DESIGN AND COMPUTER ANALYSIS

OF THE

SIREN PROMPT NOTIFICATION SYSTEM

FOR

RIVER BEND STATION

APRIL 1985

PREPARED FOR:

GULF STATES UTILITIES COMPANY
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ACOUSTIC TECHNOLOGY INC.

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*To be included in FEMA 43 submittal.

ACOUSTIC TECHNOLOGY INC.

SUMMARY

Gulf States Utilities (GSU) contracted Acoustic Technology, Inc. (ATI) to assist in the design of a siren prompt notification system (PNS) which provides a physical means of alerting the populace within the River Bend Station (RBS) plume exposure pathway emergency planning zone (10-mile EPZ). The design process used an iterative approach through extensive computer analysis to ensure that an adequate acoustic alert signal is provided to all populated areas of the 10-mile EPZ. The computer analysis of the warning system design was performed in accordance with the guidelines set forth in the Federal Emergency Management Agency's (FEMA's) regulations 44 CFR 350 Planning Standard E, Appendix 3 of NUREG-0654/FEMA REP-1, and <u>The Standard Guide for the Evaluation of Alert and Notification Systems for Nuclear Power Plants (FEMA-43): September 1983.</u>

Regulatory guidelines state that an acceptable siren system design can be achieved by providing a 60 dBC acoustic alert signal for inhabited areas. For areas where the population density exceeds 2,000 persons per square mile, the siren sound level must generally exceed 70 dBC. In addition, FEMA-43 criteria states that a siren system can be designed to provide siren sound levels that exceed the average measured outdoor daytime ambient sound level by 10 dB.

The final siren PNS design uses 92 high-power sirens with an output of 122 dBC at 100 feet located within the geographical area of approximately a 10-mile radius around the plant which defines the RBS EPZ. Each siren location has been analyzed through use of a sophisticated acoustic computer

model to accurately determine the extent of the 60 and 70 dBC acoustic coverage. All factors which can affect the sound propagation have been considered in the ATI acoustic propagation model which calculates the sound pressure levels from the operation of the sirens for locations surrounding each siren. These predicted sound pressure levels at various locations around the siren are presented in tabular form (see Appendix 1a). Graphical presentation of the 60 and 70 dBC sound level contours is also provided (see Appendix 1b). The composite acoustic coverage of the entire system is presented in Map 1.

The input parameters used in the computer analysis of the siren acoustic coverage are based on assumed sound output and frequency characteristics of the siren. Actual performance and operability of the installed siren system will be validated through limited field testing and annual exercises. Performance testing of the sirens will provide site specific coefficients for use in the computer model.

Evaluation of the siren system design coverage indicates some areas within the EPZ are outside of the 60 dBC siren coverage. Field measurements of the actual siren signal strength and the background ambient noise in the small regions outside of the 60 dBC coverage will be evaluated to determine if the 10-dB-above-ambient criteria is met. For the wetland regions outside the 60 dBC coverage the use of helicopters provided by the Louisiana State Police Department of Public Safety is being arranged. The helicopters are equipped with loudspeakers to notify hunters, fisherman and transient population that may be in these areas.

1.0 INTRODUCTION AND BACKGROUND

Events at Three Mile Island (TMI) emphasized the need for better emergency preparedness procedures for commercial nuclear power plant licensees and for the state and local officials who would be responsible for alerting the public in the event of a general nuclear emergency. In November 1980, the Nuclear Regulatory Commission (NRC) and the Federal Emergency Management Agency (FEMA) issued a document entitled <u>Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants</u> (NUREG-0654, FEMA-REP-1). Among other things, this document lists the criteria for prompt notification of the public in the event of a general nuclear emergency. These criteria are presented in NUREG-0654, Appendix 3: "Means for Providing Prompt Alerting and Notification of Response Organizations and the Population." In September 1983, <u>The Standard Guide for the Evaluation of Alert and Notification Systems for Nuclear Power Plants</u> (FEMA-43) was issued to further clarify these criteria.

