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A Noise Assessment and Prediction System

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Abstract

A system has been designed to provide an assessment of noise levels that result from testing activities at Aberdeen Proving Ground, MD. The system receives meteorological data from surface stations and an upper air sounding system. The data from these systems are sent to a meteorological model, which provides forecasting conditions for up to three hours from the test time. The meteorological data are then used as input into an acoustic ray trace model which projects sound level contours onto a two dimensional display of the surrounding area. This information is sent to the meteorological office for verification, as well as the range control office, and the environmental office. To evaluate the noise level predictions, a series of microphones are located off the reservation to receive the sound and transmit this information back to the central display unit. The computer models are modular allowing for a variety of models to be utilized and tested to achieve the best agreement with data. This technique of prediction and model validation will be used to improve the noise assessment system.

Introduction

The U.S. Army has an active testing program for munitions and weapons located at Aberdeen Proving Ground, MD (APG). The results of these tests can cause high sound levels to impact on the local community. This problem has existed for a long period of time, but recently it has become more acute because of the development of the local communities adjacent to the Proving Ground. APG is actively engaged in a number of different programs to alleviate the noise problem. One of the approaches to mitigate noise complaints is to be able to better indicate when conditions could enhance the sound propagation at long distances due to the atmospheric structure. As a result of these concerns, the Noise Assessment and Prediction System (NAPS) was proposed utilizing sensors, models, and computers to predict the noise levels that might be encountered at an off-range site as a result of a particular test.

Objective and Approach

The objective of the NAPS development is to create an operational system for predicting noise intensities based upon present and forecasted diurnal meteorological conditions. The reason for specifying diurnal conditions is to limit the meteorological model to only those conditions that change with solar input. The meteorological model will not be used to forecast synoptic conditions, passage of fronts, etc; synoptic scale conditions accounted for utilizing standard weather forecast techniques and tools.

The NAPS development approach is to modify and adapt existing acoustic and meteorological prediction models for this noise prediction problem. The aim is to be able to have these models operate on a PC located at the meteorological office, providing the information to the various range offices responsible for testing. In order to provide timely information to the users, the results of the noise predictions will be made available to users every 15 to 20 minutes. Users will have an assessment of the current conditions and how they may vary within the next three hours.

These criteria required that both the acoustic and meteorological models be compact with short execution times in order to meet the required specifications. Therefore, it was initially decided to utilize a standard ray trace model[1,2] with modifications for its use to make predictions at APG. In the same vein, a 1-D planetary boundary layer model[3,4] was chosen and incorporated into NAPS.

In the development of NAPS, it was decided to utilize a SODAR which provides wind averages and the occurrence of wind shears at 15 minute intervals. The SODAR measurement coupled with other meteorological measurements from an instrumented mast at the test site and upper air data from a radiosonde would provide the required input data for the predictive meteorological model. To better aid the meteorologist and range personnel in determining the propagation conditions, the data are assimilated from the different sensors, processed through the various models to provide displays of the meteorological profile, the ray trajectories, or the contour of sound intensities overlaid on a terrain map of APG and presented at each users office. These computer displays aid in making the test scheduling and GO/NO GO decisions.

The next step in the development process is the evaluation of the system to determine its performance and fine tune the system to an operational performance level for use on a daily basis in support of the test programs at APG.

Data Requirements

The data requirements and operations for NAPS consist of a radiosonde measurement at 8:00 AM, to provide information on the atmospheric conditions up to 5 km. The number of radiosonde flights depends on the synoptic conditions, ranging from a minimum of one release for no synoptic changes during the day to a number determined by the meteorologist monitoring the changing synoptic conditions. The radiosonde provides vertical profiles of temperatures, winds, and relative humidity from near surface to 5 km. The vertical profile can detect for occurrences of temperature inversion and wind shear conditions which can cause the sound to be refracted to the surface rather than being refracted upward.

Wind conditions within the planetary boundary layer (PBL) (surface to 1-2 km), whose height varies diurnally, are monitored by a SODAR. The SODAR is a remote sensor which provides 15 minute averages of winds and wind shears to approximately 600 meters. This permits a continual update of the atmosphere near the surface; the part of the PBL subject to the greatest changes during the progression of the day. As mentioned previously, there are two-meter meteorological masts located at each of the test locations. These measure surface temperature, winds, humidity, pressure, and solar radiation. In the future, plans call for adding a ten-meter mast. This would permit measurements of meteorological parameters at the two-meter and ten-meter levels. The two and ten-meter configuration will enable meteorologists to utilize similarity theory and other techniques to model the surface layer meteorological conditions. Again, the vertical extent of the surface layer varies and is dependent upon the solar radiation input, the type of surface and wind speed.

Data from the various sensors will be continually monitored by the meteorologist to ensure the accuracy of the observations. The data is then entered into NAPS to provide an assessment of the present conditions and how these conditions vary under the influence of diurnal and terrain conditions. Once the meteorological data is verified, it is provided as input into the acoustic propagation model (ray trace) to calculate ray trajectories and noise intensity contours. These are again examined by the meteorologist to verify that the predicted intensities at the different locations are reasonable and agree with the meteorological conditions. The meteorologist, after verifying the data is consistent, can now release the data to the range personnel to assist them in making a decision about upcoming tests.

Acoustic Models

NAPS provides an estimate of peak noise intensity from a blast source at ground level in all directions from the blast source. An essential feature of the model is its ability to account for variations in meteorological conditions in the calculation of sound propagation. In performing noise intensity estimates, acoustic ray traces are generated each 5^o (or multiples of 5^o) in azimuth, over a sufficient range of elevation angles to define the focusing and shadow regions in the area surrounding the blast. The NAPS model accounts for spherical spreading, absorption[5], focusing, shadow zones, reflection of rays from water, interference of multiple rays arriving at the same location, the directional asymmetry of a blast, and the terrain elevation. Essential model inputs are the vertical temperature, vector wind speed, humidity structure of the atmosphere, the blast charge weight, blast location, and blast height.

