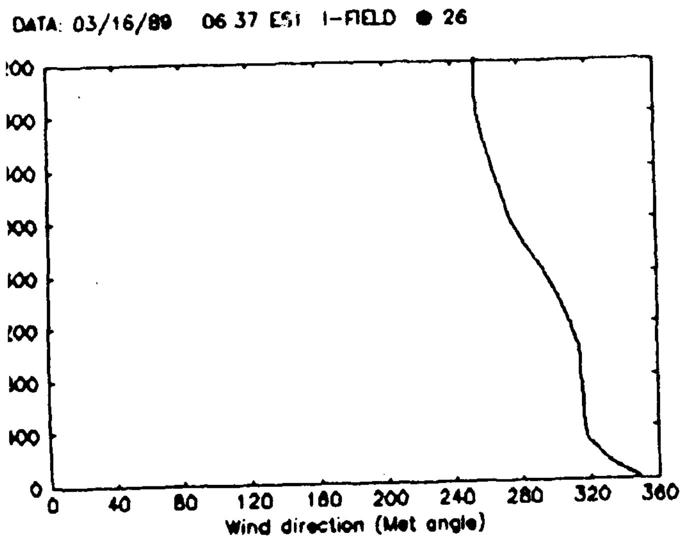

Figure 19. Altitude vs wind direction.

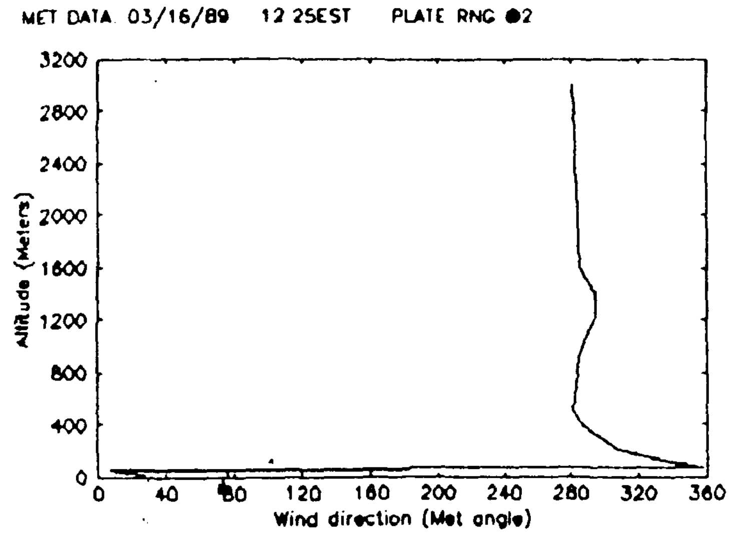

Figure 20. Altitude vs wind direction (wrap).

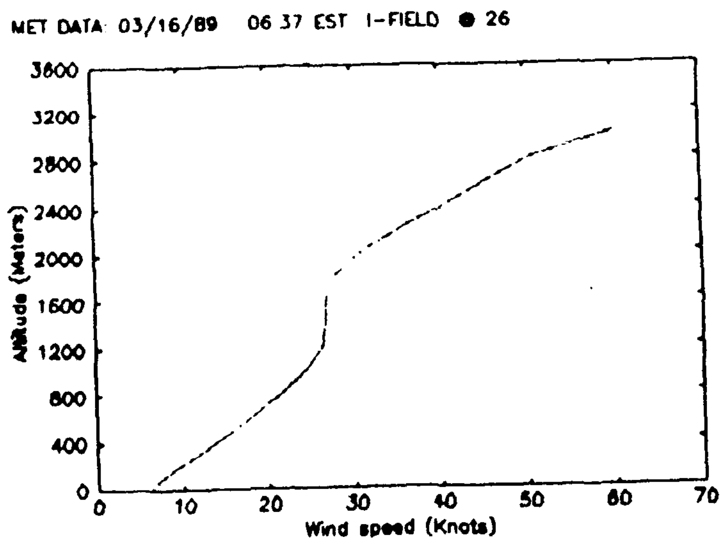

Figure 21. Altitude vs wind speed.

The ray trace trajectories are drawn in red. If all the sound for this azimuth is refracted upward, the plot shows only four or five upward trajectories. Several examples of ray trace plots are shown in figures 22 through 25.

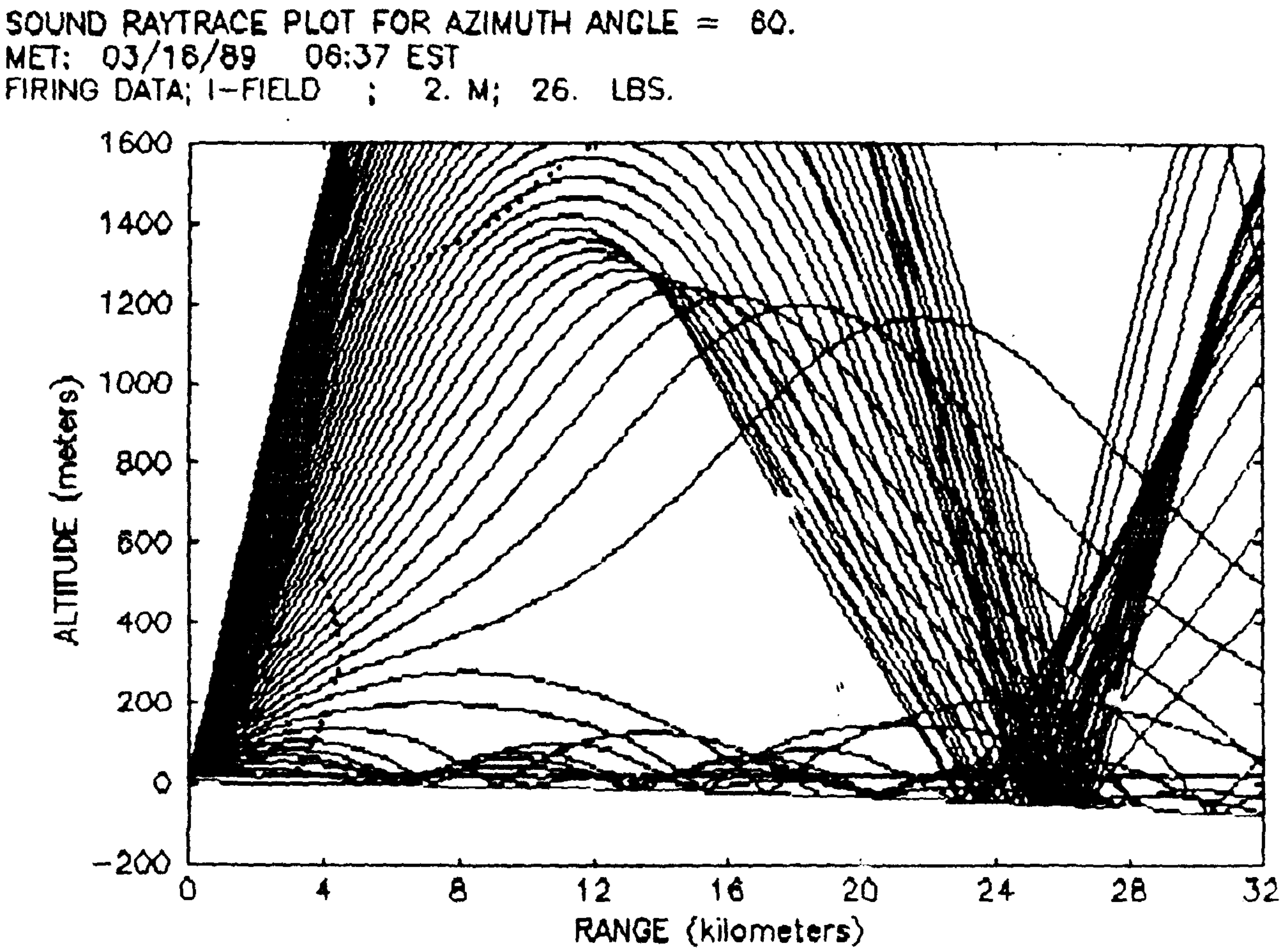

Figure 22. Ray trace plot - azimuth 60.

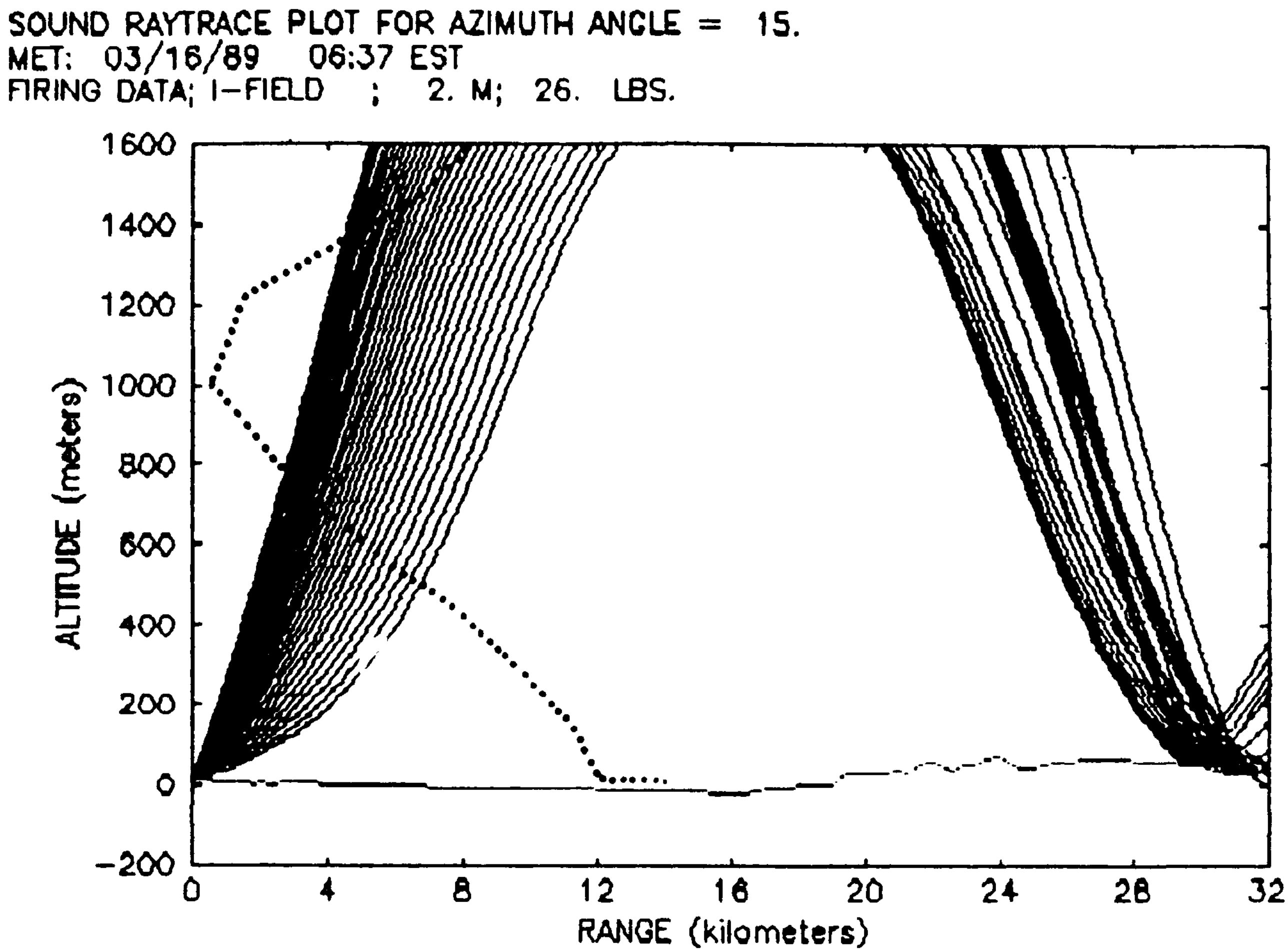

Figure 23. Ray trace plot - azimuth 15.