The minimum acceptable design objectives for systems providing a physical means of initial notification of the public are listed in NUREG-0654/FEMA-REP-1 and FEMA-43 as follows:

a) "Capability for providing both an alert signal and an informational or instructional message to the population on an area wide basis throughout the 10 mile EPZ, withing 15 minutes."

b) "The initial notification system will assure direct coverage of

essentially 100% of the population within 5 miles of the site."

c) "Special arrangements will be made to assure 100% coverage within 45 minutes of the population who may not have received the initial notification within the entire plume exposure EPZ."

Based on these requirements and the geographic and demographic characteristics of the site, a public alert system design that uses outdoor warning sirens was determined by GSU to be the most reliable approach in providing full acoustic alert coverage for areas within the RBS 10-mile EPZ. The Whelen Engineering WS-3000R electronic sirens, with an output of 122 dBC at 100 feet on a centerline axis from the siren horn, were selected by GSU. A siren fundamental tone frequency centered at the 500 Hz one-third octave band was determined optimum for sound propagation.

Proposed siren locations were developed initially by ATI. These initial proposed locations for sirens were investigated in the field by GSU personnel to determine suitability for installation. As reports were forwarded to ATI from the field upon the securing of the tentative sites, corresponding adjustments were made to the input in the computer model to take into account any changes in location. After these locations were secured, additional siren locations were specified by ATI for areas that were identified by the computer analysis as outside of adequate sound coverage.

2.0 EVALUATION OF RIVER BEND STATION EPZ

2.1 Topographic and Ground Surface Conditions

As recommended in FEMA-43, U.S. Geological Survey (USGS) topographic maps were used during the design and analysis process. The plume exposure pathway EPZ of RBS includes a composite of 11 USGS topographic map quadrangles of scale 1:24,000. An index of the topographic map quadrangles used for this analysis with latitude and longitude indications is shown in Figure 1. These maps indicate population centers, waterways, and wetland areas within the RBS EPZ. In addition, land elevations and ground conditions were read directly from the USGS maps as input into the computer for sound propagation.

RBS is located on the eastern bank of the Mississippi River in West Feliciana Parish near St. Francisville, Louisiana. The area included in the RBS EPZ is primarily woodland, alternating with flat, open fields. However, there is also a considerable amount of marshland, particularly to the west of the site. The Mississippi River cuts into the RBS EPZ from the west. The river meanders east, coming within 2 miles of the site, and then turns due south. A natural levee follows the river along the southwest bank. The plant lies at an elevation of approximately 100 feet above mean sea level (msl). To the west and south of the site, the land is mostly flat, with an elevation range of 20 to 35 feet msl. The land to the north and east of the plant is gentle rolling hills, with the land elevation ranging from 100 to 250 feet msl.

Dense land vegetation coverage, such as that found in the RBS EPZ substantially attentuates the sound propagation of siren warning signals. Therefore, significant topographical features and ground surface conditions of the EPZ must be considered in the calculation of sound attenuation over long distances.

2.2 Demographic Distribution

Five parishes, West Feliciana, East Feliciana, West Baton Rouge, East Baton Rouge, and Pointe Coupee, are located within the EPZ of RBS. The 1985 population distribution within 10 miles of RBS is estimated to be 24,171 as stated in the RBS Final Safety Analysis Report (FSAR). This number includes permanent residents, and the prisoner and patient population within the 10-mile EPZ. Special facilities and major employers within the EPZ were also identified during the design process. Tables 1 and 2 provide listings of the special facilities and major employers as well as the number of people who use the respective facilities.

According to the guidelines of FEMA-43, areas where the population density is greater than 2,000 persons per square mile require a siren sound signal of at least 70 dBC. As identified in Table 3, the largest population centers within the EPZ are Jackson in East Feliciana Parish, New Roads in Pointe Coupee Parish, and St. Francisville in West Feliciana Parish. Each of these locations has an estimated 1985 population that exceeds 2,000 persons. The incorporated land area of these population centers was examined on USGS maps. The area within these centers where the population is the most dense is within an increment of one square mile. Therefore,

the population density of St. Francisville, Jackson, and New Roads was conservatively set at 2,000 persons per square mile for the purpose of the siren system design.