Meteorological Model

The acoustic model requires input from meteorological sensors or meteorological parameters derived from a meteorological prediction model. NAPS is required to be able to predict favorable propagation conditions and when conditions are not favorable for the test. To accomplish this, a 1-D planetary boundary layer model was acquired and adapted to operate on a PC. The initial meteorological conditions are input to the model utilizing the surface meteorological data at the firing site, SODAR data from the adjacent location and the upper air data from the standard morning sounding or a sounding closest in time to the test period. The 1-D model generates a vertical profile of temperature, vector wind speed, and humidity from the surface to the top of the boundary layer.

The measured data from the sensors are merged into a single wind and temperature profile at the site. The profiles with additional meteorological measurements and the geostrophic winds at 850 mb are used as input into the 1-D Planetary Boundary Layer model. The model is then used to predict meteorological profiles at one hour intervals up to three hours in time. These profiles are then used as input into the ray trace model to predict acoustic intensity levels resulting from a particular test and firing.

System Description and Operation

The various components and sensors comprising the NAPS system are shown in figure 1. Data from the various sensors are linked to the PC in the Meteorological Station by either hardline or RF link. The data is ingested into the PC, evaluated, and then sound contours are predicted for a particular test. The meteorological data, both measured and predicted from the model, are transferred to the Range Control Office, where it is used as input into the same acoustic ray trace model as being run at the meteorological station. This permits the Range Control Office to share the same information that is available at the Meteorological Station. A view of the data flow in the system is shown in figure 2, where the data are used as input into the meteorological model. Examples of this output are shown in figures 3-6 which are the wind speed, direction, temperature and speed of sound, respectively. From this point, the data are input into the acoustic model with output from the acoustic model shown in figures 7 and 8 as ray trajectories generated at given azimuths. Also displayed are the speed of sound profiles showing the atmospheric structure which causes the rays to be refracted either upward or downward. Sound level contours are generated by utilizing the ray traces at 5° increments from 0° to 360°. In addition, for post analysis and system evaluation, data from the off-post microphones are collected and put into the computer for inclusion in the graphic display for archiving with the meteorological data.

To demonstrate how NAPS would operate, meteorological data are used as an input into the acoustic model which produces the sound level contours shown in figure 9. These contours are generated from measured data and indicate what the sound intensity levels would be at the present time. The contours are elongated and could result in some loud noises impacting upon the local community. The next step is to determine how the situation might change in the next several hours. Prediction of the meteorological conditions for one and three hours later are made by the meteorological model and inserted into the acoustic model with the results shown in figures 10 and 11. In figure 10, one hour later, the changes in the contours are appreciable, with the overall contour shape becoming rounder. Three hours later, there are some changes in the contours, but these are not as significant compared to those showing the change from present time to one hour later. Reviewing the data, as it becomes available, indicates that the test might be delayed to an hour until conditions for testing have improved.

System Evaluation

The situation at APG is excellent for evaluating meteorological and acoustic models since the sound source characteristics[6,7] and locations are known; and there are a large number of atmospheric sensors located throughout APG. To verify the complaints and provide comparisons for NAPS, a noise monitoring system is used to provide measurements of the propagated sound levels. Figure 12 is a map which shows the location of the meteorological and acoustical sensors on and off APG. The asterisks in figure 12 indicate the seventeen microphone sites which are located off APG. These are set up to operate at a threshold of 108 db. When the noise exceeds this level, it is recorded and transmitted with the time of occurrence to a computer at range control and from here it is transmitted to the meteorological station. There are five surface meteorological masts sited on APG and three that are located off APG to the east, west, and north of the Proving Ground. In addition, there are two SODARS located approximately 12 miles apart which provide winds and wind shear heights; these are shown by the open circle. Upper air soundings are made at the meteorological station which is also indicated by an open circle located adjacent to the SODAR at the north end of APG. These sensors then provide detailed data on the meteorological conditions at APG, and the microphone monitoring system provides sound level intensities from those tests that exceed a level of 108 db.

This configuration of sensors and sources can provide a system for evaluating the acoustic predictions made by the ray trace model as well as the predictions of meteorological conditions made by the meteorological model.

As mentioned earlier, preliminary evaluations have been made of the NAPS prediction capability. An example of this is shown in figure 13 where there is a fair agreement between the predicted sound level contours and those levels measured by the microphones.

It is planned to evaluate the performance of the NAPS over a minimum of an annual cycle, since there are seasonal periods when the occurrence of high intensity off range are greatest. To be able to capture the required data, a NAPS data base management system is being developed. Figure 14 is a diagram of this system. There are two major parts to the system; one is located at APG, the NAPS operational site, and the other site is located at WSMR* which is the prototype development site. The WSMR site will be used to test and evaluate the software and hardware before integration into the operational NAPS at APG. The data base will consist of data obtained at both sites, which have markedly different environments from each other. In the case of WSMR, the environment is a desert one, with low humidity, higher temperatures and greater solar radiation. The APG site is more a continental maritime site situated on the Chesapeake Bay. This site would be more humid, with lower temperatures and less solar radiation due to the presence of clouds, vegetation, and inclement weather. It will be interesting to compare similar type data from each of the sites. By analyzing data from both sites, it may be possible to gain further insight to local variations at each of the sites, thereby making the utilization of NAPS at other locations easier.

Summary

The NAPS was developed to predict sound level intensities resulting from testing at APG. NAPS utilizes standard in-situ meteorological sensors in addition to remote sensors. A ray trace acoustic model and a 1-D planetary boundary layer model are used to predict sound propagation conditions out to three hours based on the meteorological model. A data base is being developed to capture the acoustic and meteorological data and to utilize this data on evaluating and improving the sound intensity predictions. The data will include data from at least a years period to insure that NAPS has been evaluated and utilized under a variety of diurnal and seasonal conditions. After a thorough evaluation, the NAPS will become an operational system. The information learned by putting this type of operation at APG can then be used in installing the NAPS at other sites that may be having a noise problem which could be mitigated by taking into account the effects of the atmosphere on acoustic propagation.

