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SUPPLEMENTAL NOISE SURVEY OF THE DAVIS-BESSE NUCLEAR POWER STATION UNIT 1

Prepared for

THE TOLEDO EDISON COMPANY

by

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I. INTRODUCTION

A noise survey was conducted at the Davis-Besse Nuclear Power Station Unit 1 on November 20-21, 1978 to assess the operational noise impact of Davis-Besse Unit 1 at full load conditions. Station operational noise data collected during this survey supplements data collected during a previous noise survey while the station was not operating at full load. Due to the high wind speeds during the survey, sampling locations were limited to the immediate area around the major noise sources. The major noise sources include the natural draft cooling tower, the transformers, and the turbine building. Station operational noise was not measurable offsite or at the site boundary due to wind and wave noise. However, the maximum noise impact of the station offsite has been determined by comparing the measured sound levels from the cooling tower with sound level measurements of other natural draft cooling towers. The noise impact of the station has been determined based on the noise from the cooling tower because the cooling tower is the predominant noise source. This report presents a description of the characteristics of sound, the methodology used during the survey, a summary of the collected sound level data, and a discussion of the results.

II. CHARACTERISTICS OF SOUND

Noise can be defined as undesirable sound. Sound is created when a pressure disturbance is propagated through air in the form of compression waves, for which the following relationship holds

$$c = f\lambda \qquad (1)$$

where

c	=	velocity of sound (1130 ft/sec for standard atmospheric conditions of 70°F and 29.92 in. Hg)
f	=	frequency, Hz
λ	=	wavelength, ft.

The pressure fluctuation at a point in space from sound waves is measured in terms of the sound pressure levels, defined as:[(1)]

$$L_p = 20 \log_{10}\left(\frac{p}{p_o}\right) \qquad (2)$$

where

L_p	=	sound pressure level, decibels referenced to p_o
p	=	sound pressure, N/m^2
p_o	=	reference sound pressure, N/m^2.

A sound pressure variation that barely can be detected by the human ear is defined as the threshold of hearing, and has been established as $2 \times 10^{-5} N/m^2$. This value is used as the reference sound pressure, p_o.

Sounds are composed of many frequencies, with a sound pressure level associated with each frequency, but most humans perceive only those in the frequency range of 20 to 20,000 Hertz. This wide frequency range is usually divided into octave bands to provide a more detailed description of noise. The upper frequencies of these bands are twice the lower frequencies. Since the response of people to sound is frequency dependent, a sound is often measured in terms of the A-weighted sound pressure level (dBA re $2 \times 10^{-5} N/m^2$), which adjusts the contribution of each octave band according to the frequency response curve of the human ear. The A-weighted sound pressure level is an approximation of human ear response to a given level of noise.

The contribution of a given noise source to the background sound levels can be estimated based on its sound power level frequency spectrum. The sound power level frequency spectrum of a noise source is a measure of the total sound energy radiated by the source per unit time as a function of frequency. The sound pressure level at a distance r from a source is related to the sound power level at a given frequency by the following equation:[1,2]

$$L_p(r, \theta, f) = L_w(f) - 20 \log r$$

$$+ 10 \log Q(\theta, f) - A_n(f) r - 0.5 \qquad (3)$$

where

$L_p(r, \theta, f)$	=	sound pressure level, dB re $2 \times 10^{-5} N/m^2$
$L_w(f)$	=	sound power level, dB re 10^{-12} watts
r	=	distance from source, ft
f	=	frequency, Hz
$A_n(f)$	=	excess attenuation, dB/ft
$Q(\theta, f)$	=	directivity factor, dimensionless.

The term $A_n(f)$ accounts for excess attenuation from atmospheric, terrain, and vegetation effects, and can be determined from field studies and empirical equations based on experimental data. The sound power level frequency spectrum, $L_w(f)$, may be evaluated for a given source based or sound level measurements around the source or calculated from measurements made around similar sources.

The directivity factor, Q, is defined as the ratio of the mean square sound pressure, at some fixed distance, averaged over all directions from the source. The directivity index is defined as

$$G(\theta, f) = 10 \log Q(\theta, f)$$

For uniform spherical sound propagation G=0; for uniform hemispherical sound propagation G=3.