2.3 Meteorological Considerations

FEMA-43 guidelines suggest that average summer daytime weather conditions be used to calculate siren sound contours. To determine these conditions, the Local Climatological Data Summary for the weather station in Baton Rouge, Louisiana was acquired from the National Climatic Data Center. Summaries of meteorological observations for the months of June, July, and August were used to assess levels of temperature, relative humidity, wind speed, and direction in order to determine the summer daytime averages for these parameters.

- Temperature:

  In order to calculate the average daytime temperature for the summer months, the following procedure was applied. The monthly normal temperatures for June, July, and August were averaged to give a daytime summer average temperature of 81.3 degrees Fahrenheit.

- Relative Humidity:

  The average summer daytime relative humidity for the RBS area was calculated as follows. Humidity data recorded at 0000, 0600, 1200, and 1800 hours daily at Baton Rouge were averaged to get monthly averages. Averages for the months of June, July, and August were then averaged, yielding the average summer daytime relative

humidity. This value was calculated to be 76.7 percent.

- Wind Speed and Direction:

  The average daytime wind speed was derived by averaging the mean wind speeds of the summer months, June, July, and August. These values were then averaged to yield an average summer daytime wind speed of 6.1 miles per hour (mph). The average wind direction for the summer months is predominantly Southeast.

Based on this evaluation, the following average summer daytime meteorological conditions were used in the computer analysis for the siren sound coverage:

Temperature:	81.3 degrees Fahrenheit
Relative Humidity:	76.7 percent
Wind Speed:	6.1 mph
Wind Direction:	Southeast

2.4 Background Ambient Noise

During the prompt notification system design process an ambient noise survey was performed within the EPZ of RBS. In February 1983 ATI consultants visited the EPZ and performed substantial direct and statistical background noise measurements. Over 100 measurement locations were selected throughout the EPZ to determine site specific characteristics of the ambient noise. The survey indicated that approximately 75 percent of the EPZ is rural in nature with background ambient noise levels less

than or equal to 50 dB in the 500 Hz octave band center frequency. Therefore a 60 dBC siren signal is adequate for the majority of the EPZ. Approximately 25 percent of the EPZ can be classified as urban/suburban or industrial with a background ambient noise level greater than 50 dB but less than or equal to 60 dB in the 500 Hz octave band center frequency. A siren acoustic level of 70 dBC is adequate for most of these locations. A small percentage of these locations had background noise levels that exceeded 60 dB in the 500 Hz octave band center frequency. These locations were typically in industrial areas. Therefore, during the design process sirens were located in close proximity to these high noise areas to insure that the siren level would be greater that 70 dBC. In addition, ATI recommended that industries at these locations be provided with tone alert radio receivers as a backup method of notification. Suburban/urban areas identified during the survey were located within the three population centers of Jackson, St. Francisville, and New Roads where the siren system design coverage was set at 70 dBC. Therefore, all ambient noise measurement locations within suburban/urban areas are covered by siren signal that is 10 dB above-the-ambient.

3.0 SIREN ACOUSTIC COMPUTER MODEL ANALYSIS

The siren sound levels within the RBS plume exposure EPZ were calculated by a computer model developed by ATI. The computer model considers meteorological factors, topographical factors, and land surface conditions. These factors can affect the propagation of the sound signal generated by a siren.

The results of the analyses for each siren location are presented in Appendix 1a. From these results, the 60 and 70 dBC sound contours have been plotted for each siren location. These siren sound contours are presented in Appendix 1b and have been plotted to the scale of the USGS maps for the RBS EPZ.

3.1 Factors for Calculation of Siren Sound Levels

The various factors considered in the sound propagation analysis by the computer model are summarized as follows:

<u>Hemispherical Wave Divergence</u>

This change in the sound pressure level from hemispherical divergence is uniform in all directions and occurs at a rate of 6 dB per doubling of distance from the sound source. This non-dissipative sound pressure level attenuation is a result of the decrease in energy density (energy per unit area) of the propagating sound wave. The energy density of a sound wave decreases as the distance from a sound source increases because of the increase in

the surface area over which the constant energy of the wave is distributed.