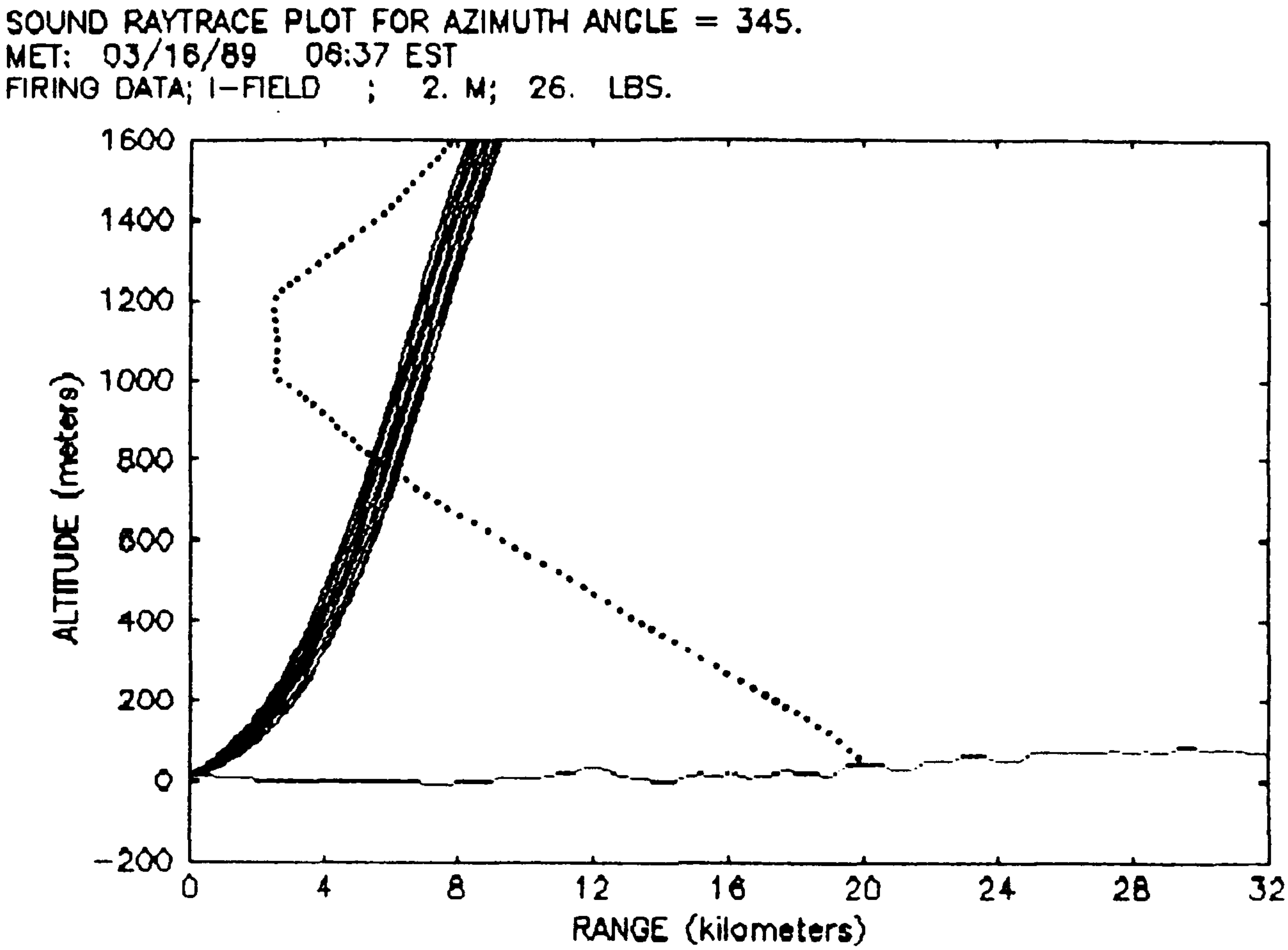

Figure 24. Ray trace plot - azimuth 345.

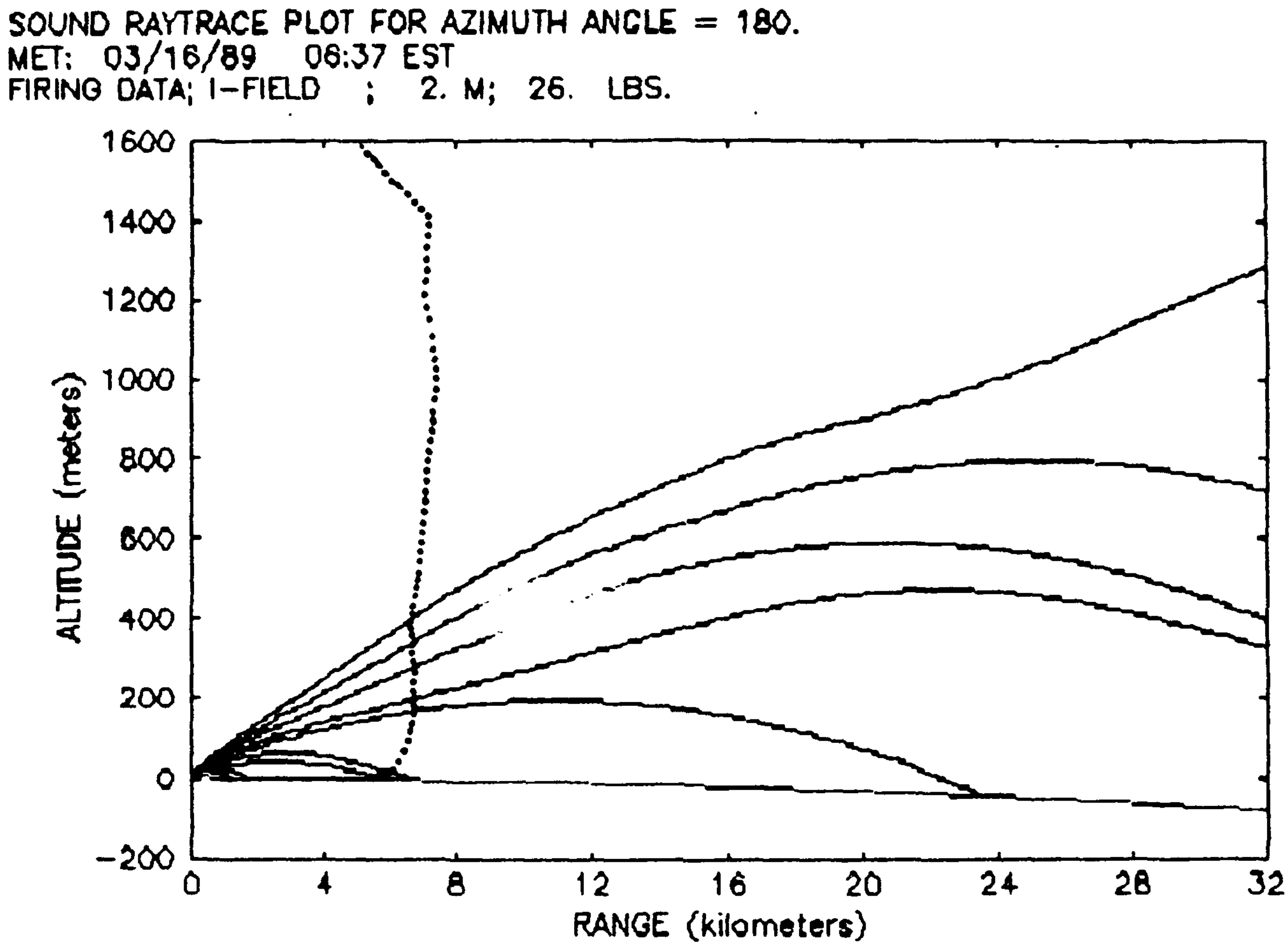

Figure 25. Ray trace plot - azimuth 180.

6.3 Sound Contour Plots

The NAPS model generates sound intensity levels along the entire range of a spoke from the blast source to 40 km at a specified azimuth angle as previously described. The azimuth angle is then incremented by the user specified amount, which is a multiple of 5° and is a divisor of 360°, and then the process is repeated. When the entire 360° of azimuth have been spanned and combined for overlapping rays, the arrays of sound intensity level by range and azimuth are written to the storage file "Decibel.dat." The contour plotting portion of the model uses this data to draw the contours at fixed levels of intensity. The contour levels are superimposed on a colored background map of the Aberdeen area. The blast site is marked and the contour levels are drawn in various colors. The default dB levels are 108, 115, 125, and 137, but the user can opt for up to a total of 10 levels. The legend on the lower right corner of the plot states the decibel levels used. If the user chooses an azimuth angle increment of 15° or less, the contours will be smooth; but if the increment is larger, the resulting contour tends to be segmented into pie-shaped wedges. The <PRINT SCREEN> key allows the user to get a hard copy of the contour plots. Figures 26 and 27 are examples of sound intensity contour plots.

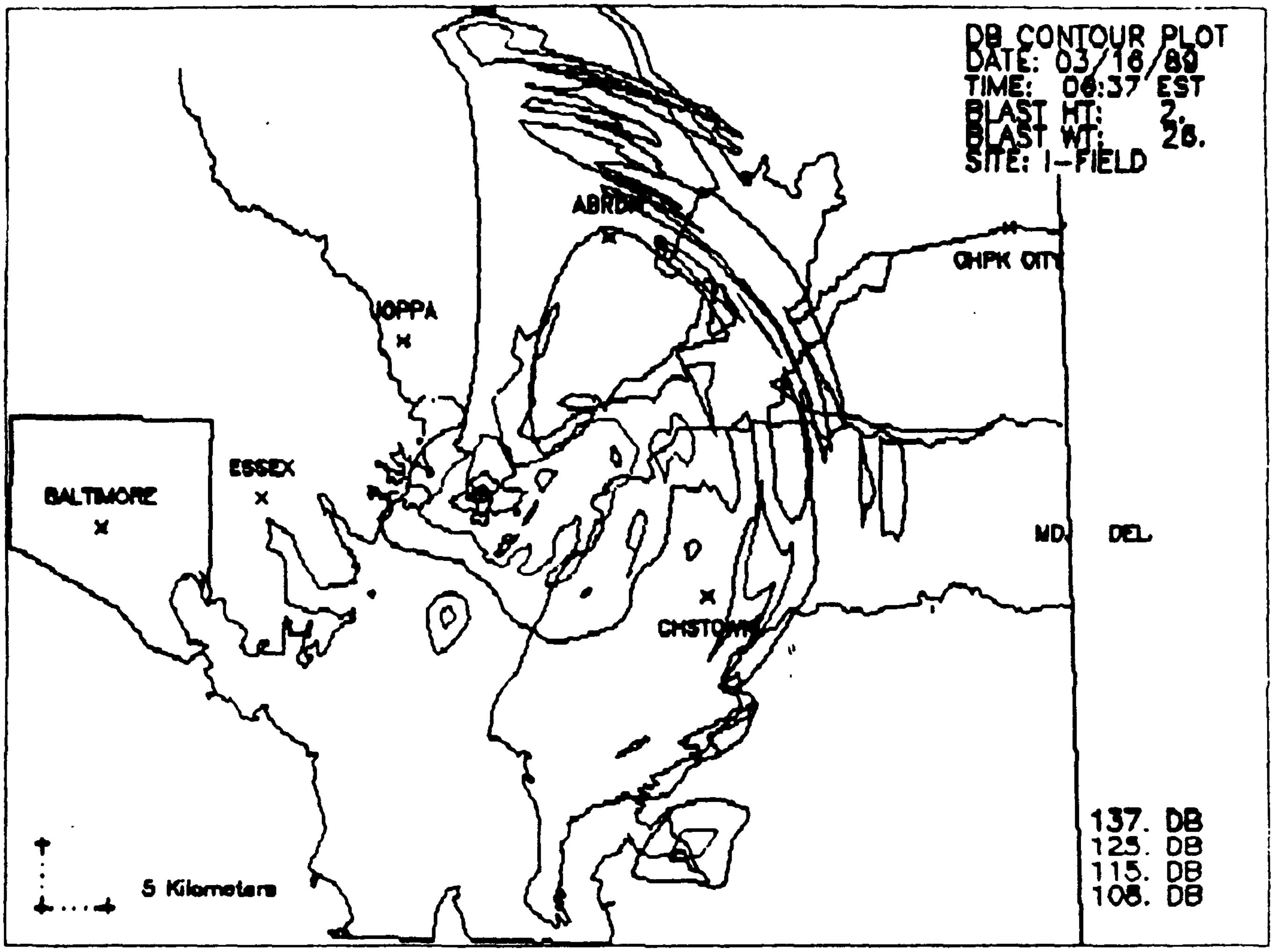

Figure 26. Sound contour plot 03/16/89 data.