*White Sands Missile Range

References

1. N.H. Gholson, "An Analysis of Sound Ray Focusing," NWL-TR-2834, January 1973.

2. N.H. Gholson, "Evaluation and Utilization of the NWL Sound Intensity Prediction System," NWL-TN-T-4/74, Oct 1974.

3. Dalin Zhang, *A Verification of One-Dimensional Model Simulations of the Planetary Boundary Layer Over Dry and Moist Terrain*, M.S. Thesis, The Pennsylvania State University (1981).

4. Dalin Zhang and Richard A. Anthes, "A High-Resolution Model of the Planetary Boundary Layer–Sensitivity Tests and Comparisons with SESAME-79 Data," J. Appl. Meteor. **21**, 1594-1609(1982).

5. Acoustical Society of America, "Estimating Air Blast Characteristics for Single Point Explosions in Air with a Guide to Evaluation of Atmospheric Propagation and Effects," ANSI S2.20-1983, Acoustical Society of America.

6. P. Schomer, L. Little, and A. Hunt, "Acoustical Directivity Patterns for Army Weapons," CERL-IR-N-60, January 1979.

7. P. Schomer and R. Raspet, "Acoustical Directivity Patterns for Army Weapons: Supplement 2," CERL-TR-H-60, August 1984.

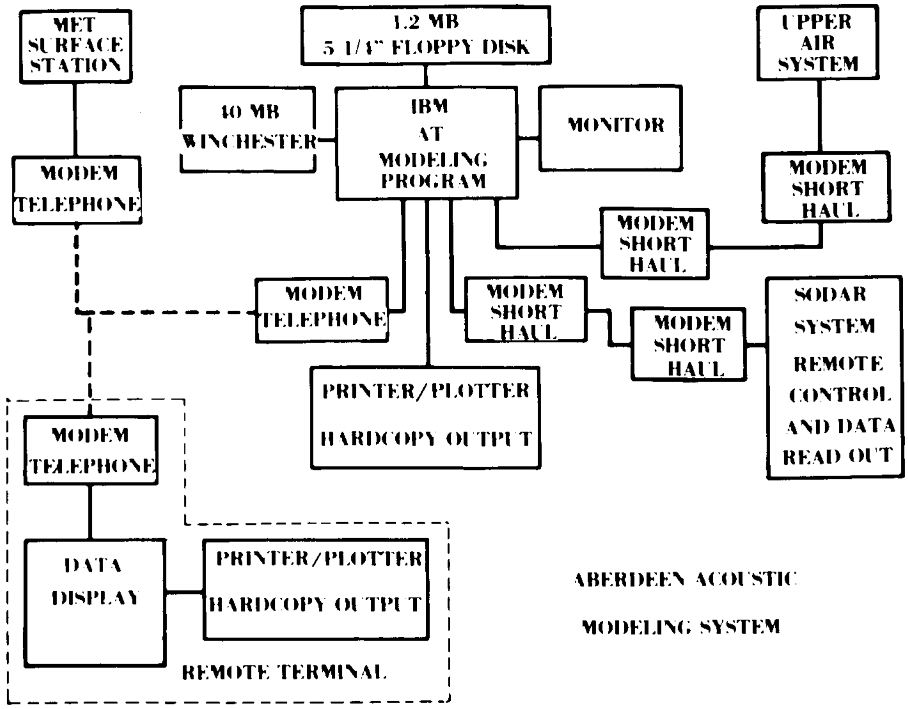


FIGURE 1. NOISE ASSESSMENT AND PREDICTION SYSTEM SENSORS AND INSTRUMENTATION.

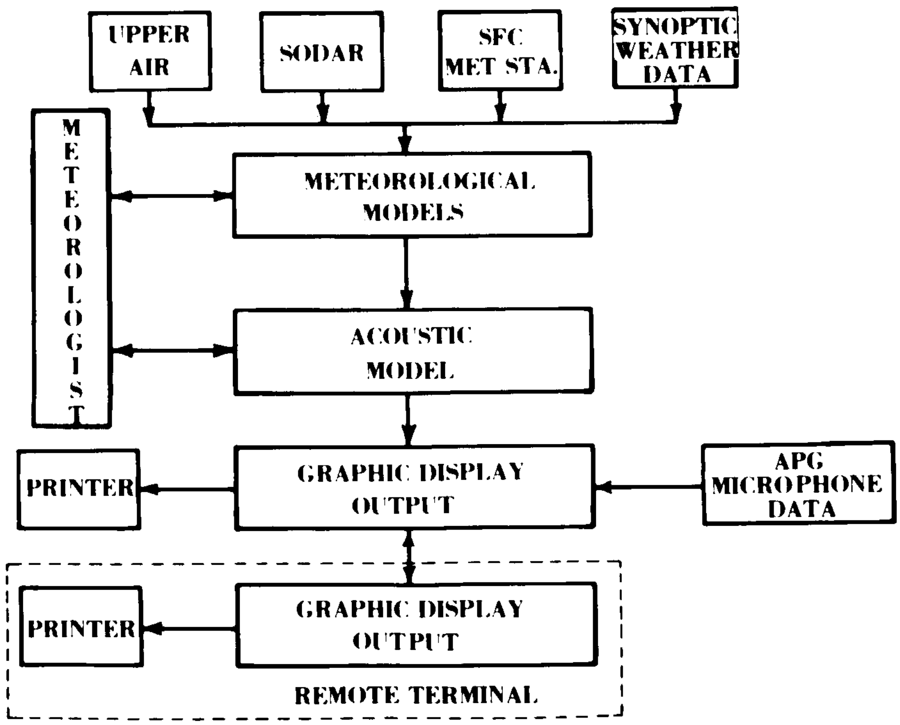


FIGURE 2. NOISE ASSESSMENT AND PREDICTION SYSTEM DATA FLOW.