Atmospheric Absorption

Molecular (atmospheric) absorption further reduces the sound energy. This dissipative sound level attenuation is from inelastic collisions of air molecules. Absorption is highly dependent on the temperature and the relative humidity of the air and is quite pronounced at large distances and a high frequencies.

Ground Effects

Sound attenuation is a function of the ground cover and the siren's height. The ground cover conditions were read directly from USGS maps at various directions and distances from the installed siren locations. These conditions were used to calculate the sound attenuation from the absorptive effect of the different ground coverings.

The primary path of the outdoor sound propagation is the direct line-of-sight path; the secondary path is the ground reflected path. Both of these paths are subject to sound attenuation due to the effect of ground cover between the sound source and distant locations.

In general, five types of ground cover are distinguishable from USGS maps for evaluation by the ATI computer model:

a) Dense vegetation - forests, mangrove and thick brush attenuate sound to the greatest extent.

b) Wooded marsh - vegetation attenuates sound, but water reflects sound to a certain extent, so attenuation by this ground cover is not as great as that by denser vegetation.

c) Water, marshes - water acts as a reflector for sound propagation, so attenuation over water is very slight.

d) Open fields - where there is no dense vegitation or other barriers to sound, attenuation is slight.

e) Urban and suburban areas - sound reflects well from pavement at acute incidence angles. Sound is attenuated to a significant extent, however, in urban areas close to the siren; buildings act as sound barriers and reflection is poor because of high incidence angles. In urban areas further away from the siren, sound propagates with a low attenuation rate as a result of increased reflection because of the lowered angle of incidence.

Within the EPZ of the RBS, the typical ground features are dense vegetation, wooded marsh, and open fields. Also, some suburban areas exist which were considered in the computer analysis.

Wind Shadows

Wind gradients near the ground are usually positive; that is, wind

speed increases with height. As a result, a wind shadow zone is most commonly encountered upwind of a siren because headwinds with positive wind gradients bend sound rays upward. Downwind, the sound rays are bent downward and no shadow zone is produced. Crosswind, there is a zone of transition.

Barrier Attenuation Effects

A mound of earth, a hill, or a structure, if large enough, is a partial barrier to sound and can provide a moderate amount of sound reduction within its shadow zone. The sound attenuation caused by a barrier is calculated by the computer model.

The computer model determines the effective barrier height which is the height above the line-of-sight from the siren to the receiver location. The other two essential dimensions are the distance from the siren to the barrier, and the distance from the barrier to the receiver. These dimensions are used to calculate the attenuation of sound from the barriers.

Topographical data from USGS maps is used by the computer model to calculate the souns attenuation from barrier effects caused by the high elevations generating acoustic shadow zones behind ridges and hills.

Near-field Interference Factors

Obstructions taller than the height of the siren horn, such as trees, foliage, and high structures, and in very close proximity to the siren pole can cause excessive sound attenuation. Accordingly, this effect

can produce significant difference for the 60 dBC sound coverage at far distances from the siren. Each installed siren location was evaluated through a field survey for possible near-field interference factors. These factors were considered by the ATI computer model. Predictions for the siren acoustic coverage have input for near-field interference factors. Field testing for a sample number of sirens is recommended in order to verify the computer model input parameters and the effect of near-field interference to insure FEMA-43 criteria is met.

Siren Characteristics

The RBS siren system design is based on using rotating outdoor electronic warning sirens manufactured by Whelen Engineering. Specifically, the WS-3000R siren model was used.

Based on ATI's previous data obtained from anechoic chamber tests and field tests at other nuclear power plant sites for this type of siren, a sound output of 122 dBC at 100 feet was used as input to the computer model. The fundamental tone frequency used in the computer analysis was in the 500 Hz one-third octave band. FEMA-43 guidelines state that the method for determining siren sound output and the resulting SPL contours should be documented. One method for determining the siren characteristics is anechoic chamber testing of representative sirens of the type installed. The second method is to perform onsite field measurements for the type of siren used in the EPZ. Limited field measurements can be performed to determine experimentally the actual installed siren performance for the RBS siren system.

The pole height for each siren is considered in the analysis. The sirens are mounted on poles at a height of 50 feet above the ground surface.