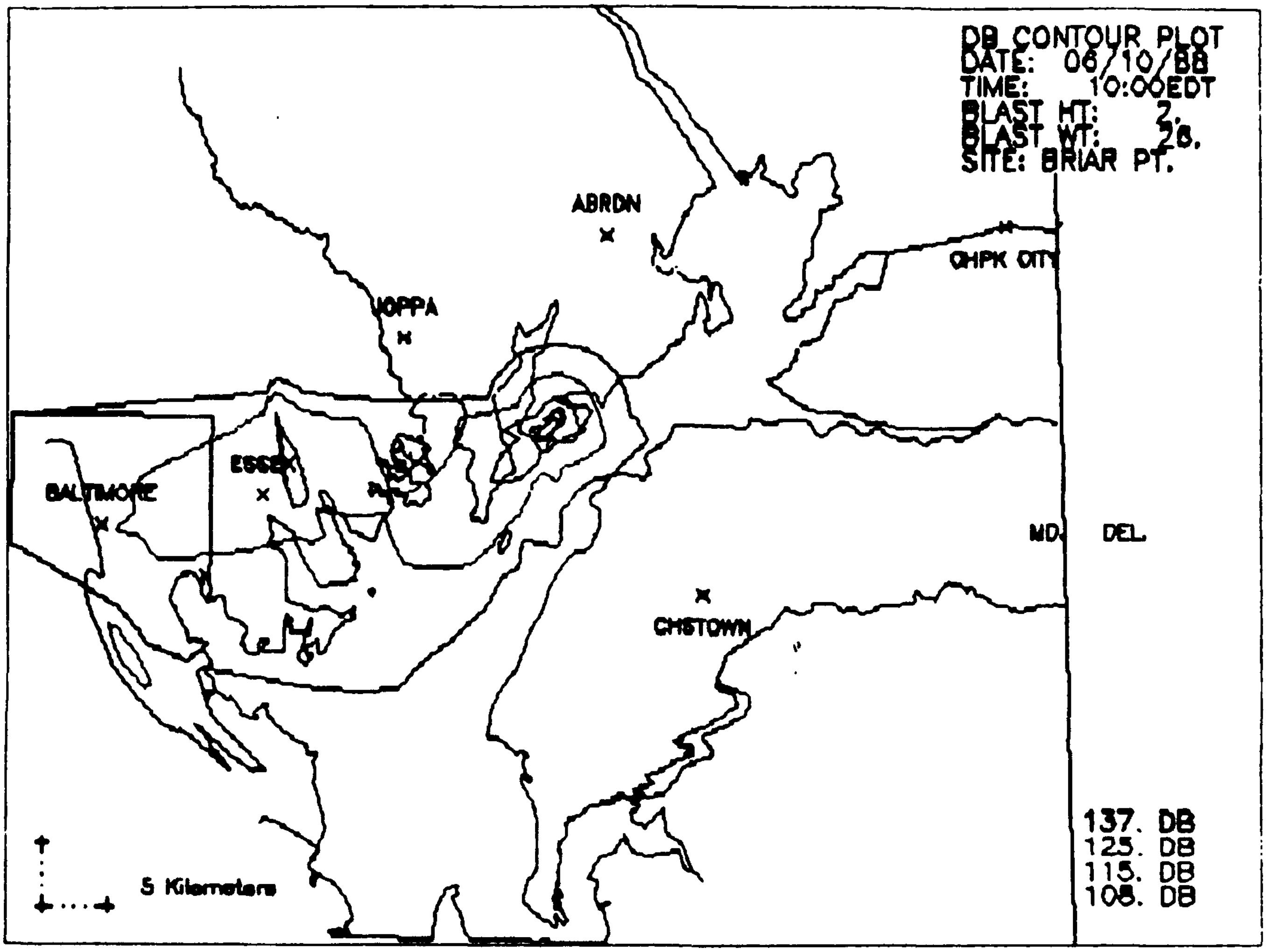

Figure 27. Sound contour plot 10/06/88 data.

6.4 Elevation Contour and Background Plots

These two outputs, although seldom used, can be helpful. If at any time a background map of the area surrounding the blast sites is needed, this is a quick method to obtain one. The background map contains land/water boundaries, APC boundaries, and the location of cities. If the elevation around the blast site is of some significance, a map can be drawn showing the contours of elevation in the APG area surrounding the blast site. The maximum number of elevation contour levels is 10 and can be selected by the user. (See figures 28 and 29.)

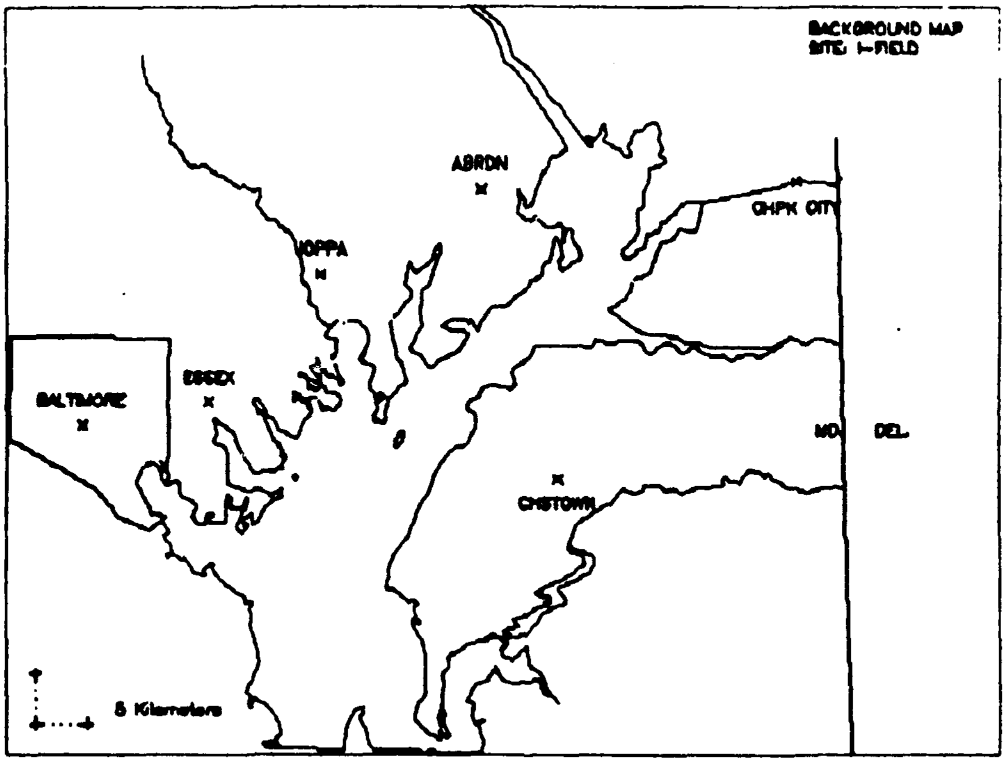

Figure 28. Background map of APG area.

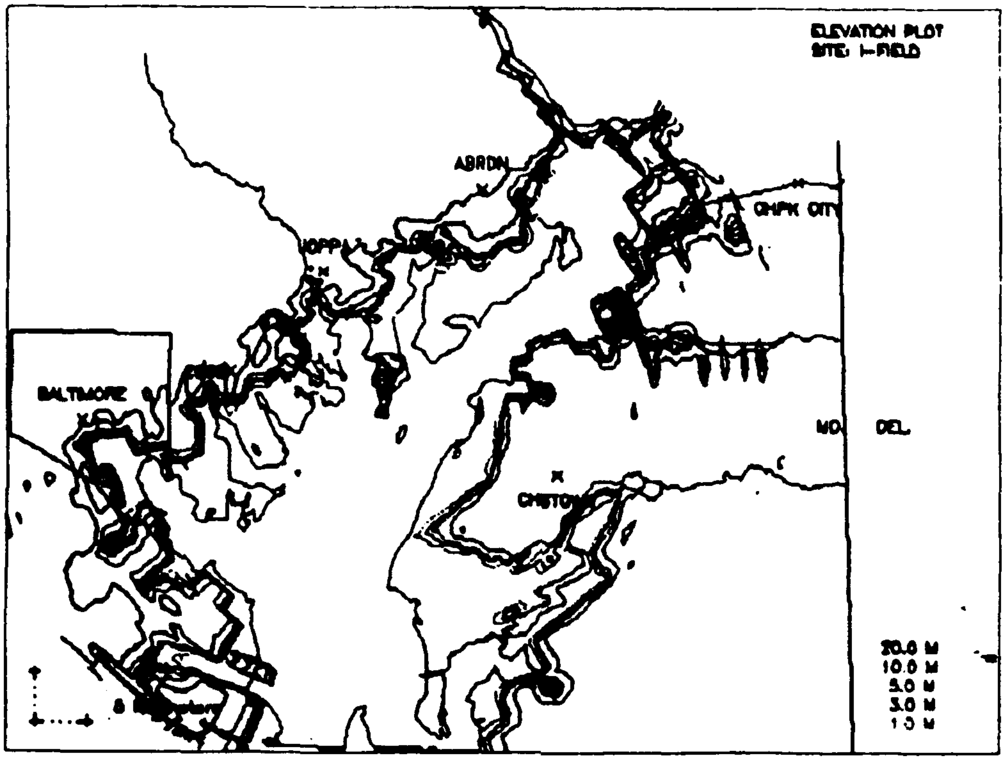

Figure 29. Elevation contour map of APG area.

6.5 Attenuation Plots

The model allows for the plotting of transmission loss over the terrain from a reference distance of 1 km according to the guidelines from the RS6-11 meeting as compiled by Dr. Alwin Gudesen. The broken line (red) is the transmission loss in decibels from a reference distance of 1 km due to atmospheric refraction and reflection off water. The solid line (green) is the transmission loss in decibels from a reference distance of 1 km due to the refraction and reflection, and also includes the loss due to atmospheric absorption. Figures 30 and 31 are examples of attenuation plots.

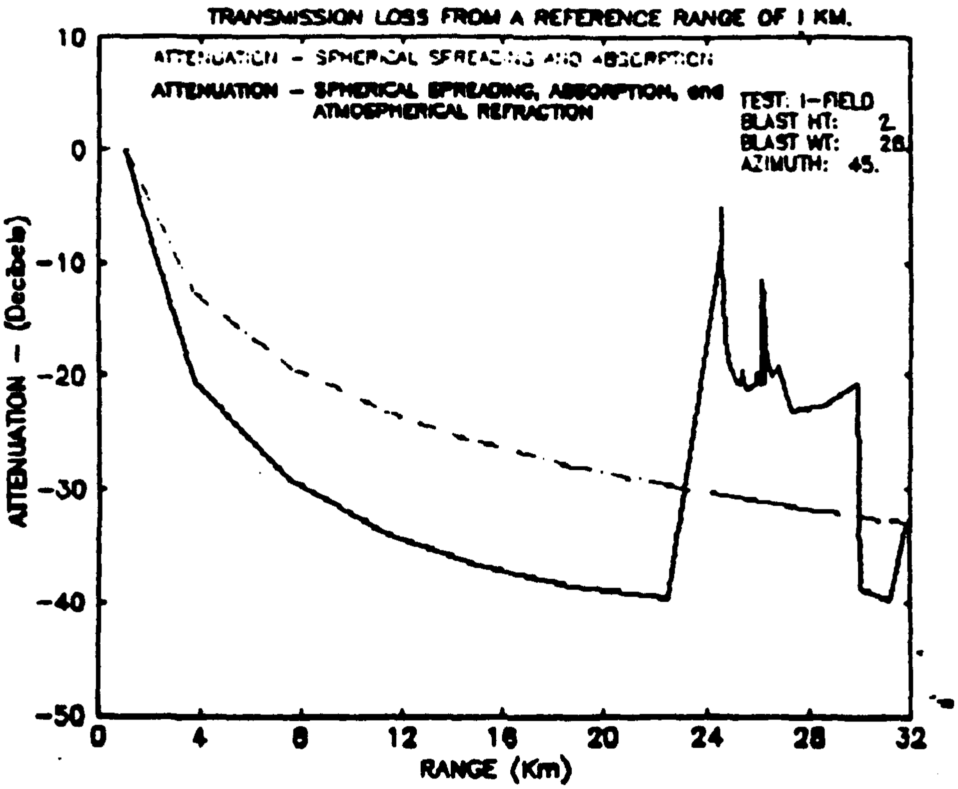

Figure 30. Sound attenuation plot - azimuth 45.