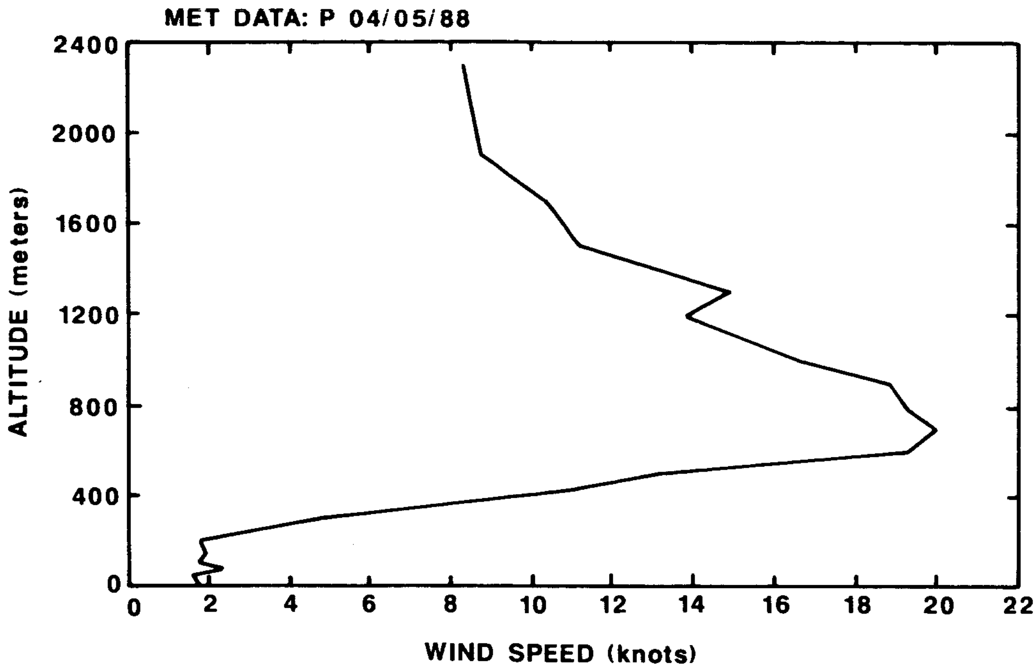


FIGURE 3. COMPUTER DISPLAY OF WIND SPEED PROFILE.

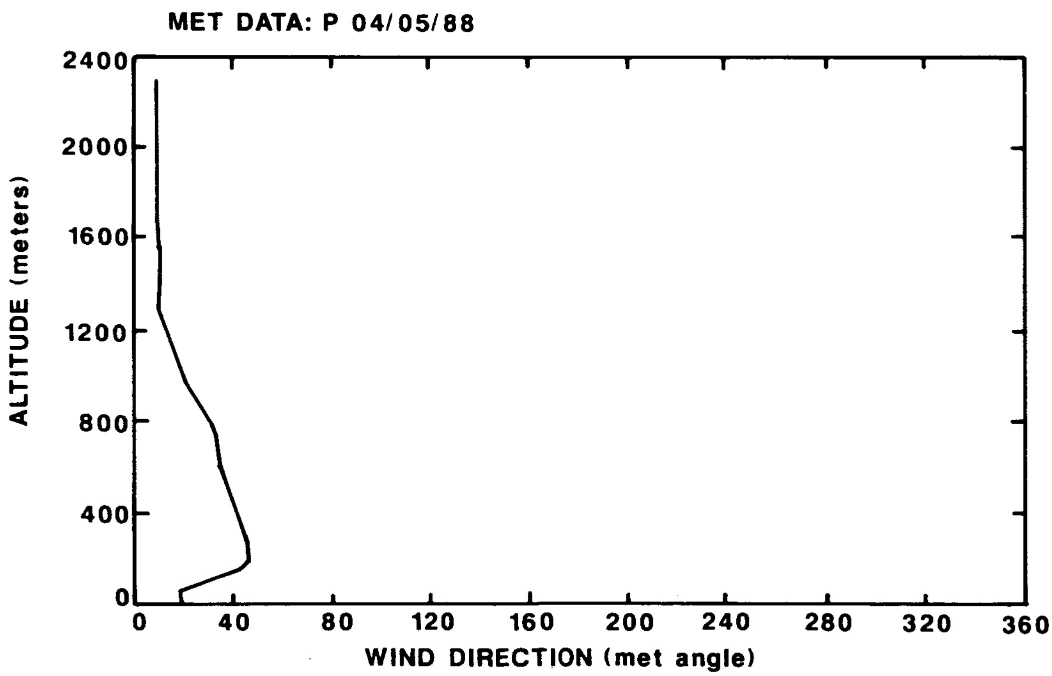


FIGURE 4. COMPUTER DISPLAY OF WIND DIRECTION PROFILE.