Several environmental factors will affect the sound levels at a given location, including variations in both meteorological conditions and the state of vegetation and ground cover.[1,2] Variations in vegetation and groundcover, because of seasonal effects, will result in varying amounts of excess attenuation through the year, depending on the nature of the intervening vegetation and groundcover between the source and the receptor.[3,4]

Meteorological conditions will affect the sound levels at any location.[5] Vertical temperature and wind gradients will affect the directivity of a noise source because of the variation in the speed of sound with height, sometimes resulting in shadow zones into which sound waves are not effectively propagated. A shadow zone is commonly encountered upwind from the source, where the wind gradient refracts the sound waves upward. Downwind, the wind gradient refracts sound waves downward, and no shadow zone is produced. This results in a greater noise impact downwind of a source than upwind, along the direction of the prevailing wind.

Temperature induced sound refraction tends to be symmetrical about the source. A shadow zone may completely encircle a source during unstable conditions with a strong negative temperature gradient (Pasquill A or B stability class), and low wind speeds, such as on a calm, sunny day. However, there will be no shadow zone during stable conditions with a strong positive temperature gradient (Pasquill E or F stability class) and low wind speeds, such as on a clear, calm night. This results in a greater noise impact under very stable atmospheric conditions than under very unstable conditions.

Under low-level inversion conditions, in which the temperature decreases to a certain level and then begins to increase, a channeling effect can occur in which the sound waves are refracted back into the levels beneath the inversion, leading to higher sound levels than normal and longer range sound propagation.

III. REGULATIONS AND CRITERIA

U.S. Environmental Protection Agency (EPA)

In a residential environment, the time-weighted day/night outdoor average sound level, L_{dn}, of 55 dBA has been identified as compatible with the protection of public health and welfare.(6) This guideline protects the majority of the exposed population, under most conditions,against annoyance.

To determine the L_{dn} sound level, the equivalent sound level, L_{eq}, is first computed from

$$L_{eq} = 10 \log \left[\frac{1}{100} \sum_i f_i \left(10^{L_i/10}\right) \right] \qquad (5)$$

where

L_i = sound level in the i^{th} time interval, dBA

f_i = percentage of total analysis time represented by the i^{th} time interval.

The time-weighted day/night outdoor average sound level, L_{dn}, is computed from

$$L_{dn} = 10 \log \left\{ \frac{1}{24} \left[15 \left(10^{L_d/10}\right) + 9 \left(10^{(L_n + 10)/10}\right) \right] \right\} \qquad (6)$$

where

L_d = L_{eq} for the daytime (0700 to 2200 hours)

L_n = L_{eq} for the nighttime (2200 to 0700 hours)

These are noise level guidelines which EPA recommends; they are not standards. According to EPA, nearly half the nation's population is exposed to L_{dn} sound levels of 55 dBA or greater. In a long-term national strategy document for noise abatement and control,(5) the following regulatory actions are recommended:

a. Immediate reduction of environmental noise exposure of the population to an L_{dn} value of no more than 75 dBA;

b. reduction of environmental noise exposure levels to an L_{dn} value of 65 dBA or lower through vigorous regulatory and planning actions;

c. aiming for environmental noise levels that do not exceed an L_{dn} value of 55 dBA in future programs affecting environmental noise exposure.

U.S. Department of Housing and Urban Development (HUD)

The HUD noise impact criteria state that noise levels below 45 dBA are Acceptable for continuous 24-hr exposure; levels up to 65 dBA are Normally Acceptable provided that 65 dBA is not exceeded more than 8 hr/day; levels exceeding 65 dBA more than 8 hr/day are Normally Unacceptable; and levels which exceed 75 dBA more than 8 hr/day or 80 dBA more than 60 min/day are Unacceptable.(6) The HUD noise criteria are standards only for HUD sponsored projects, and may be considered recommended guidelines otherwise.

IV. NOISE SURVEY METHODS AND MEASUREMENTS

In devising the methodology used during the noise survey, consideration was given to the American National Standards Institute (ANSI) guidelines which establish a method for the evaluation of noise in an area in which the ambient sound levels result from the superposition of multiple noise sources.[9, 10] Sound pressure level measurements were obtained at the seven locations shown in Figure 1. Table I presents a description of each location including the distances from major noise sources.