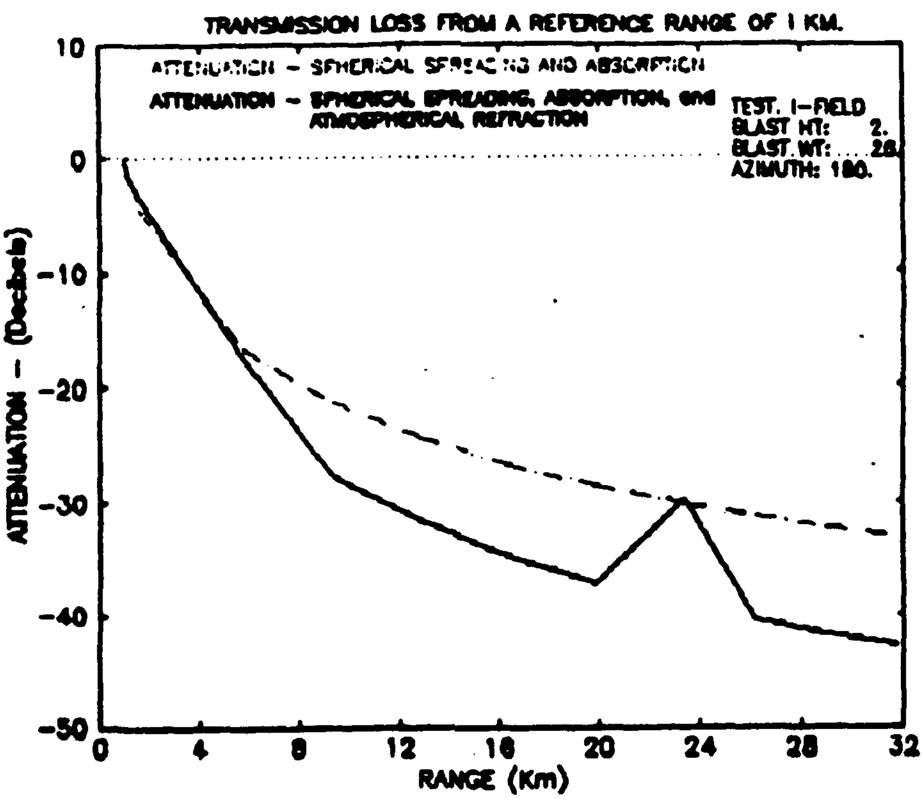

Figure 31. Sound attenuation plot - azimuth 180.

6.6 Tabular Output - Sound dB File and Summary File

The main thrust of the NAPS is to provide the user with various visual outputs to explain the propagation of sound around a blast site, but there are some tabular data files generated by the model. As mentioned previously, the sound contour intensities and ranges for each azimuth are stored in a file, "Decibel.dat." This file functions as a store house for the data, but once the sound contour plot has been drawn, the data is no longer needed. This file remains on the directory until the next time the model is run, and then it will be overwritten by the next set of values generated. If for any reason the user would want to look at this file or keep this file, the user should rename the file so that it can be saved. This can be done at any time after the completion of a run. Appendix C contains an example of this file.

The largest output file is "Summary.dat." This file retains much of the intermediate values calculated by the model as it generates the ray trace trajectories and determines the sound levels. One set of data is generated for each azimuth. Appendix C gives an example and a full interpretation of this output file.

APPENDIX A. COMMAND FILES

1. COMPILING AND LINKING

The noise assessment prediction system (NAPS) program code is divided into eight modules. Each module has to be compiled and then linked together with the graphics library. Figure A1 is an example of the command file used for the Aberdeen version of the program. This command file uses the "Make" utility. The options used to compile are:

fl - fortran compile option

/c - compile but do not link

/Gt[n] - data size threshold, cutoff value for allocating data segments. This is a large program, and it requires several large data files, so the value of n was set at 1024.

/4Yb - debug option, gives error code numbers, subroutine, and line number where error occurred. It is advisable to recompile without this option once the program has been debugged. The executable code will be much smaller.

/AH - huge model, the memory model defines rules compiler uses to organize program's code and data segments in memory.

/G2 - compile with the math co-processor instructions

Link the seven NAPS modules to the graphics library, GRAFLIB. The executable code is NAPS.EXE.

```
            .for.obj:
            fl /c /Gt1024 /AH /G2 $*.for
            naps1.obj:      naps1.for
            naps2.obj:      naps2.for
            naps3A.obj:     naps3A.for
            naps3b.obj:     naps3b.for
            naps4.obj:      naps4.for
            naps5.obj:      naps5.for
            naps6.obj:      naps6.for
            naps7.obj:      naps7.for

naps.exe:  naps1.obj  naps2.obj  naps3a.obj  naps3b.obj naps4.obj
naps5.obj naps6.obj naps7.obj

LINK  naps1+naps2+naps3a+naps3b+naps4+naps5+naps6+naps7,naps,NUL,
GRAflib,,
```

Figure A1. Command file to compile and link NAPS.

APPENDIX B. INPUT DATA FILES

1. METEOROLOGICAL DATA FILES

As stated in section 3.1 of the manual, the meteorological (met) profile was generated from the data gathered at various sources. The profile contains values for designated heights above the surface. The vertical profiles are for **temperature** in Celsius, **relative humidity** (a percent), **wind speed** in meters per second, **wind direction** referenced in meteorological notation (North as 0°), and **pressure** in millibars. Figure B1 is an example of a met profile.

The first line of the file is used for identification on several of the output plots. Characters 1 to 10 represent the date of the data, characters 11 to 20 the time the file was generated, and the remaining characters on the first line can be any information that the user wants to use for identification of the various output plots. Our example file places the site and the charge weight on this line.

Lines 2 and 4 are identification labels for the data in lines 3 and 5. Line 3 states the surface altitude (meters) at mean sea level and the surface pressure (millibars).

The main body of data starts at line 5. The titles above the columns identify the data. Column "line" is an integer numbering of the lines of data. Column "AGL" is the predetermined heights above the surface (in meters) that are needed to give the best results for the noise assessment prediction system (NAPS). The critical heights are those below 1000 m, thus giving finer resolution for the lower altitudes. It is also recommended that the data go at least 3000 m above the surface. Column "RH" is the relative humidity, column "WSPD" is the wind speed, column "WDDIR" is the wind direction, and column "PRESS" is the atmospheric pressure. Starting with line 5, seven data entries per line are read in with a free format so the spacing is not critical, just separate entries with commas or spaces. The actual number of data lines may vary. The last line must be a line of actual data and not zeros or other invalid data.

2. PHYSICAL DATA FILES

Four data files define the background map for the APG area: "City.dat," "Politic.dat," "Boundary.dat.," and "Water.dat." The source of most of the physical data defining APG came from the USGS land use and land cover digital data tapes. The coordinates used in USGS files are scaled UTM values. Due to the magnitude of the actual UTM values, scaling factors for X (-4300000) and for Y (-200000) were used to get this "pseudo" set of UTMs as coordinates for the mapping of the area.

03/16/89 06:37 EST 1-FIELD @ 26#

SFALT	SFPRES					
3.00	1022.					
LINE	AGL	TEMP	RH	WSPD	WDDIR	PRESS
1	0.	5.9	63.0	1.5	350.0	1022.
2	2.	5.9	62.8	3.1	349.7	1022.
3	10.	5.9	61.9	3.2	348.6	1020.
4	50.	5.8	57.3	3.5	343.0	1019.
5	70.	5.8	55.0	3.7	340.2	1014.
6	100.	5.7	51.6	3.9	336.0	1008.
7	150.	5.4	49.5	4.4	330.0	1002.
8	200.	4.9	49.4	5.0	325.4	996.
9	300.	4.0	51.5	6.2	318.7	983.
10	400.	3.1	53.6	7.2	316.6	971.
11	500.	2.2	55.8	8.2	316.1	959.
12	600.	1.3	58.0	9.2	315.7	947.
13	700.	.3	60.2	10.2	315.2	936.
14	800.	-.4	60.8	11.1	314.6	924.
15	900.	-.9	60.5	11.8	314.1	913.
16	1000.	-1.5	60.3	12.6	313.5	901.
17	1200.	-1.3	44.1	13.5	308.3	879.
18	1400.	1.0	22.9	13.7	301.6	857.
19	1600.	1.4	10.4	13.7	293.3	836.
20	1800.	.5	3.7	14.2	282.2	816.
21	2000.	-.6	3.8	15.8	274.0	795.
22	2200.	-1.8	9.4	18.3	269.0	776.
23	2400.	-3.0	14.9	20.8	264.1	756.
24	2600.	-4.1	20.4	23.3	259.1	737.
25	2800.	-5.3	27.4	26.1	254.9	719.
26	3000.	-6.6	41.4	31.0	254.1	701.

Figure B1. Example of met profile.

2.1 Background Data

The "Politic.dat" and the "Water.dat" files were taken directly from the USGS tapes via a program supplied by the agency. They have the same format as the original tape files, but only the data covering the desired area were retained. The first five lines are header and general information not pertinent to the NAPS program, but were retained for ID purposes. Figures B2 and B3 are examples of these files. Line 6 of the file gives the data ID number, the number of sets the data were divided into, and the total number of coordinate values in the file. The next several lines give the set number and the number of points in that set. The remaining lines are the actual coordinates written in a (16I5) format per line.

The "City.dat" (figure B4) file lists the number of characters in the city name, the city name string, and the coordinates for the location of each city. The city name is drawn at a given interval above or below the city location mark.

The "Boundary.dat" file lists first the number of text lines, then the number of characters in the string, the string, and finally the location for this string. The remaining data points, starting at line 5, outline the APG area. An example of this file is shown in figure B5.

```
     3      152       33    3    8
 1    2    0    1    393700    1972 4017  17052146913184 4016
390000   780000   400000   780000   400000   770000   400000   760000
390000   760000   390000   770000   0    50    156    81328
BALTIMORE, PA WV MD VA ,  1:250000 QUAD POLITICAL MAP
    1    3  152    33  156    40 4017 17052146913184    62
    1   98
    2  102
    3  152
16794 443516797 456116794 456916802 485016801 486216805 511116804 512516807
5358
16806 536316810 559316809 560716814 589016813 589416799 589815762 591915756
5918
15751 591615726 591915261 592715257 591515258 590715256 590115257 588815236
4895
15256 488215267 487515354 482315376 480915393 479915484 474215496 473615559
4697
15570 469115655 463815667 463115696 461415707 460815801 455015812 454315881
4501
15899 449115910 448315934 447215946 446515963 445615982 444615993 444016012
4432
16031 441123400 785023550 171016740 405416734 404916724 404616706 403116669
4002
16648 398516612 396016586 397116322 408516301 411016288 412516271 414616258
4162
16246 417716204 423016187 425116170 427216153 429216137 431316120 433416103
4355
16086 437516074 439116061 439716031 4411
```

Figure B2. File: POLITIC.DAT.

```
    27     5288     33     3     8     1     2     0     1    393700     1972
4017 17052146913184 4016 2085 4387131831292912946214681280321337 170612683
1849
390000     780000     400000     780000     400000     770000     400000
760000
390000     760000     390000     770000     0    50   156          81328
BALTIMORE, PA WV MD VA ,  1:250000 QUAD POLITICAL MAP
    1    27 5288    33  156    40 4017 17052146913184    62
    1   188
    2   262
    3   336
    4   364
    5   396
    6   744
    7   924
    8  1912
    9  2656
   10  2790
   11  2890
   12  2926
   13  3064
   14  3102
   15  3860
   16  3914
   17  3932
   18  3968
   19  4144
   20  4288
   21  4500
   22  4684
   23  4808
   24  4854
   25  4884
   26  4896
   27  5288
20116 284120123 283920132 283320144 282720159 281420152 279920143 278920125
2777
20118 277820112 277520100 276720092 274920092 274120094 272220103 270220101
2690
20101 269020201 263020350 280020360 260020500 250020550 235020650 220020600
2275
      .    .    .

18256 620918276 619518281 618418282 617118282 612418288 609118302 606818319
6057
18350 604418369 604218382 603818414 6026
```

Figure B3. File: WATER.DAT.