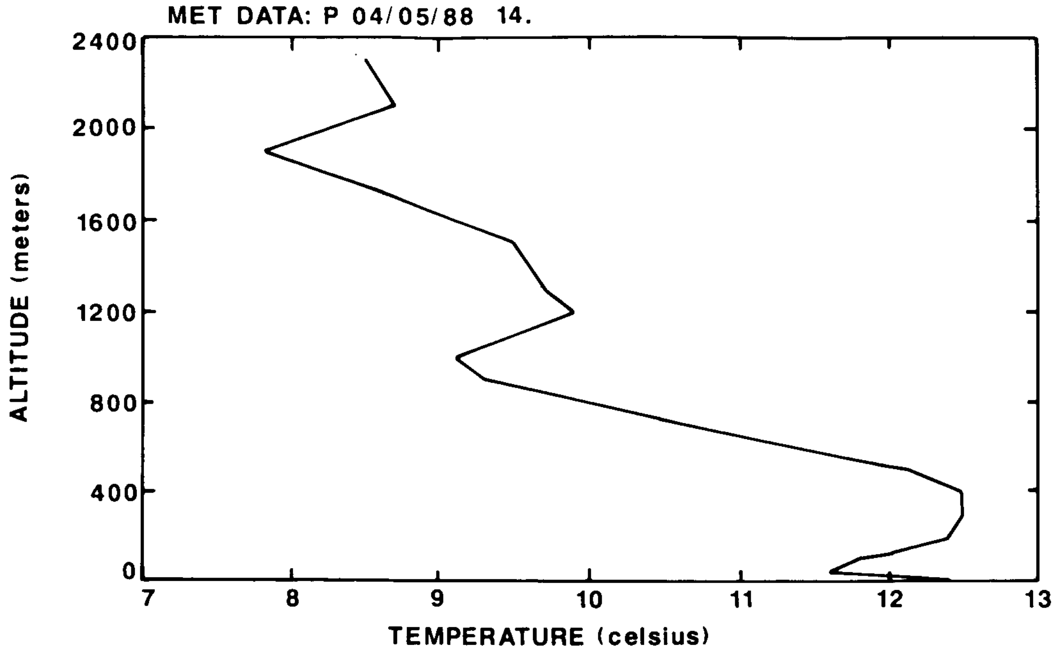


FIGURE 5. COMPUTER DISPLAY OF TEMPERATURE PROFILE.

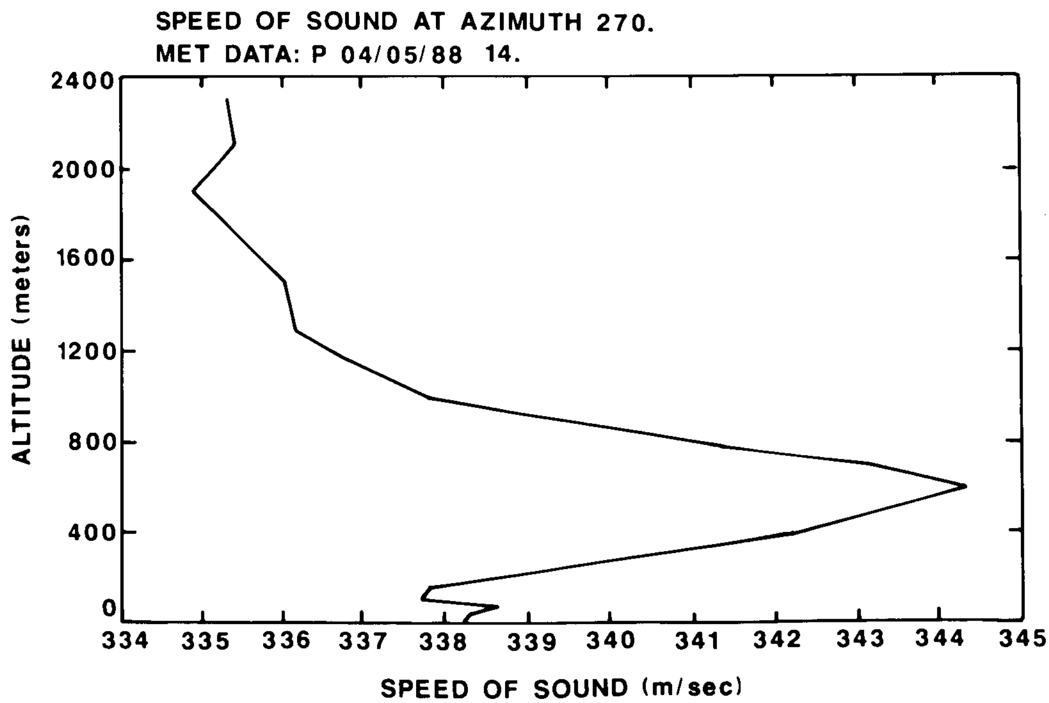


FIGURE 6. COMPUTER DISPLAY OF SOUND SPEED PROFILE.

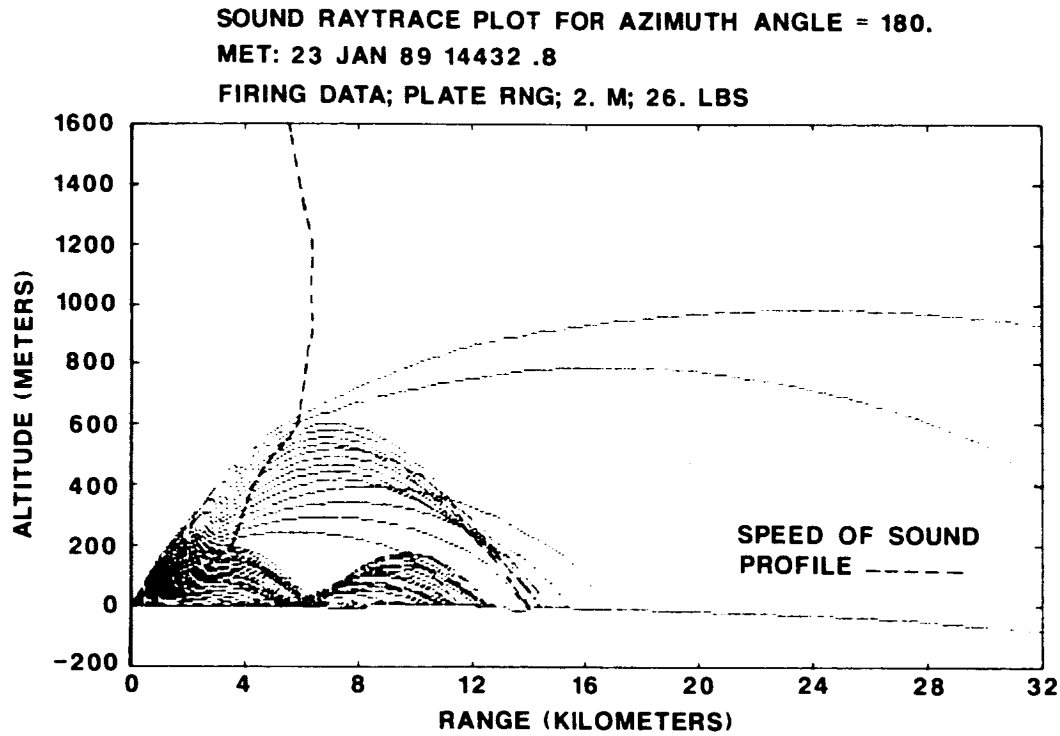


FIGURE 7. RAY TRACE WITH SOUND SPEED PROFILE.