The instrumentation used during the survey consisted of the following:

1. Bruel and Kjaer Type 2209 Precision Sound Level Meter
2. Bruel and Kjaer Type 4145 Condenser Microphone
3. Bruel and Kjaer Type 4220 Pistonphone
4. Nagra Type SJS Magnetic Tape Recorder

This instrumentation meets the requirements of the ANSI standards for a Type I or precision sound level meter.[11] A 1-inch diameter condenser microphone was used to assure that accurate low level ambient sound measurements could be made. The meter was acoustically calibrated using the B&K Pistonphone before and after each measurement period to assure continued accuracy. Headphones were used to determine any distortion, improper amplification characteristics, and intermittent electrical connections. The microphone was tripod mounted and located a sufficient distance away from all vertical surfaces to minimize reflection effects. All measurements were made using an open celled polyurethane foam wind screen to attenuate the effect of wind generated noise around the microphone. However, with a steady wind of 12 mph during the survey, the wind induced noise on the sound level meter was approximately 42 dBA.[12] Occasional gusts of wind would increase the wind induced sound level reading. Thus, except for location one, sound level measurements at the Davis-Besse station were limited to those areas with sound levels above 50 dBA to insure the accuracy of the measurements. A measurement below 50 dBA was obtained at location one when the wind speed had dropped to 9 mph. The gust effects were discernible during the measurement period.

Sound level measurements were made with the sound level meter operated in the A-weighted slow response mode. The instrument reading method involved observing and recording the meter reading once every five seconds, regardless of the location of the needle within its swing. These measurements were repeated until a statistically reliable sample was obtained. The number of readings required to achieve this condition was determined by the variability of the ambient sound level. The measurement approach of taking a sample every five seconds resulted in a statistically independent sample because the interval was considerably greater than the meter averaging time. Table II presents the noise sources and the L_{50} sound levels (the sound level exceeded 50% of the time) at each sampling location for the indicated dates and times during the survey.

Octave band analyses were obtained during all but one measurement period to identify the presence of any pure tone. The instrument reading method during the octave band analyses involved observing and recording the sound level corresponding to approximately the L_{50} sound level for each octave band. The measured sound levels in each octave band are presented in Table III for each sampling location and measurement period. The sound levels measured in the 31.5 Hz and 63 Hz center band frequencies can be attributed to the wind effect on the microphone windscreen. The measurements in the center band frequencies above 63 Hz were not affected by the wind.[12]

The hourly windspeeds and directions as recorded at the Davis-Besse site meteorological tower during the survey are presented in Table IV for the 35 foot and 250 foot levels. The wind speeds presented are average hourly wind speeds. During the survey the average wind speed ranged from 9 to 14.5 mph at the 35 foot level while the wind direction varied from 15 through 50 degrees.

V. RESULTS AND DISCUSSIONS

With the exception of measurements in one octave band near the cooling tower, the sound level measurements during the November 1978 survey at the Davis-Besse station are consistent with the sound levels measured during the first operational noise survey in March 1978.[13] The cooling tower noise predominates throughout the Davis-Besse station except in the immediate vicinity of the turbine building and the step-up transformers. Since the cooling tower is the major noise source, the noise impact of the station offsite can be determined from the sound levels from the tower. Although sound level measurements could be made only close to the tower due to the wind conditions, the maximum contribution of tower noise to the offsite sound levels has been determined by comparing the measured sound levels with sound level measurements of other natural draft cooling towers. A study of measured sound levels from twelve natural draft cooling towers resulted in the development of a curve of maximum predicted sound levels versus distance from a natural draft tower.[14] The measured sound levels from the Davis-Besse tower are 1 to 2 dB less than the maximum predicted levels at specific distances near the tower. Therefore, the sound levels offsite will be less than the maximum values determined in the study. Figure 2 presents the sound level isopleths around the Davis-Besse station based on the measured sound levels within 1000 feet of the tower and the maximum predicted sound levels determined by the tower noise study for distances beyond 1000 feet. Since the water flow through the tower is constant, the sound levels in Figure 2 represent approximately the L_{eq} sound levels. Actual sound levels will vary depending on the operation of auxiliary equipment, the use of equipment producing intermittent noise, and meteorological conditions. The maximum expected sound level at the site boundary due to cooling tower noise is 52 dBA in the absence of any excess attenuation due to meteorological effects. The maximum expected distance for a 45 dBA sound level contribution from the tower extends to just south of the Sand Beach residences. Neither the HUD acceptable level of 45 dBA nor the EPA L_{dn} level of 55 dBA will be exceeded at Sand Beach due to the operation of Davis-Besse Unit 1. However, the noise from wave action can normally exceed 50 dBA at Sand Beach.[15] Depending on the size of the waves, the wave noise will partially or completely mask the cooling tower noise at Sand Beach.