9	BALTIMORE	15950.00	5041.13
5	ESSEX	17212.40	5275.85
5	JOPPA	18320.00	6535.00
7	BEL AIR	18405.00	7685.00
5	ABRDN	19900.00	7370.00
3	HdG	20520.00	7740.00
7	N. EAST	21900.00	8350.00
9	CHPK CITY	23002.00	7439.00
7	CHSTOWN	20652.00	4487.00

Figure B4. File: CITY.DAT.

```
  3
1  A       19580.87    6350.60
1  P       19880.84    6600.00
1  G       20180.00    6850.00
19081.57    4797.02
18234.56    5169.08
18588.26    6052.71
18457.95    6089.92
18988.49    6331.75
19035.03    6024.81
20263.65    7131.67
20784.88    7029.36
20915.19    6685.21
19081.57    4797.02
```

Figure B5. File: BOUNDARY.DAT.

2.2 Terrain Data

Each of the 10 blast sites is defined by an altitude and a land use file. The files are named by prefixing "Elev" and "Att" to the site number (for example "Elev4.dat" and "Att4.dat" are files for site number 4).

The first line of these files states the actual UTM coordinates of the blast site, the maximum horizontal range (in meters), the number of points in each subset of data, and the horizontal increment (in meters) between each data point in the subset. These subsets of data are often referred to as "spokes."

The "Elev" file records altitudes at the designated locations along the spokes. Using an altitude grid terrain map, azimuths at 5° intervals are extended out 40 km from the blast site. The altitude is read every 200 m along these azimuths. The data for each azimuth is a subset or a "spoke" and the spokes are recorded sequentially starting with the azimuth to the east (90°) and proceeding counterclockwise. As previously stated, all directions refer to meteorological direction, which sets north as 0° and east as 90°.

The "Att" file records the surface type at the same designated locations, and the data are assembled in spokes in the same manner as the "Elev" file. A water surface is indicated by 1 and a land surface by 0. Each file contains a total of 72 spokes of data. Figure B6 is an example of an elevation file, and figure B7 is an example of an attribute file for the first spoke of data for site 4.

```
    389112.  4353177.  40000.    201    200.
  14   11    9    6    0    0    0    0    0    0    0    0    0    0    0
 0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0
   0    0    0    0    0    0    0    0    0    0    0    1    0    0    0
 0
   0    0    0    1    2    5   10   12   14   14   15   15   15   15   15
 15
  15   15   15   15   15   15   15   15   15   16   16   15   15   15   15
 15
  15   15   15   15   14   12   12   12   12   12   12   13   18   18   16
 16
  15   15   15   15   15   15   15   15   15   15   15   15   15   15   15
 15
  15   15   15   15   15   15   15   15   15   15   15   15   15   15   15
 15
  15   15   15   15   15   15   15   15   15   15   15   15   15   15   15
 15
  15   15   15   15   15   15   15   15   15   15   15   15   15   15   15
 15
  15   15   15   15   15   15   15   15   15
```

Figure B6. File: ELEV4.DAT spoke data at azimuth 90.

```
    389112.  4353177.  40000.   201    200.
  0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0
 0
  0 0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1
 0
  1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

Figure B7. File: ATT4.DAT spoke data at azimuth 90.

APPENDIX C. OUTPUT FILES

1. SOUND PROPAGATION DATA

All output files generated by the noise assessment prediction system (NAPS) program are stored in the C:\MET\DATA directory.

Table C1 is an example of part of a "Decibel.dat" file generated during the running of the NAPS model. Because of the length of the files, only a portion of the first set of the data has been included in this example.

The first four lines provide the identification for this run and the parameters under which it was run. Most of this information is used for titles to the plots.

The first line is the ID line from the met profile data. The second line is the ID line used in the met profile plots and the ray trace plots. The third and fourth lines give the actual UTM coordinates of the blast site, blast height, blast weight, range, azimuth increment, and the resolution of the elevation data base.

The remainder of the file is divided into sections, one for each azimuth. The first line of a section gives the azimuth and then the number of data entries for this azimuth. The azimuth values have been converted to the Cartesian system, thus the azimuth 0 is the azimuth to the east. A portion of the section was deleted to conserve space and to present a more compact representation of the file. The number of azimuths in a file depends on the azimuth increment chosen by the user.

The first column is the range at impact and the second column is the sound intensity in decibels at that range. These values are used for a sound contour plotting. The third column is the "many ray focus dB." The values in column 3 are the values needed to plot the attenuation curves.

TABLE C1. DECIBEL.DAT DATA FILE

```
03/16/89   06:37 EST  I-FIELD  @ 26#
I-FIELD   ;   2. M;  26.  LBS.
389112.000000  4353177.000000    2.000000    26.000000
40000.000000        15.000000      200.000000
0.000000E+00          98
   1.000004       202.598000    5.722046E-06
  14.262450       177.219300    1.352501E-02
  27.524890       171.017200    9.313011E-02
  40.787330       167.419400    2.529507E-01
  54.049770       164.989900    5.132809E-01
  67.312210       163.243900    8.638973E-01
  80.574650       161.528500    8.668118E-01
  93.837100       160.171300    9.654903E-01
 107.099500       159.083600        1.140860
 120.362000       158.197800        1.370489
 133.624400       157.467000        1.638418
 155.436700       160.877700        6.493856
 1175.471000      131.829400       -3.223955
 1666.160000      129.905100       -1.815149
 2088.125000      130.849900        1.286505
   . . .             . . .            . . .
30049.510000      109.242300        5.156645
30081.620000      109.101700        5.026320
30271.000000      108.356200        4.340704
30321.490000      108.181300        4.181761
30515.000000      107.130100        3.191343
30901.100000      107.009300        3.190733
31028.140000      106.971200        3.191748
31378.120000      107.401700        3.729460
32065.300000      108.532600        5.067312
32070.040000      103.468700    4.873276E-03
32160.730000      103.504200    6.731987E-02
32357.800000      103.875300    4.967861E-01
32773.120000      104.423200        1.166510
34048.970000       91.582930      -11.308820
36032.650000       90.267280      -12.083440
38016.320000       89.154410      -12.684280