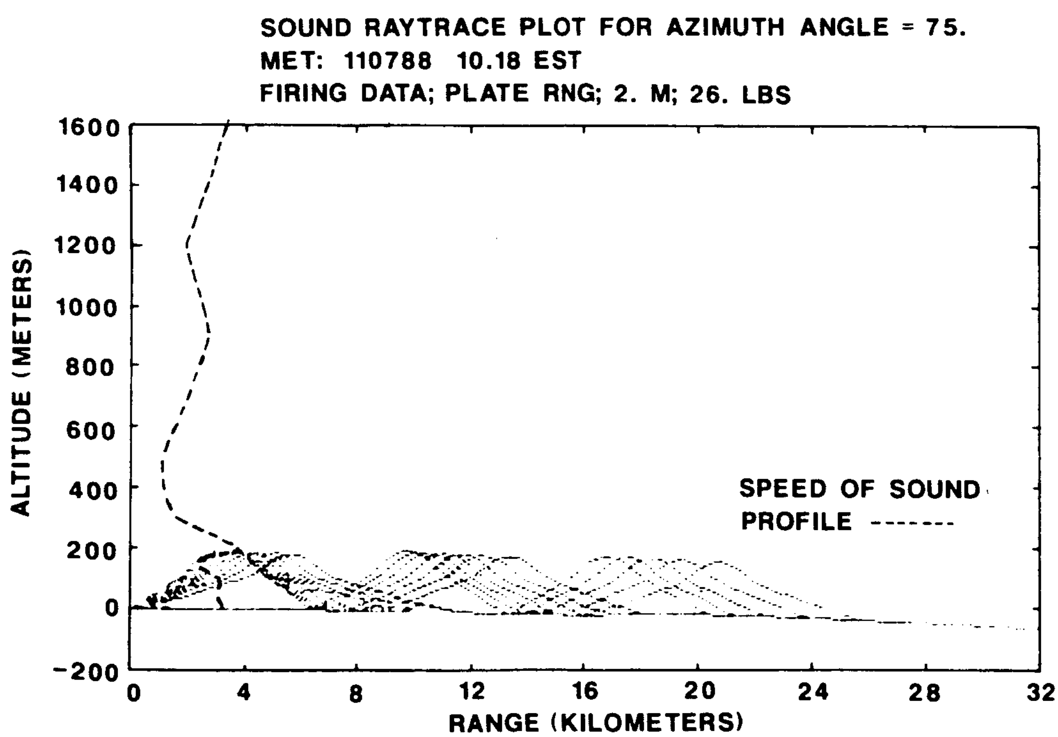


FIGURE 8. RAY TRACE WITH SOUND SPEED PROFILE.

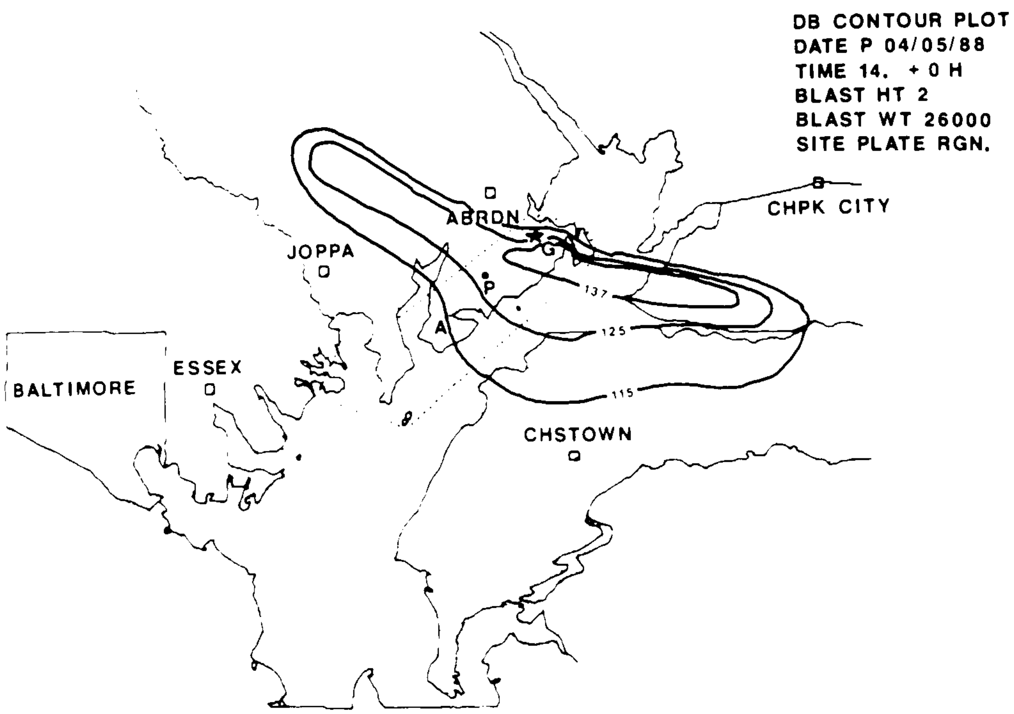


FIGURE 9. SOUND LEVEL CONTOURS DERIVED FROM METEOROLOGICAL MEASUREMENTS.