During the November survey the water flow rate through the tower was at the maximum rate of 480,000 gallons per minute, but during the March survey the water flow rate was only half the maximum rate. During the November survey the L_{50} sound levels at location 2 near the cooling tower were 2 to 3 dBA higher than the L_{50} sound levels in March. However, the sound levels measured at the base of the tower, location 3, in November were nearly identical to the sound levels measured in March. This indicates that the difference in the sound levels measured at location 2 can not be attributed to an increase in the tower water flow rate. Rather, an increase in the background sound levels due to wind and wave noise is most likely responsible for the difference in the measured sound levels between the two surveys.

There was one noticeable difference in the tower noise between the March and November survey. In the 125 Hz centerband frequency the sound level at location 3 had increased from 57 dB in March to between 74 to 82 dB in November. This low pitched drone from the tower was distinctly audible over the other frequencies even at a distance of several hundred feet. The increase in the 125 Hz band did not affect the A-weighted measurements because the sound pressure levels in the 125 Hz band are attenuated by 16 dB in the A-weighted full spectrum sound level measurements. The increased sound level in the 125 Hz band may be due to a combination of the increase in water flow and a corresponding increase in air flow through the tower between the two surveys.

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TABLE I

NOISE SAMPLING LOCATIONS AT THE
DAVIS-BESSE NUCLEAR POWER STATION
NOVEMBER 20-21, 1978

Location	Description
1	On the southern side of the intake canal, approximately 1000 feet east of the plant.
2	On the perimeter access road approximately 700 feet north of the cooling tower.
3	Approximately 100 feet north of the cooling tower.
4	At the flagpole in parking lot, approximately 200 feet east of transformer.
5	At the entrance gate to tower and perimeter access road, approximately 700 feet west of the cooling tower.
6	At the southeastern corner of the parking lot.
7	On access road between the switchyard and the reactor building.

TABLE II

SOUND PRESSURE LEVEL MEASUREMENTS AND NOISE SOURCES AT THE DAVIS-BESSE NUCLEAR POWER STATION NOVEMBER 20-21, 1978

Sampling Location	Date	Time	L_{50}	Noise Sources
1	11/21	21:03	44	Turbine building, cooling tower
2	11/20	15:17	58	Cooling tower, wind, birds
	11/21	11:00	57	
	11/21	21:20	58	
3	11/20	15:45	70	Cooling tower
	11/21	11:23	70	
	11/21	21:32	70	
4	11/20	16:45	60	Transformer, turbine building, bell, cooling tower
	11/21	14:45	62	
	11/21	20:05	62	
5	11/20	17:10	58	Cooling tower, traffic
	11/21	15:00	60	
6	11/21	14:20	51	Wind, turbine and water treatment buildings, vehicles
7	11/21	20:25	58	Turbine building, cooling tower

TABLE III

OCTAVE BAND SOUND PRESSURE LEVELS AT THE DAVIS-BESSE NUCLEAR POWER STATION NOVEMBER 20-21, 1978

			Octave Band Sound Pressure Levels (dB re 2 x 10^{-5} N/m^2)									
Location	Date	Time	31.5	63	125	250	500	1000	2000	4000	8000	16000 (Hertz)
1	11/21	21:04	68	60	52	48	48	48	40	40	30	26
2	11/20	15:20	58	56	67	50	50	52	53	48	34	8
	11/21	11:10	56	58	70	50	50	52	52	44	32	9
	11/21	21:25	62	50	64	52	43	44	47	42	33	10
3	11/20	15:46	62	58	74	54	55	57	58	57	52	40
	11/21	11:28	61	63	80	59	60	64	64	63	58	44
	11/21	21:35	60	62	80	57	60	63	64	63	58	44
4	11/20	16:55	72	68	73	63	56	54	44	36	-	-
	11/21	14:50	74	68	74	65	56	55	48	40	32	17
	11/21	20:10	71	69	76	63	56	54	47	40	32	32
5	11/20	17:15	60	54	66	48	55	53	52	47	33	8
	11/21	15:05	62	68	68	51	52	54	53	49	32	18
6	11/21	14:20	(no data due to wind)									
7	11/21	20:25	64	57	55	52	51	54	53	46	29	11