  15.000000          22
   1.000000       202.598000    5.722046E-06
 7976.662000      107.380000       -9.377985

   . . .             . . .            . . .
```

The "Decibel.dat" file remains in the directory until deleted by the user or overwritten by the next model run.

2. SUMMARY DATA FILE

The "Summary.dat" file is generated every time the NAPS model is run. If a "Summary.dat" file exists prior to a run, it will be overwritten; thus, there is no buildup of files in the system. The file is large and is arranged into sections, the first six lines give identification information and parameters used during the run, and the remaining portion of the file is divided into one section per azimuth. Again, the number of azimuths depends on the azimuth increment chosen by the user.

The first line is the met profile header line (table C2). Lines 2 and 4 are title lines identifying the variables that follow in lines 3 and 5. The data for each azimuth are identified by met angle notation and the columns of data are titled.

A complete explanation of the derivation and implementation of the equations used by the NAPS model can be found in the technical manual, UDR-TR-91-87, section 4.2. The following excerpt is from the technical manual and is included here to aid in the discussion of the summary file.

NAPS calculates the decibel level of sound ray from the equation:

$$dB = 20\log_{10}\left(\frac{42.48}{R^{1.1}}\right) + 20\log_{10}\left(W^{0.367}\right) - 20\log\left(P_o\right) \pm DbDir(Az) + 20\log_{10}(Factor) \quad (1)$$

where

R = the range from source to impact along a spoke
W = the blast charge weight in equivalent pounds of TNT
P_o = the reference pressure used in defining decibels
DbDir (Az) = the excess attenuation due to asymmetric directionality of noise from the source
Factor = a magnification factor

The first column of azimuth data, "Ray No," identifies a range location, usually associated with a ray trace, and decibel information at that location. It may or may not represent the impact location of a ray trace, depending upon whether it is within a downward refraction zone or a shadow zone. Shadow zone range points can be identified by the fact that the value in the "Elev Angle" column will be the same as that for the following ray number. The value of elev angle gives, for downward refracting rays, the initial elevation angle of the ray at the blast source. The column "Range" gives the range (meters) at impact point. Otherwise, if a ray refracts upward and the range value is in a shadow zone, then the elev angle value is not associated with that ray number, but rather represents the elevation angle of the next downward refracting ray that impacts the ground.

The first term of Eq. (1), $20\log_{10}\left(\frac{42.48}{R^{1.1}}\right)$ is derived from the recommendations of ANSI S2.20-1983 and accounts for attenuation due to spherical spreading and atmospheric absorption. This term is added to the third term (Reference dB term) and printed in the NAPS tabular output (table C2) as "Free Air dB." This is the calculated sound intensity in decibels for that ray at the impact range point if only spherical spreading and absorption were taken into account. If a ray number is in a shadow zone, that is, the ray bends upward and does not return to the ground, then the range value is an interpolated value between the first (or last) downward refracting ray that impacts the ground and the maximum (or minimum) range. The associated free air dB for this range value is calculated using this value of range as R in the first term of Eq. (1). Thus, this represents the sound decibel level that would exist at R if a ray could arrive at this location via spherical spreading. The ray height value in the "Ray Apogee" column for downward refracting rays is the height of the ray above the earth (earth curvature included) at its turnover point. For range points in a shadow zone, the ray height is the terrain height at the location halfway from the blast source to the range distance. A ray height value of .00 indicates the mid-range distance is over water. For shadow zone ray numbers, the ray height is used to derive an average speed of sound and an estimated time of arrival of a diffracted ray at the specified range. This is identified as "Arrival Time." For downward refracting rays, the arrival time is the impact time of the ray as derived from ray trajectory calculations.

In summary, for rays that refract downward, **elev angle** is the elevation angle of the ray, the **range** is the straight line distance from the source to the impact point, the **ray height** is the height that the ray attains at its turnover point (upward to downward refraction) on its trajectory, the **arrival time** is the exact time of ground impact obtained from the ray trace integration, and the **free air dB** is the sound intensity taking into account spherical spreading and atmospheric absorption. For rays that refract upwards (identified by a repetition in the value of elev angle from the next ray number), the range value is in a shadow zone and is interpolated. The **ray height** is the ground elevation at the middistance to the range, the arrival time is estimated for a diffracted ray traveling at the speed of sound at the **ray height** altitude, and the **free air dB** is the spherical spreading plus absorption value associated with the **range**.

The "Charge Wt. dB" column gives the magnitude of the second term of Eq. (1). This term is the ANSI S2.20-1983 recommended expression for excess dB due to the charge weight exceeding 1 lb of TNT. This value is constant for any value of range. Thus a change in explosive charge weight produces a constant change in decibel level over the entire three-dimensional region.

The fourth term of Eq. (1) consists of the change in decibel level for directionally dependent blast sources, that is, when the blast source is not hemispherically uniform. This condition generally occurs from a weapon blast. The NAPS model contains arrays that empirically provide the excess attenuation (either $\pm$) for a nonuniform distribution as a function of the azimuth angle and the type of weapon. This parameter, DBDIR, is constant for all ranges and varies only with azimuth direction. Its influence is included in the printout of "Many Rays Focus dB."

The "One Ray Focus dB" column represents the fifth term in Eq. (1). This term gives the excess attenuation of a sound ray due to refraction (either upward or downward). For downward refracting sound rays, the excess attenuation is derived by the Krol method.

The column "Many Ray Focus dB" gives the sum of terms 4 and 5 of Eq. (1) after having sorted and combined the data for overlapping rays. The fifth term represents the excess attenuation for rays from all elevation angles that impact at the same range. The column "No. of Rays" indicates that ray whose arrival produced the peak intensity, as well as the combined peak intensity of all the overlapping rays. The magnitude of this combined peak intensity is printed in the column "Many Rays Focus dB." The output table is only generated after the combining and summing of all ray traces are complete. Thus, the first rays shown may be influenced in total dB by rays following it in the printout.

The column "Total 1 lb dB" is the sum of "Many Rays Focus dB" and "Free Air dB." It is the dB level for a reference 1 lb charge at the range location specified, taking into account overlapping rays. The column "Total dB" is the sum of the "Total 1 lb dB and the "Charge Wt." columns. It is the dB level at the specified range. The "Type" column indicates whether the ray is: -0- in a shadow zone; -1- a downward refracting ray that strikes the surface, -2- a downward refracting ray that defines a focal point (a shadow zone boundary); or -3- a downward refracting ray that defines a land - water boundary.

TABLE C2. SUMMARY.DAT DATA FILE

03/16/89 06:37 EST I-FIELD @ 26# XUTM, YUTM, BLT HT, BLT WT, SURF PRESS
389112. 4353177. 2.00 26.00 1022.00
RANGE, MAX/SKIP RAYS, MAX/RAYS, AZI INCR, REFL RRATIO
40000. 5 55 15.00 .100

PEAK SOUND INTENSITIES IN DB ALONG AZIMUTH OF 90.00 DEG

RAY NO.	ELEV ANGLE	RANGE (M)	RAY APOGEE (M)	ARRIVAL TIME(S)	FREE AIR (DB)	CHARGE WT.(DB)	ONE RAY FOCUS(DB)	MANY RAYS FOCUS(DB)	TOTAL 1LB.(DB)	TOTAL (DB)	NO OF RAYS	TYPE
1	19.91	37929.38	15.00	113.078	91.475	10.386	-11.584	-11.584	79.891	90.277	1	0
2	19.91	35858.75	15.00	106.905	92.011	10.386	-10.983	-10.983	81.028	91.414	1	0
3	19.91	33788.13	15.00	100.732	92.579	10.386	-10.208	-10.208	82.371	92.757	1	0
4	19.91	31717.50	15.00	94.559	93.184	10.386	-9.116	7.258	100.441	110.827	6	0
5	19.91	29646.88	15.00	88.386	93.829	10.386	-7.250	7.040	100.868	111.254	6	0
6	19.91	27576.26	3066.53	81.657	94.520	10.386	1.946	1.936	96.457	106.842	3	2
7	19.45	28098.17	3014.00	83.134	94.341	10.386	.620	.544	94.885	105.271	4	1
8	18.98	28837.02	2963.63	85.225	94.093	10.386	-.967	-1.736	92.358	102.744	4	1
9	18.52	30029.14	2916.52	88.601	93.706	10.386	-3.361	5.092	98.799	109.184	5	1
10	18.05	33159.95	2871.79	97.479	92.759	10.386	1.148	1.148	93.906	104.292	2	2
	• • •											
39	5.90	9560.47	249.28	28.424	104.642	10.386	-.645	11.231	115.873	126.258	6	1
40	5.46	8778.26	210.58	26.105	105.457	10.386	-1.971	.770	106.228	116.614	4	3
40	5.46	17344.18	205.43	51.584	98.951	10.386	-2.227	-2.227	96.724	107.110	2	1
41	5.01	7532.92	172.44	22.411	106.919	10.386	-4.762	.674	107.593	117.978	4	1
41	5.01	14853.12	169.52	44.196	100.432	10.386	-3.114	-3.114	97.318	107.704	2	3
41	5.01	21656.78	157.27	64.444	96.829	10.386	-2.424	8.848	105.677	116.063	3	1
42	4.57	6594.88	144.40	19.627	108.190	10.386	-.447	-.219	107.970	118.356	4	1
42	4.57	13315.89	142.68	39.632	101.476	10.386	-.425	-.446	101.030	111.416	2	3
43	4.13	5939.04	119.95	17.679	109.190	10.386	-.818	-.818	108.372	118.758	3	1
43	4.13	12002.14	118.61	35.730	102.468	10.386	-.709	-.775	101.693	112.079	3	3
43	4.13	17563.51	109.89	52.287	98.831	10.386	-.828	-.828	98.003	108.389	2	1
44	3.69	5257.99	98.41	15.655	110.354	10.386	-1.101	-1.101	109.253	119.639	2	1
44	3.69	10686.43	96.99	31.819	103.578	10.386	-1.370	-1.442	102.136	112.522	3	3
45	3.25	4505.87	80.72	13.418	111.829	10.386	3.228	3.228	115.057	125.443	2	2
45	3.25	9400.92	81.26	27.997	104.802	10.386	4.906	7.995	112.797	123.183	5	2
45	3.25	14395.85	78.89	42.873	100.731	10.386	4.349	3.851	104.582	114.967	3	1
45	3.25	19447.13	72.09	57.915	97.857	10.386	1.281	1.281	99.138	109.524	1	1
46	2.81	4439.92	68.09	13.222	111.970	10.386	1.774	1.774	113.743	124.129	2	2
46	2.81	9871.73	69.73	29.398	104.335	10.386	-.799	5.673	110.008	120.394	4	2
47	2.37	4006.25	53.53	11.932	112.952	10.386	-.626	-.176	112.776	123.162	2	1
47	2.37	8579.46	49.73	25.552	105.676	10.386	-1.953	.840	106.516	116.902	4	1
47	2.37	12797.94	43.92	38.117	101.855	10.386	-2.373	-.566	101.289	111.675	3	1
47	2.37	16378.25	33.32	48.782	99.498	10.386	-2.737	-2.555	96.944	107.330	3	1
48	1.93	3405.31	40.43	10.143	114.505	10.386	-.609	.051	114.556	124.942	2	1
48	1.93	7117.28	33.17	21.199	107.461	10.386	-2.627	.407	107.868	118.254	4	1
48	1.93	10477.69	28.38	31.209	103.766	10.386	-3.267	-.696	103.070	113.456	3	3
49	1.49	2901.55	30.12	8.643	116.034	10.386	.213	.511	116.546	126.932	2	1
49	1.49	5725.37	19.97	17.055	109.540	10.386	-3.610	-.903	108.637	119.023	3	1
49	1.49	8057.35	15.97	24.002	106.276	10.386	-4.565	.795	107.071	117.457	4	3
49	1.49	9757.52	10.08	29.067	104.447	10.386	-5.653	9.810	114.256	124.642	6	1
50	1.05	1866.08	22.48	5.560	120.252	10.386	-1.750	-1.750	118.502	128.888	1	1
50	1.05	3790.82	10.81	11.294	113.480	10.386	-5.714	-.149	113.331	123.717	2	1
50	1.05	5392.59	8.45	16.066	110.113	10.386	-7.075	-1.042	109.070	119.456	3	1
50	1.05	6280.47	4.46	18.711	108.656	10.386	-9.356	-.343	108.313	118.699	4	3
50	1.05	6539.19	2.75	19.482	108.271	10.386	-9.201	1.505	109.775	120.161	5	1
51	.61	1396.16	18.26	4.160	123.024	10.386	-2.547	-2.547	120.476	130.862	1	1
51	.61	2517.99	5.00	7.503	117.389	10.386	-9.377	.201	117.590	127.976	2	1
52	-.71	159.28	16.00	.475	143.765	10.386	.001	.001	143.766	154.152	1	3
53	-1.15	1.00	16.00	.003	192.212	10.386	.000	.000	192.212	202.598	1	0

APPENDIX D. GENERATING MET PROFILES

1. BLDPROF2 - MET PROFILER BUILDER

The noise assessment prediction model (NAPS) model requires a vertical met profile as input data. The BLDPROF2 program was written in Quick Basic and is used at Aberdeen Proving Grounds (APG) to generate the necessary profiles for running NAPS. The program builds a profile in two ways: it can fuse together data from different sources (surface, SODAR, and upper air), or it can be used to edit a data file previously created.

1.1 Building Profile from Raw Met Data

Meteorological data is gathered daily and stored in files in the C:\RAWMET directory. Some of the data is updated periodically during the day. This met data is used as input to the BLDPROF2 program, which generates the resulting met profile. These profiles meet the data content and format requirements that are necessary for NAPS input. The software is very user friendly and guides the user through the process. The steps for building a profile are outlined in section 2.

1.2 Building Profile from Other Profiles

At times the user may wish to make changes in an existing met profile and then rerun the NAPS model using this new profile. This provides the user with a "what if" scenario for analyzing certain conditions or the effect of changes in the conditions. If at any time there are several test sites in use, one profile could be built and then modified to fit each test site. Since the upper-air and the SODAR data would be the same for all sites, the BLDPROF2 program allows the user to edit and change the surface data for each test site and then save the new profiles under new file names.

Furthermore, the program can display the current vertical profile for any of the met parameters in graphic form, by pressing a function key. The method of entering or editing data uses a spreadsheet-like user interface.

1.3 Building Profiles from User Input Data

Another feature of the program is the ability to generate a met profile from user input raw met data. The met profile input data file required for NAPS has assigned heights above the surface altitude. The user does not have to enter data at these given heights because the program will interpolate and record the values for the needed heights. The only requirement is that the minimum altitude value be the surface readings and maximum altitude value be at least 3000 m.

2. PROCEDURES FOR RUNNING BLDPROF2 PROGRAM

When the BLDPROF2 program is run, the sequence of events that occur depends to some extent upon the user's inputs, but the following sequence is a general outline for running the program.

Step 1 - Create new profile or edit existing profile? - The program first asks if the user wishes to edit an old met profile data file. An <ENTER> defaults to a "no" answer, implying that the user wishes to make a new file. In this case, skip to step 7 below. If the user answers "Y" (or "y"; upper-case or lower-case will do), the program asks for the name of the old file to edit.

Step 2 - Name the file. - The user should type in the complete name of the old file that he wishes to edit, followed by an <ENTER>. If the met profile data file is in the "C:\MET\DATA" subdirectory (which is where it needs to be for the NAPS model to find it properly), it is unnecessary to enter the directory path; this subdirectory is the default location BLDPROF2 looks for old files (as well as where it defaults to creating new files).

Step 3 - Edit ID line? - The program now displays the ID line of the old profile data file and asks the user if he wishes to change it. An <ENTER> defaults to a "no" answer, in which case skip to step 5.

Step 4 - Enter new ID line. - The program now asks the user for a new ID line. It is wise to enter an ID line that sufficiently identifies the date, time, and site. This line becomes a header on any graphs that the NAPS model produces. The first 10 characters are reserved for the date and will accommodate slashes, dashes, or spaces as delimiters between the day, month, and year. Characters 11 to 20 are reserved for the time the profile was built. The remaining characters on this line should contain information to help identify the profile. The maximum line length is 80 characters.