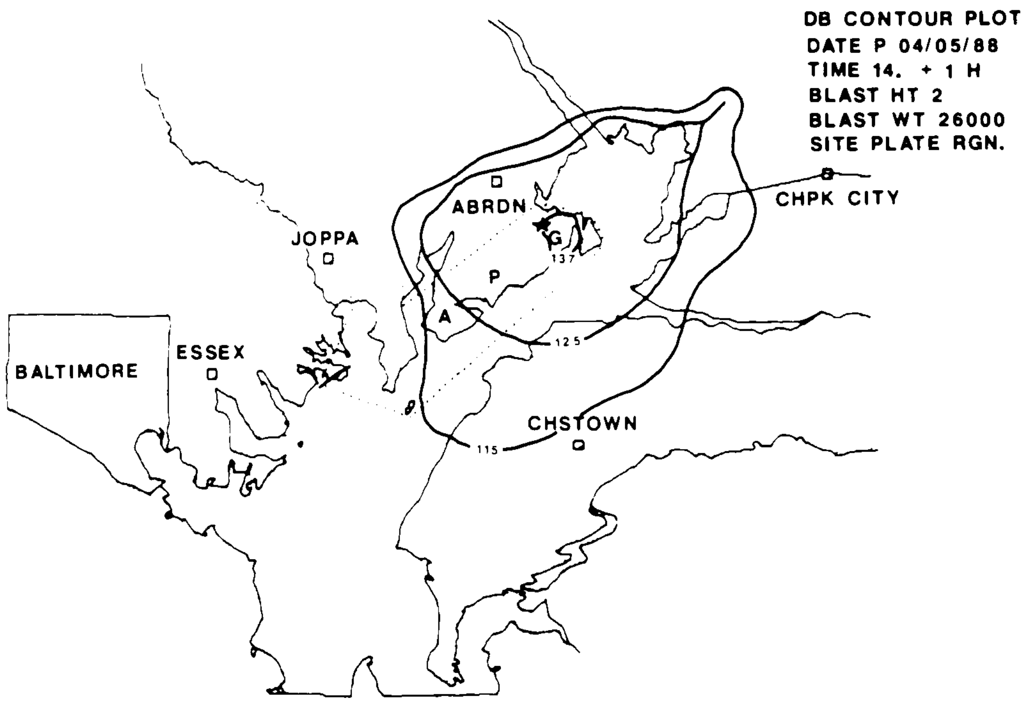


FIGURE 10. SOUND LEVEL CONTOURS DERIVED FROM PREDICTED METEOROLOGICAL CONDITIONS ONE HOUR LATER.

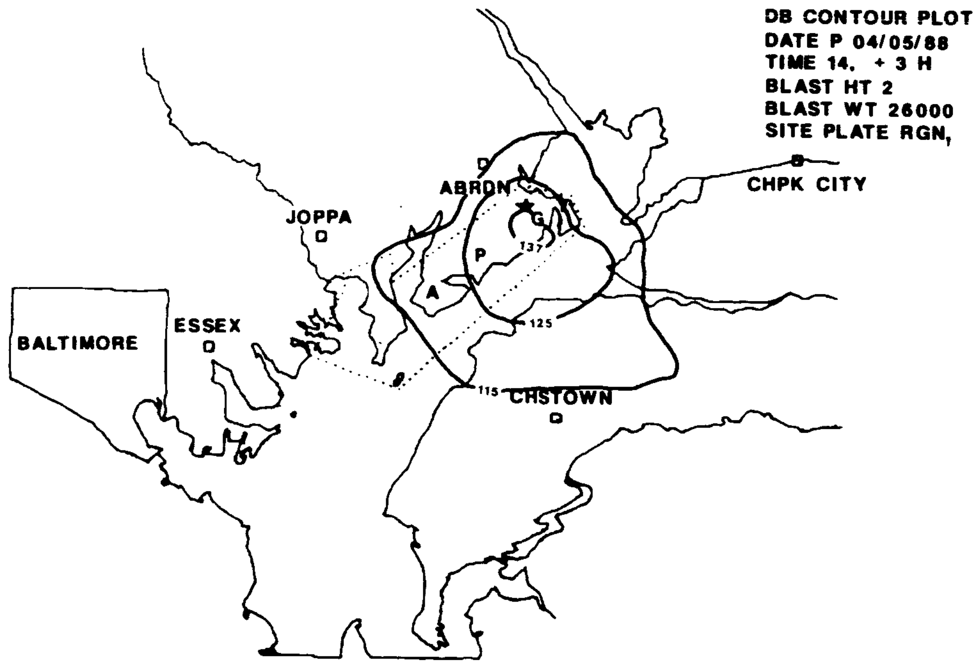


FIGURE 11. SOUND LEVEL CONTOURS DERIVED FROM PREDICTED METEOROLOGICAL CONDITIONS THREE HOURS LATER.