TABLE IV

WIND SPEED AND DIRECTION DURING THE NOISE SURVEY AT THE DAVIS-BESSE NUCLEAR POWER STATION, NOVEMBER 20-21, 1978

		35 Foot Wind Data		250 Foot Wind Data	
Date	Hour	Wind Speed (mph)	Wind Direction (degrees)	Wind Speed (mph)	Wind Direction (degrees)
11/20	14:00	12.0	025	12.5	035
	15:00	14.5	030	15.0	045
	16:00	12.5	035	13.5	045
	17:00	13.5	040	15.0	050
11/21	11:00	12.5	030	13.5	040
	12:00	12.5	025	13.5	035
	13:00	13.0	025	14.0	035
	14:00	13.5	025	14.0	035
	15:00	12.0	025	13.0	035
	16:00	11.0	025	12.0	035
	17:00	10.0	025	10.0	040
	18:00	9.5	025	10.5	040
	19:00	8.0	015	10.5	035
	20:00	10.0	020	12.0	025
	21:00	9.0	020	11.0	030
	22:00	9.0	020	11.0	030

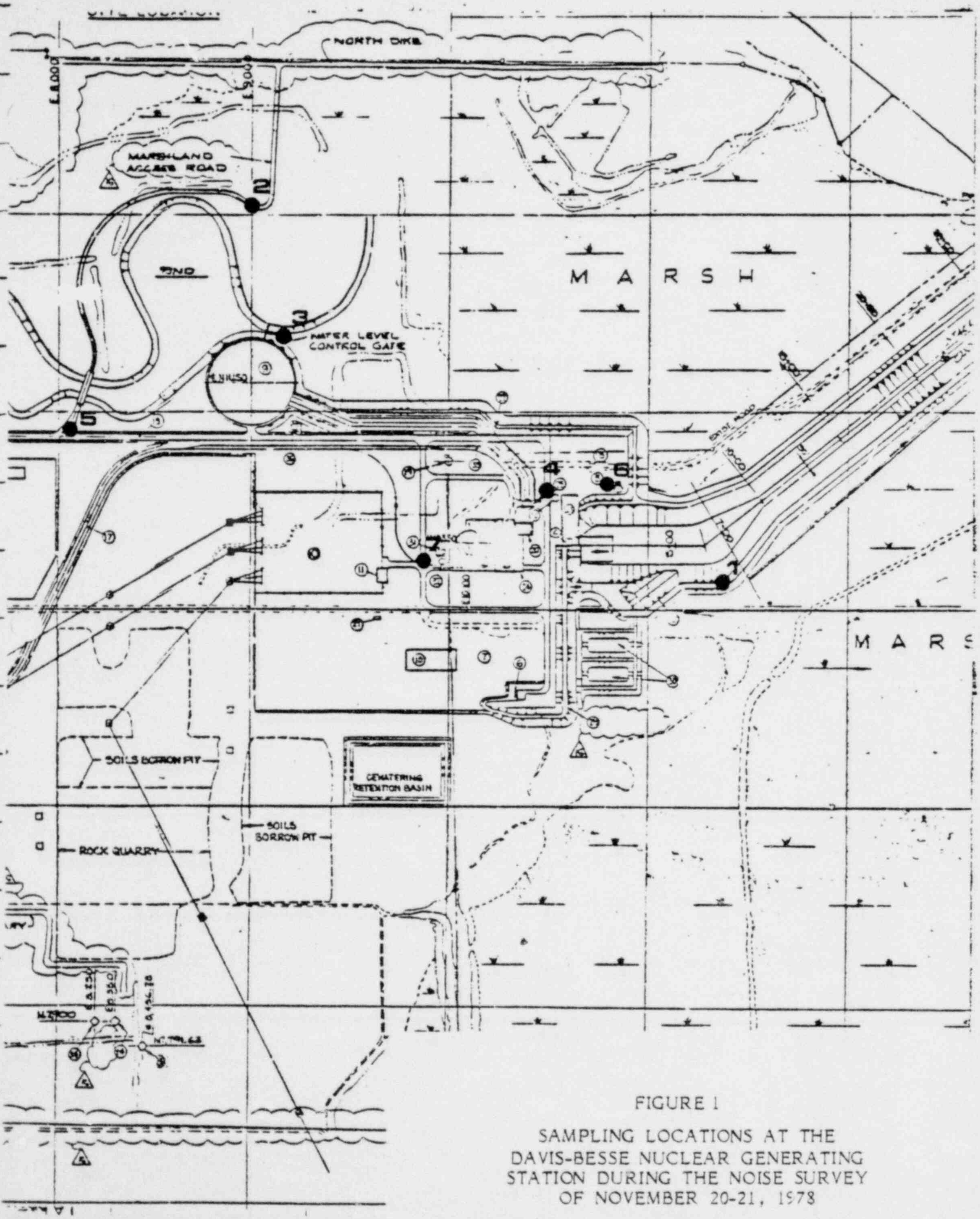

FIGURE 1

SAMPLING LOCATIONS AT THE DAVIS-BESSE NUCLEAR GENERATING STATION DURING THE NOISE SURVEY OF NOVEMBER 20-21, 1978

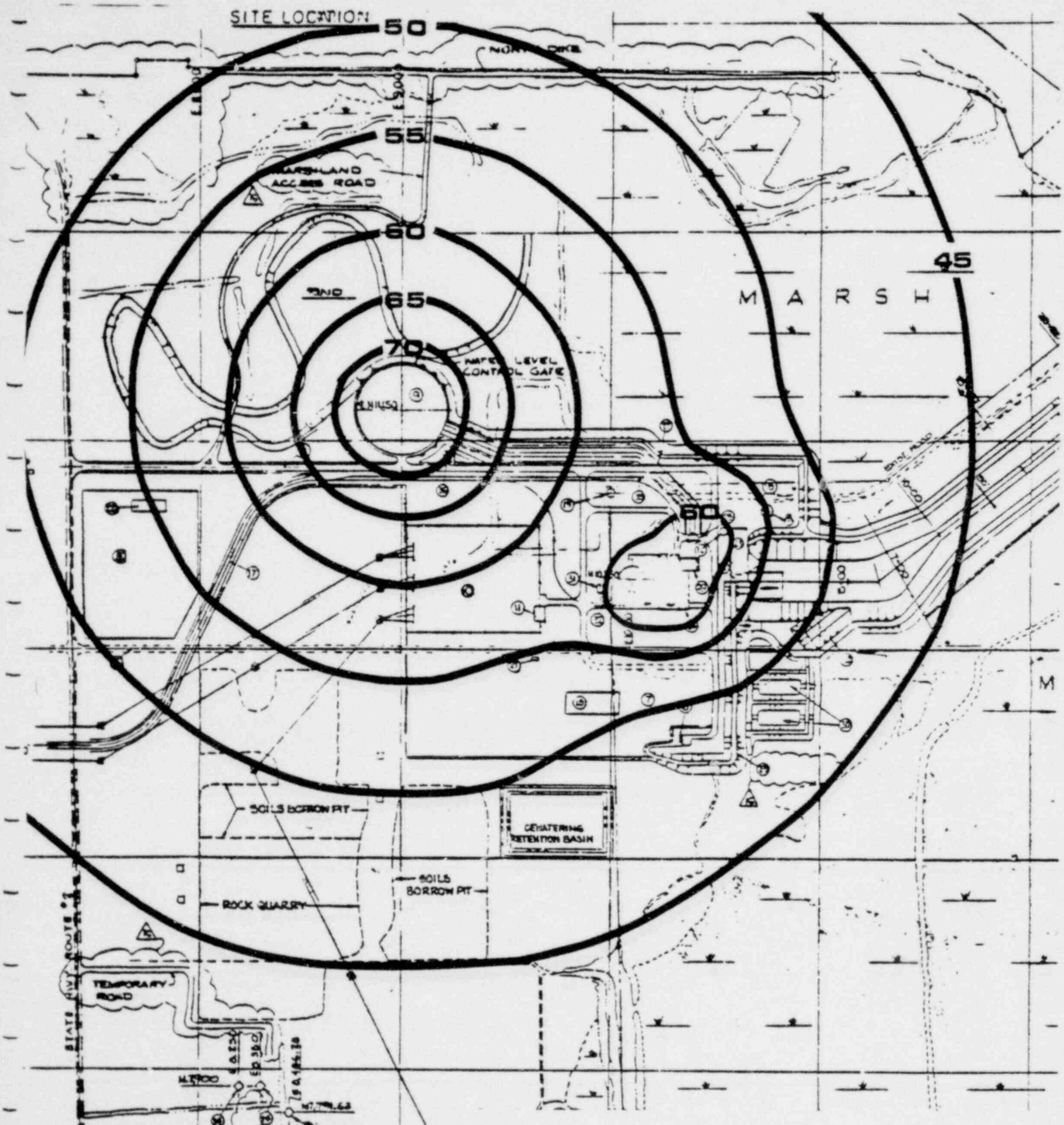

FIGURE 2

OPERATIONAL SOUND PRESSURE LEVELS AT THE DAVIS-BESSE NUCLEAR GENERATING STATION, dBA