Step 5 - Overwrite or rename? - The program now asks the user if he wishes to overwrite the existing data file, or write a new (differently named) data file. An <ENTER> is equivalent to a "new file" answer. If overwriting, skip to step 14.

Step 6 - Name new file. - If the user is writing a new file using the data from the old file he opened in step 2, he needs to type in the new file name followed by an <ENTER>. Then skip to step 14.

Step 7 - Declare the height upper limit. - If a new data file is being created, either by fusing separate data files or by manual entry, the program asks the user how high the profile data should go vertically. The NAPS program expects data from the surface (0 m) to 3000 m above ground level (AGL). If the user presses <ENTER>, the profile height defaults to 3000 m. However, there may at times be interest in sound propagation conditions at considerably higher altitudes. If the user enters a number greater than 3000, more lines are appended to the file. This poses no problems for the NAPS model.

Step 8 - Name new file. - When the user is creating a new profile from manual entry, raw met data files, or a combination of both, it is necessary to specify the output (met profile) file name. The full name, including extension, should be typed in, although the directory path may be omitted. (If omitted, the file is written in the "C:\MET\DATA" directory.)

Step 9 - Enter ID line. - The program now asks the user for an ID line for the output file, which should be typed in and followed by an <ENTER>. This line (as described in step 4) should adequately identify the profile and the various output displays from the NAPS program.

Step 10 - Identify the surface parameters. - After some encouraging words, the program asks the user to type in several different surface parameters. These are altitude at mean sea level (AMSL) (meters), temperature (degrees Celsius), relative humidity (percent), wind speed (meters/second), wind direction (degrees), and pressure (millibars), in that order. Each parameter is prompted for separately, and an <ENTER> causes a default to 0 (except for pressure, which defaults to 1 to avoid a program crash in pressure interpolation).

Step 11 - Identify method for building the profile. - The program now asks the user if he wishes to "fuse" existing data files, or to build the profile manually, with interpolation between user-input levels. An <ENTER> defaults to fusing existing files. To build the profile in manual mode, type a "2" followed by an <ENTER>, and skip to step 14.

Step 12 - Name upper-air file or manually enter upper-air values. - At this point the program prompts for an upper-air data file name. The user should type in the file name of an appropriate flight's data, followed by an <ENTER>. If no directory path is specified, it defaults to "C:\RAWMET." An <ENTER> with no file name defaults to using no upper-air file. If no upper-air data is used, then the user must manually enter all entries on the spreadsheet that are not provided by the SODAR data or the surface values.

Step 13 - Name the SODAR data file. - The program prompts for the name of a file containing a SODAR wind profile. The user should type in the name of the file followed by an <ENTER>. If an <ENTER> is hit with no file name, the file name defaults to "C:\RAWMET\SODAR.DAT," which is the name of the file that stores the most recent profile data received from the SODAR. If no directory path is specified, the path defaults to "C:\RAWMET."

If the user does not wish to use any SODAR data, he should type in "NUL" followed by an <ENTER>.

Step 14 - Pause for interpolations. - At this point, the program performs the necessary interpolations to fill in as many entries as possible in the met profile. No user inputs are necessary here.

Step 15 - Spreadsheet display of the profile data. - The profile data is displayed on the screen and can be edited by the user. The format includes line numbers at the far left, followed by the altitude of the given line's data, followed by the temperature, the RH, the wind speed, the wind direction, and the pressure. When this numeric display first starts up, the numbers displayed are shown in white, except for the current data field to be edited, which is highlighted in yellow on a cyan background. If altitude levels are to be interpolated from manual entry data, all the interpolated data points are shown in white, and all the manually entered data points are shown in magenta.

Step 16 - Editing features of the program. - The <NUM LOCK> and the <CAPS LOCK> keys must be turned off for the program's editing features to work properly. If the program beeps or other difficulties arise, check the upper right portion of the key board to ensure these keys have been released.

The current data field (highlighted in yellow on cyan background) is the field that can be modified. The arrow keys move the cursor around the screen to activate various data fields. The screen scrolls up or down as needed to reach the desired location. The <PAGE UP> and the <PAGE DOWN> keys move the cursor in increments of 20 lines up or down on the screen.

The line number field and the altitude field cannot be changed, but lines can be deleted or added as desired. Pressing a capital "D" deletes the current line. Pressing a capital "I" allows the user to insert a line of data between the current line and the line below.

Pressing the <ESC> key while the numeric display is on the screen stops the editing and writes the data out to the output data file (met profile).

To view a graphic display of the current data column, press the <F10> key. To return to the numeric display, press <SPACE> or <ENTER>.

To abort the editing of a current data field, press the <CTRL> and the <Z> keys at the same time. This returns the process back to the beginning of step 16.

Step 17 - Graphic display of the current column data. - While in the numeric edit mode, a profile of the current edit field data column is displayed graphically whenever the <F10> key is pressed. Pressing <SPACE> or <ENTER> will return the display to numeric edit mode and to step 16.

Step 18 - Edit value in current data field. - To edit the value of the current highlighted field, type in the new number value followed by an <ENTER>, an arrow key, or <PAGE UP> or <PAGE DOWN>. As soon as the user starts typing in the new value, the old value is blanked out, but if the user wishes to recover the original value, press a <CTRL>-<Z> before entering an <ENTER> or an arrow key. If the user's entry has too many characters or does not evaluate to a legal numeric string, the program beeps and redisplays the old value of the field. If the entry is a legal numeric string, the new value is written out in a proper columnar format when it is accepted. Furthermore, if the program is running in manual mode, and the necessary conditions are met, interpolation of data in the column in which the data is entered takes place (and in the case of the wind speed and wind direction, in both columns). Interpolations are performed between the data field just entered and any surrounding data that the user has already entered.

Step 19 - Inserting a line of data. - When the user wishes to insert a data line, the program inserts the line on the screen, positions the cursor to the altitude column, and requests that the user enter the altitude (AGL) for the new data line. The user should type in that altitude, in meters, followed by an <ENTER>. If the user tries to type in an altitude that is not between the surrounding lines' altitudes, the program "beeps" and prompts again for an altitude. If the program is in manual mode, and there are user-input data points for a given type of met data that are above and below the altitude selected, the data field is filled in with the interpolated value between the surrounding user-input data fields. The program then returns to step 16.

APPENDIX E. INTEGRATED PLANETARY BOUNDARY MODEL

1. OVERVIEW OF THE INTEGRATED PLANETARY BOUNDARY MODEL

The integrated planetary boundary layer model (IPBL) used in the noise assessment prediction systems (NAPS) program is a modification of a model originally developed by Alfred K. Blackadar and others at the Pennsylvania State University. Changes have been made to the IPBL to make its input and output compatible with the NAPS and to use graphics programs and libraries already incorporated into NAPS. The users of NAPS execute the IPBL as a means of predicting the change in sound propagation that results from an evaluation of the boundary layer.

The IPBL program simulates the atmospheric boundary layer up to a height of 3 km. This model provides a means by which the user can input the present meteorological profiles and other current data and then allow the model to forecast for some future time the structure of the met profiles. The process for obtaining these new profiles is a three-step procedure. These procedures are performed by the PREPBL, IPBL, and POSTPBL programs.

PREPBL reads in the necessary met data and then generates a file properly formatted for input into the IPBL. The program IPBL uses the input data to generate a forecasted met profile. The third program, POSTPBL, reverses the formatting procedure and generates an input file for NAPS.

2. REPROCESSOR PROGRAM PREPBL

PREPBL is an interactive program that combines user input values and met profile data to generate a file for input to the IPBL model. The user is asked to identify the desired met profile data file and is queried for several data inputs. The parameters listed in table E1 are either hard wired into the program, interactively entered by the user, or are values calculated from input variables.

The user must enter the geostrophic winds. The entry is free format and values must be entered for 2 m and at least 3000 m. The altitude, geo wind direction and geo wind speed are entered at enough levels to provide an accurate profile of the geostrophic winds. The program interpolates these entries at all the NAPS input altitude levels. Table E2 is an example of geo wind input.

Once all necessary data have been entered, the preprocessing program produces the data file, INFILE.DAT (figure E1). This data file can be edited by the user and values can be changed as long as the **format is not changed**. The user can archive this file by changing the filename. Any archive file can be used as input to IPBL by first copying the archive file into the file INFILE.DAT and then running the program.

One of the major differences between the IPBL input met profile data format and the NAPS met profile format is the levels used. The IPBL model requires altitudes at 100-m levels and a starting level of 10 m. The potential temperature is used instead of actual temperature and the wind components instead of the wind speed and wind direction.

In the preprocessor program, PREPBL, it was necessary to include the surface altitude and pressure and the atmospheric pressures at each altitude level into the INFILE.DAT file. These values are not used by the IPBL program, but they are needed for converting the potential temperature output from the IPBL back to the actual temperature for use in NAPS.

TABLE E1. INPUT VARIABLES TO PREPBL

Fixed variables for a given geographical area:

GLATD - average latitude of the data gathering sites, 39.4
CAPG - soil heat capacity per unit of area 108527.734
CSD - soil heat capacity (Joules/M**3,k), 1.13E+6
CSW - probable heat capacity of water, 4.19E+6
RHOGX - soil water capacity (Kg/m3), 250.
RHOWLT - soil water content when vegetation wilts, 90.
FN - leaf area index (seasonal), 1.0,1.5,2.5
SIGNAF - area fraction covered by vegetation (seasonal), .25,.50,.75
ZO - surface roughness height, 0.03 M
TRANSM - transmissivity for solar radiation, 0.75

Interactive input variables:

JDATE - date met data read
JTIME - time data was read
TG - ground temperature
TM - substrate temperature (2''depth)
PCT_H2O- percent saturation of surface layer of the soil

Variables calculated from inputs:

RHOG - soil water content - ground level
RHOM - soil water content - deep soil layer
DECLD - sun's declination angle

TABLE E2. SAMPLE GEO WIND INPUT

ALT.	SPEED	DIRECTION
2.	3.1	350.
300.	6.2	318.
1000.	12.6	313.
2000.	15.8	274.
3000.	31.0	254.

03/16/89 06:37 EST I-FIELD @ 26#

TA = 4.17	UA = .26	VA = -1.48	QA = .0036
UGA = .54	VGA = -3.05	GLATD = 39.4	DECLD = -2.4
ZO = .0300	CAPG = 108527.700	TM = 6.00	PRH2O = .0
TX = 40.	TN = 0.	GOTIME = -330.00	TRANSM = .75
TG = 6.	RHOGX = 250.00	RHOWLT = 90.00	RHOM = 75.00
RHOG = 75.00	CSD = 1130000.	CSW = 4190000.	FN = 1.5
SIGMAF = .50			

POTENTIAL TEMPERATURES T(I)

4.266	4.979	5.125	5.202	5.279	5.356	5.423	5.430	5.733	6.211
6.670	7.783	9.005	11.218	13.334	14.567	15.732	16.288	16.834	17.287
17.735	18.139	18.542	18.948	19.360	19.823	20.282	20.694	21.100	21.460

WIND COMPONENTS U(I)

.633	1.709	2.964	4.178	5.021	5.760	6.502	7.259	7.961	8.540
9.212	9.940	10.648	11.185	11.714	12.171	12.648	13.296	13.973	14.915
15.888	17.156	18.417	19.613	20.799	21.894	22.996	24.155	25.430	27.737

WIND COMPONENTS V(I)

-3.137	-3.612	-4.170	-4.715	-5.299	-5.976	-6.650	-7.293	-7.836	-8.258
-8.658	-8.505	-8.308	-7.713	-7.091	-6.211	-5.298	-4.089	-2.906	-1.957
-1.031	-.320	.410	1.320	2.251	3.385	4.526	5.722	6.88	7.731

MIXING RATIOS Q(I) X 1000

3.538	2.908	2.691	2.664	2.633	2.601	2.563	2.504	2.433	2.362
2.262	1.988	1.710	1.388	1.069	.784	.509	.336	.180	.177
.186	.302	.416	.515	.612	.701	.791	.891	1.002	1.200

GEOSTROPHIC COMPS. UG(I)

.635	1.847	3.058	4.221	4.945	5.669	6.392	7.116	7.840	8.564
9.281	9.935	10.590	11.244	11.899	12.554	13.208	13.863	14.518	15.172
15.902	17.306	18.709	20.113	21.517	22.921	24.324	25.728	27.132	28.536

GEOPSTOPHIC COMPS. VG(I)

-3.095	-3.616	-4.138	-4.664	-5.234	-5.803	-6.373	-6.942	-7.511	-8.081
-8.518	-7.769	-7.020	-6.271	-5.522	-4.773	-4.024	-3.275	-2.525	-1.776
-1.006	-.041	.924	1.888	2.853	3.818	4.782	5.747	6.712	7.677

PRESSURE AT PBL LEVELS

1020.750	1008.335	996.048	983.869	971.800	959.840	947.989	936.244	924.610	913.096
901.710	890.509	879.340	868.466	857.623	847.069	836.540	826.237	815.958	805.868
795.802	785.923	776.065	766.389	756.733	747.258	737.804	728.527	719.269	710.184

SURFACE ALT AND PRESS.
3.000 1022.000

Figure E1. Sample of File INFILE.DAT.

3. The IPBL Program

The following technical discussion of the IPBL is a summary of the documentation that accompanied the Blackadar model.

The IPBL program simulates the atmospheric boundary layer up to a height of 3 km. (Only the lowest 2 km are displayed.) The model includes two soil layers, a vegetative layer, a surface atmospheric layer, and 30 more layers of air each 100 m deep. In each of the layers, budgets are kept of the heat, water, and momentum, and these are updated at 2-min intervals during the course of a diurnal cycle.

The vertical distributions of temperature and wind speed are displayed on a color screen, and this display is updated every 10-min of model time. The initial time and distribution of variables and parameters are read from the data input file, "INFILE.DAT." The desired data is selected by copying the desired data file to a file named INFILE.DAT, which is the default file and automatically selected by the program.

In addition to graphic displays, two output files are produced by the running program. The first is DIURNL.DAT; it consists of a listing of various surface temperatures versus time at 10-min intervals. It may be displayed by typing 'TYPE DIURNL.DAT'. The second file is OUTFIL.DAT. This file has the identical format as the input file, INFILE.DAT, and contains the forecasted values calculated by the program. This file can be viewed by typing the command 'TYPE OUTFIL.DAT'. An example of the OUTFIL.DAT file can be seen in figure E2.

The model handles turbulent transfer in two different ways. When the surface heating rate is large and the wind speeds are not large, the free convection regime prevails within the buoyantly driven mixed layer. Thermals rise from the surface layer and exchange properties between the upper layers and the surface layer.

Elsewhere and at other times, turbulent exchange is controlled by the local gradients using K type exchange. The magnitude of the exchange coefficient, K, is determined by the local Richardson number in accordance with the prevailing lapse rate and wind shear. Exchange ceases when the local Richardson number exceeds the critical value, which is one of the interactively adjustable parameters.