3.2 Verification of the ATI Siren Acoustic Computer Model

To illustrate the accuracy of the ATI model, comparisons have been made between measured sound levels obtained during actual field tests at various nuclear power plant sites and those predicted by the computer model. Some of the results from ATI's siren testing are shown in Table 4. Excellent agreement between the measured and predicted sound levels was found. It should be noted that the model-predicted values are slightly less (by 1-3 dB) than the measured sound levels. This indicates that the computer model is conservative in its prediction of sound level contours.

4.0 EVALUATION OF SIREN SYSTEM DESIGN COVERAGE

The initial set of siren locations provided by ATI included sites throughout the 10-mile EPZ. These locations were sited on USGS maps and direct reading of the land elevations and ground surface conditions for each siren propagation area were performed by ATI for use in the computer model analyses. Since topographic gradients create attenuation from barrier effects, non-circular siren sound contours resulted. Through this initial computer analysis, gaps in the full acoustic coverage were identified.

Following an iterative approach with the specialized acoustic computer model, ATI specified additional sirens in certain locations in order to achieve the design objective of a minimum of 60 and 70 dBC acoustic coverage throughout the EPZ.

GSU personnel performed actual field inspections for each siren location to ensure suitability for installation, and changed recommended locations where necessary. Distance to nearby residences and power availability were critical in determining the suitability of siren installations. Final computer analyses were then made based on actual obtained locations. For each location, predictions of siren acoustic coverage were made. The final system design of 92 sirens is broken down by parish as follows:

43 sirens in West Feliciana Parish

18 sirens in East Feliciana Parish

1 siren in West Baton Rouge Parish

8 sirens in East Baton Rouge Parish

22 sirens in Pointe Coupee Parish

During the process of finalizing siren locations, a few areas with less than the 60 dBC minimum design criteria coverage have resulted. Due to the rural nature and lack of permanent residents in these areas, field measurements will be performed to verify and document the background ambient noise and the installed siren signal strenth within these areas. If the 10-dB-above-ambient criteria outlined in FEMA-43 is met for these regions, no additional siren installations will be required.

Wetlands and areas where no houses or structures are located were identified outside of the 60 dBC siren coverage through the computer analysis. GSU, the Louisiana State Police, and the Department of Wildlife and Fisheries are arranging to use the state police helicopters to provide notification to transient population, such as hunters and fishermen, in the areas outside of the 60 dBC siren coverage. The Louisiana State Police Helicopters will be equipped with a siren/public address system to provide a public address warning message or alert signal for these geographical areas. The use of the helicopters for notification will be developed to meet FEMA-43 criteria for use of aircraft for alerting.