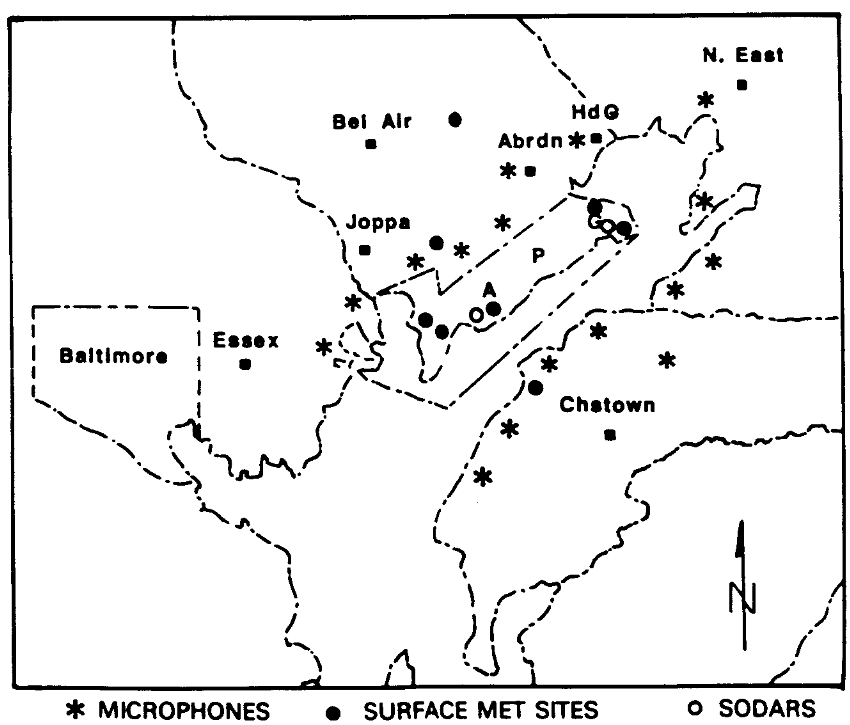
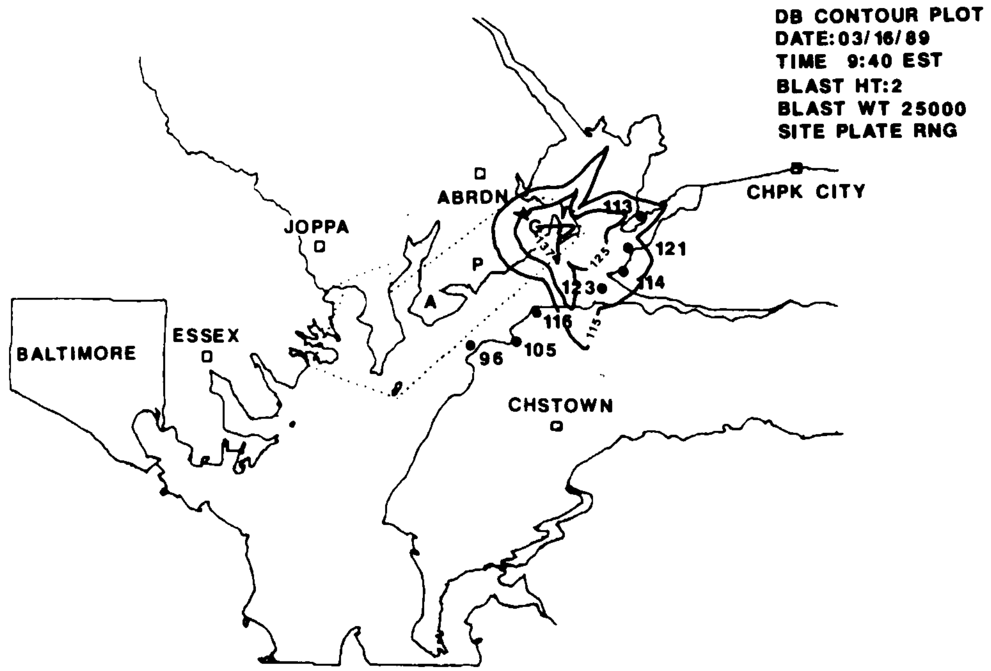


FIGURE 12. ACOUSTIC AND METEOROLOGICAL SENSOR LOCATIONS AT ABERDEEN PROVING GROUND.



13. PREDICTED SOUND LEVEL CONTOURS COMPARED TO MEASURED SOUND LEVELS FROM MICROPHONE SYSTEM.

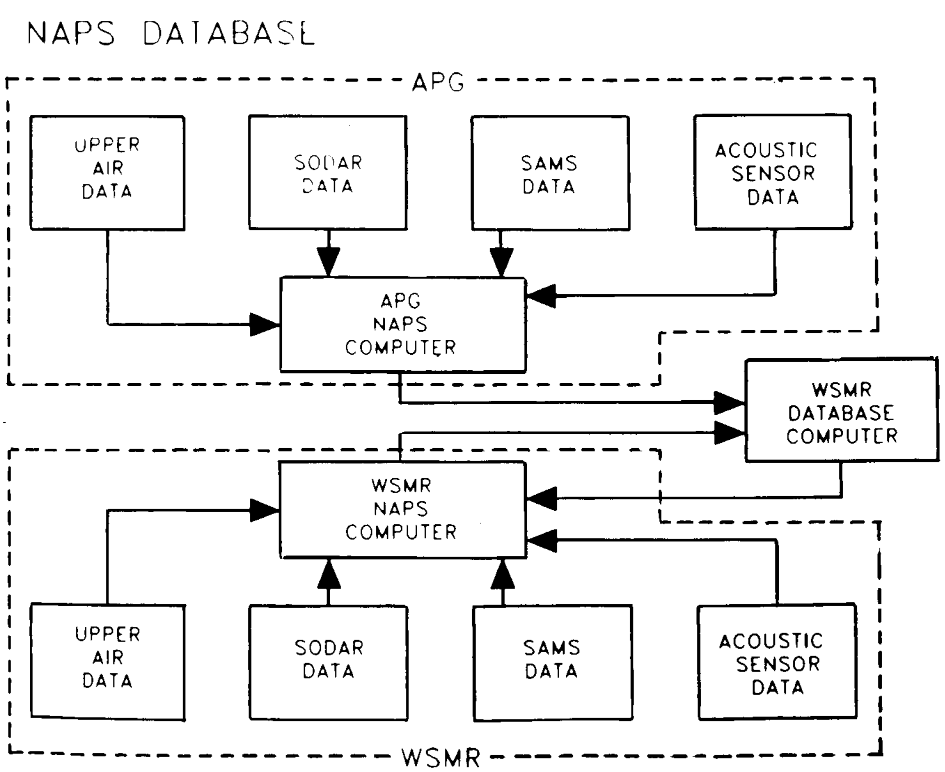


FIGURE 14. NOISE ASSESSMENT AND PREDICTION SYSTEM DATA BASE CONFIGURATION.