```
03/16/89  06:37 EST  I-FIELD    IPBL Forecast data to 13:30

ta= 10.66           ua =  3.23            va = -3.56           qa =    .0027
uga =     .54       vga =  -3.05          glatd =  39.4        decld = -2.4
z0 =    .0300       capg =  36219.267     tm =  6.00           prh2o =       .4
tx =  40.           tn =   0.             gotime =     90.00   transm =  .75
tg = 25.12          rhogx = 250.00        rhowlt =  90.00      rhom =  75.00
rhog =    7.51      csd =  1130000.       csw = 4190000.       fn = 1.5
sigmaf =  .50

potential temperatures t(i)
   7.950   7.559   7.322   7.131   6.951   6.825   6.842   7.117   7.773   8.896
  10.349  12.038  13.675  14.989  15.908  16.576  17.139  17.587  17.976  18.333
  18.658  18.999  19.313  19.593  19.821  19.987  20.226  20.618  21.100  21.460

wind components u(i)
   1.888   2.478   3.294   3.997   4.529   5.026   5.571   6.296   7.343   8.657
   9.831  10.661  11.642  12.633  13.526  14.359  15.075  15.696  16.374  17.330
  18.666  20.226  21.869  23.580  25.142  26.163  26.632  26.137  25.430  27.737

wind components v(i)
  -4.531  -4.284  -4.047  -4.000  -4.302  -4.789  -5.504  -6.430  -7.373  -7.926
  -7.837  -7.341  -6.765  -6.143  -5.572  -5.102  -4.696  -4.329  -3.976  -3.530
  -2.777  -1.640   -.539    .609   1.923   3.334   5.292   6.680   6.884   7.731

mixing ratios q(i)x1000
   2.983   2.802   2.765   2.736   2.700   2.642   2.549   2.400   2.176   1.881
   1.554   1.206    .874    .600    .408    .282    .228    .241    .305    .397
    .498    .596    .691    .785    .872    .934    .982    .999   1.002   1.200

geostrophic comps. ug(i)
    .635   1.847   3.058   4.221   4.945   5.669   6.392   7.116   7.840   8.564
   9.281   9.935  10.590  11.244  11.899  12.554  13.208  13.863  14.518  15.172
  15.902  17.306  18.709  20.113  21.517  22.921  24.324  25.728  27.132  28.536

geostrophic comps. vg(i)
  -3.095  -3.616  -4.138  -4.664  -5.234  -5.803  -6.373  -6.942  -7.511  -8.081
  -8.518  -7.769  -7.020  -6.271  -5.522  -4.773  -4.024  -3.275  -2.525  -1.776
  -1.006   -.041    .924   1.888   2.853   3.818   4.782   5.747   6.712   7.677

Pressures at pbl levels
1020.7501008.335 996.048 983.869 971.800 959.840 947.989 936.244 924.610 913.096
 901.710 890.509 879.340 868.466 857.623 847.069 836.540 826.237 815.954 805.868
 795.802 785.923 776.065 766.389 756.733 747.258 737.804 728.527 719.269 710.184

Surface values: altitude and pressure
     3.000      1022.000
    .95     1.03     1.6      1.85
   6.00     6.43     7.10     7.85
```

Figure E2. OUTFIL.DAT using data from 03/16/89.

The enhanced color display gives a running display of the vertical distributions of wind speed and temperature from the ground up to 2 km. Each hour on the hour a ghost profile is left on the screen to indicate the evolution of the profiles. A luminous solar disk is displayed during the daytime. Figures E3 and E4 are examples of the IPBL graphic output displays.

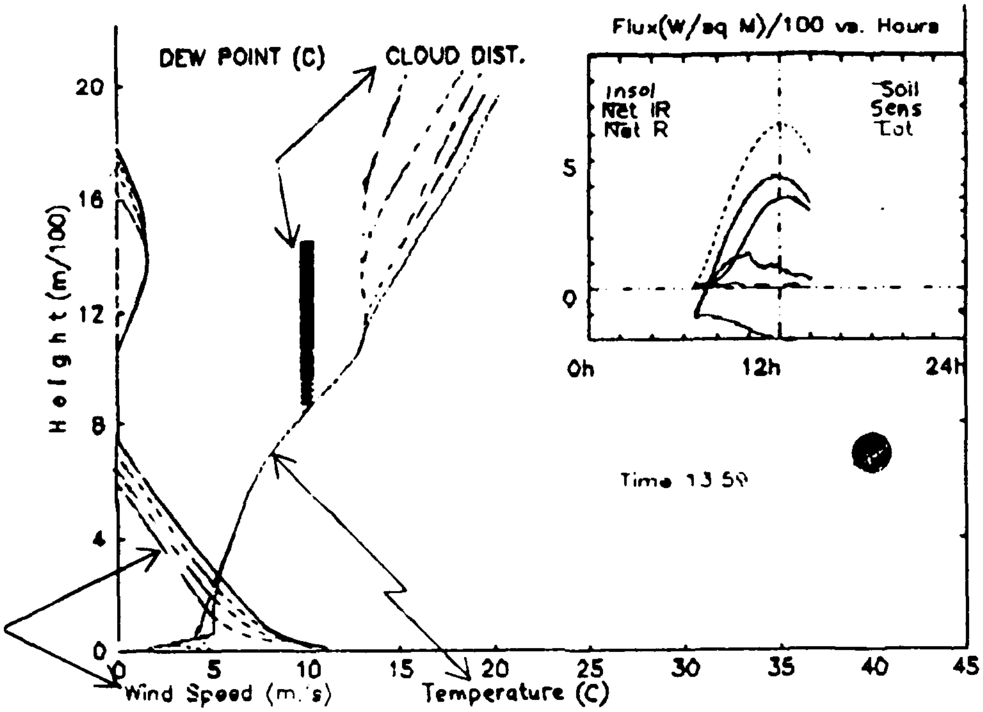

Figure E3. Graphic display of 03/16/89 met data.

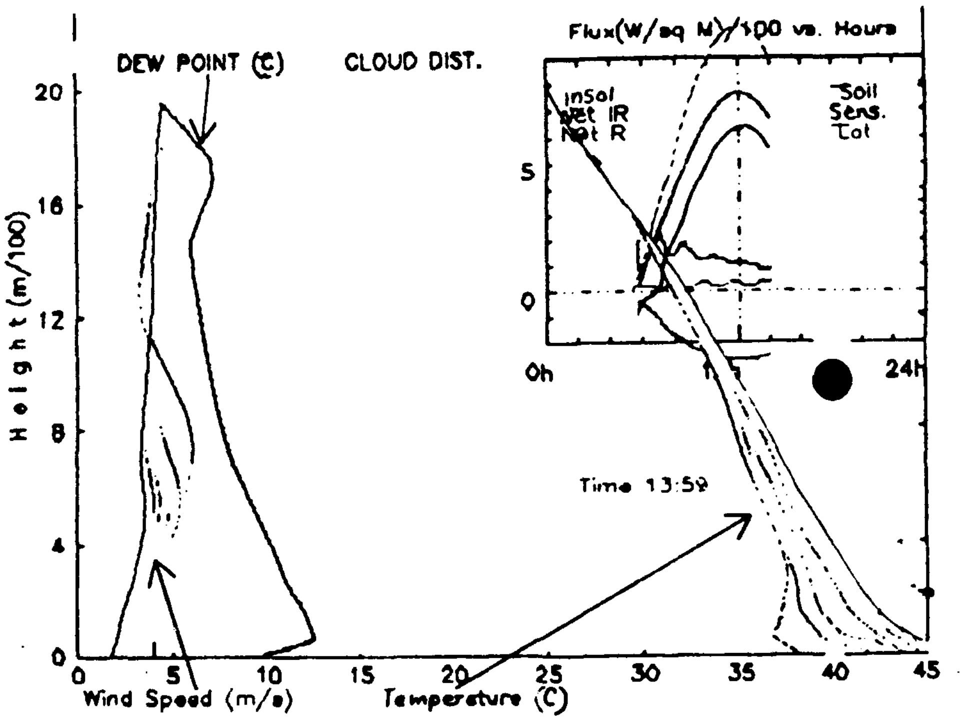

Figure E4. Graphic display of 05/25/91 met data.

Since the lower limit of the IPBL profile is 10, a similarity routine was added to generate the met profile values for temperature and wind components at the 0 and 2 m levels required for NAPS.

An inset panel is provided so that the diurnal course of the terms in the surface heat balance equation can be followed. The curves are color coded as indicated by the legend at the upper right area of the display.

Yellow	INSOL	absorbed solar insolation
White	NET IR	net absorbed radiation
Brown	NET R	net radiation
Magenta	SOIL	heat stored in the ground
Cyan	SENS	sensible upward heat flux to the atmosphere
Green	LAT	latent heat flux due to evapotranspiration

4. The POSTPBL Program

The forecasted met data generated by the IPBL program is stored in the file, OUTFIL.DAT. This file is read into the POSTPBL program and the data is reformatted to generate a met profile data file that can be used as input to the NAPS program. The user is asked to supply a name for the new profile or else the program will default to the filename, BLAST.DAT. Figure E5 is an example of an output file.

03/16/89 06:37 EST I-FIELD IPBL Forecast profile at 13:30
surf alt. surf press
3.0 1022.0

NBR	ALT	TEMP	RH	WSPED	WDIR	PRESS
1	0.	9.00	40.36	4.40	337.38	1022.00
2	2.	9.00	40.36	4.40	337.38	1022.00
3	10.	9.61	40.36	4.91	337.38	1020.75
4	50.	9.05	40.69	4.92	334.41	1015.78
5	70.	8.78	40.85	4.93	332.92	1013.30
6	100.	8.36	41.10	4.95	330.70	1009.58
7	150.	7.74	42.18	5.06	326.31	1003.42
8	200.	7.13	43.44	5.19	321.77	997.28
9	300.	5.95	46.09	5.61	315.61	985.09
10	400.	4.78	48.77	6.19	313.68	973.01
11	500.	3.67	51.04	6.87	313.61	961.04
12	600.	2.69	52.23	7.74	314.55	949.17
13	700.	1.96	51.33	8.88	315.51	937.42
14	800.	1.58	47.42	10.27	315.17	925.77
15	900.	1.65	40.52	11.60	312.74	914.25
16	1000.	2.04	32.31	12.49	308.95	902.85
17	1200.	3.26	16.52	13.41	300.60	880.46
18	1400.	3.50	7.44	14.57	292.74	858.71
19	1600.	2.74	4.19	15.73	287.53	837.59
20	1800.	1.59	5.68	16.79	283.83	816.98
21	2000.	.27	9.96	18.75	278.77	796.81
22	2200.	-1.07	14.97	21.72	271.73	777.05
23	2400.	-2.55	20.62	25.05	265.92	757.70
24	2600.	-4.13	25.61	27.07	259.16	738.75
25	2800.	-5.31	27.97	26.41	254.93	720.19

Figure E5. Example of Output File BLAST.DAT.