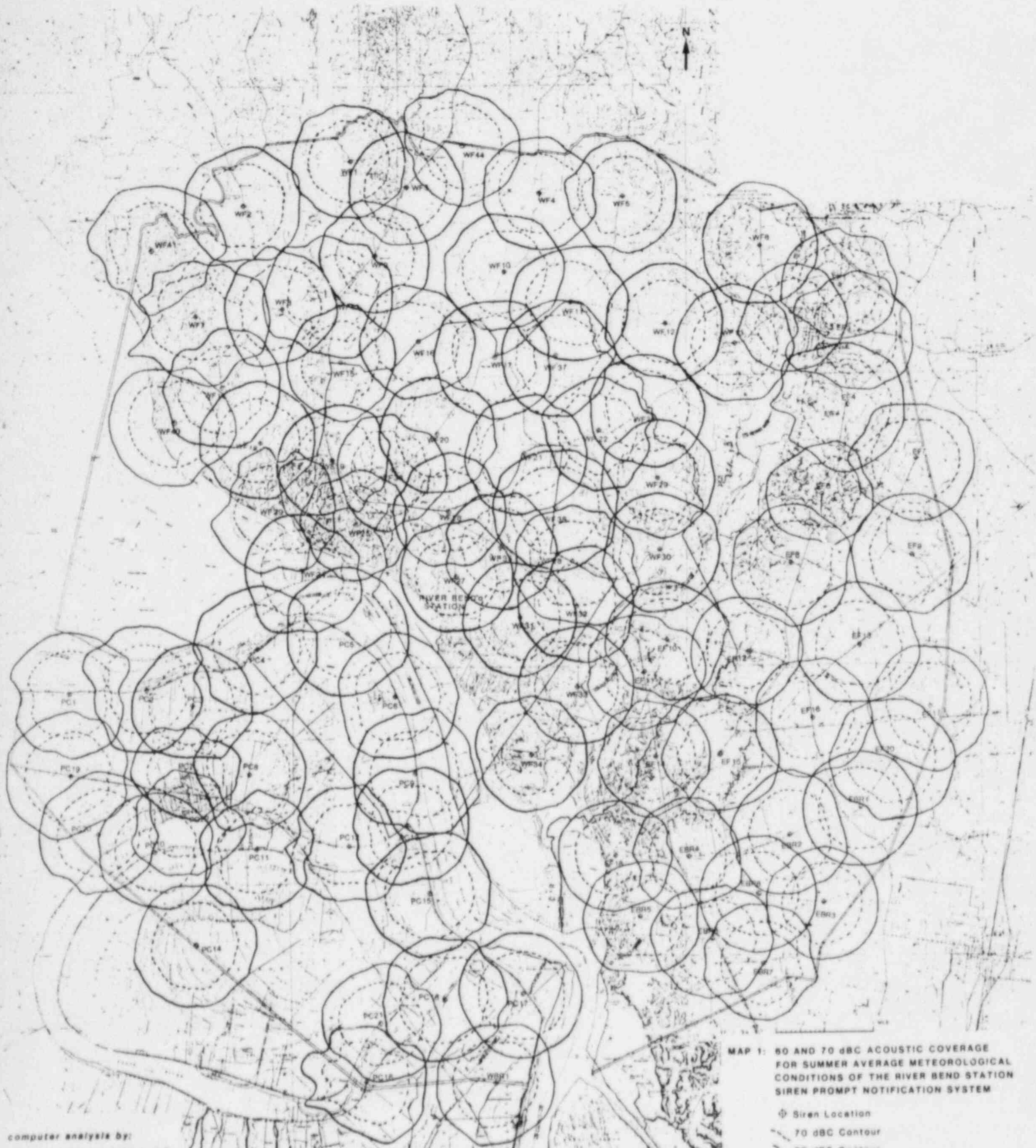
5.0 CONCLUSIONS AND RECOMMENDATIONS

The siren prompt notification system for River Bend Station has been designed and analyzed based on NUREG-0654 and FEMA-43 guidelines. The 60 and 70 dBC siren coverage was calculated by means of an acoustic computer model to determine if all areas within the 10-mile EPZ of River Bend Station receive adequate siren coverage. Validation of the computer model input parameters is required and limited siren field testing will be performed to meet FEMA-43 guidelines.

The system design of 92 sirens provides the required 60 and 70 dBC public alert coverage for most areas within the 10-mile EPZ. Small regions outside of the 60 dBC siren coverage were investigated to determine residences and transient population within these areas. These areas are predominately rural with no permanent residences. Limited acoustic field measurements for background ambient noise and siren signal strength will be performed to document adequate existing coverage in these areas. In addition, there are areas outside of the 60 dBC coverage that are wetlands or wooded areas used by fishermen and hunters. Alternative means of notification by State Police helicopters for the transient population in these areas will be documented to meet the criteria of FEMA-43.

TABLES AND FIGURES

Fig. 7.0-1



MAP 1: 60 AND 70 dBC ACOUSTIC COVERAGE FOR SUMMER AVERAGE METEOROLOGICAL CONDITIONS OF THE RIVER BEND STATION SIREN PROMPT NOTIFICATION SYSTEM

8.0 SCHEDULE AND STATUS

A. PLANNED PNS INSTALLATION SCHEDULE (additional 12 units)

April 22-26	Radio Installation at Whelen
April 29-May 3	Factory Test
May 6-10	Ship Sirens to Baton Rouge
May 13-24	Siren Installation
May 27-31	Installation Testing
February 24-28, 1986	System Activation (Exercise)

9.0
EXERCISES AND DRILLS*

*To be Supplied in FEMA 43 Submittal.

10.0
SUMMARY

*To be Supplied in FEMA 43 Submittal.