COMMONWEALTH OF KENTUCKY
DEPARTMENT OF TRANSPORTATION
Division of Research
533 South Limestone
Lexington, KY 40508

FRANK R. METTS
SECRETARY

JOHN Y. BROWN, Jr.
GOVERNOR

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MEMO TO: Henry Bennett
Acting, State Highway Engineer
Acting, Chairman, Research Committee

SUBJECT: Report 540; "Propagation of Traffic Noise;"
KYHPR-75-78; HPR-PL-1(15), Part II

Each vehicle in a traffic stream emits noise. The intensity of each diminishes in proportion to the distance squared. A listener hears the combination of diminished intensities. Doubling the distance diminishes the sound pressure to 1/4 and the loudness by 6 dBA. Reflection, damping, and mixing cause the decrease to vary somewhat from the expected, simple-theory value of 6 dBA. The variations can be significant. From a ground-level emitter to a ground-level receiver, the attenuation or loss may exceed 6 dBA. From an elevated emitter, the sound may travel in a straight line and be reinforced at the receiver by sound reflected from the ground. An increase or decrease of 10 dBA doubles or halves the loudness of the noise. The objective in defining and refining these variations is the protection of the roadside areas from noisome noises.

This work began in 1975 and has been completed. Some data acquired soon thereafter was utilized by FHWA (Tim Barry) in improving the prediction model. The new or improved model was then tested by us and recommended to the Division of Environmental Analysis (Report 534; January 1980).

Considerable instrumentation was acquired in a previous study (Report 379; November 1974). This was supplemented by other equipment to do simultaneous measurements and automatic analyses. Some of the equipment will become surplus. An inventory and disposition plan is being prepared.

Respectfully submitted,

Jas. H. Havens
Director of Research

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Attachment
cc's: Research Committee

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16. Abstract

The effects of various traffic, ground cover, and geometric conditions on traffic noise propagation were evaluated in this study. There were two general methods of data collection. The first method consisted of using as many as four sound-level meters and graphic-level recorders to take simultaneous recordings of the traffic stream; the second method involved a constant noise source using a random noise generator.

The L_{10} noise level reduction per doubling of distance was found to increase substantially when the traffic volume was less than 1,000 vehicles per hour. Wind speed and direction were found to have a large effect on noise propagation. Ground cover was also found to have a definite effect. Data were taken on short grass, tall weeds, tall grass, average grass, pavement, gravel, smooth dirt, snow, and plowed field. The drop-off per doubling of distance was found to decrease from about 4.5 dBA for receiver heights of 10 feet (3 m) or below to 3.0 dBA for heights above 10 feet (3 m). At heights above 10 feet (3 m), the type of ground cover did not have a significant influence on the propagation loss. Noise attenuation per doubling of distance remained constant back to about 400 feet (122 m) where the drop-offs were influenced by the ambient noise level. Individual noise readings indicated that noise propagation was influenced by vehicle type and speed. Noise drop-off was larger for smaller percentage levels, but the differences decreased as volumes increased. Source height was also found to have an effect on noise propagation.

17. Key Words	18. Distribution Statement
traffic noise, propagation, traffic volume, octave band, receiver height, source height, ground cover	

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Research Report
540

PROPAGATION OF TRAFFIC NOISE

KYHPR-75-78; HPR-PL-1(15), Part II B

by

Kenneth R. Agent
Research Engineer Chief

and

Charles V. Zegeer
Formerly Research Engineer Principal

Division of Research
Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

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INTRODUCTION

The propagation of traffic noise is a concept hard to quantify in the prediction of highway noise levels. To some degree, noise propagation depends on traffic conditions, type of ground cover, and the geometry of the highway and nearby terrain. The effect of these variables on noise levels, combined with the difficulty of predicting noise levels on low-volume roads, make accurate noise prediction difficult. As a general rule, sound from a point source, such as a single vehicle, spreads out uniformly (spherical spreading) and the sound level drops off at the rate of 6 dB for each doubling of distance. This is referred to in acoustics as the "inverse square law". This drop-off rate does not apply to highway situations because an observer seldom hears just a single vehicle. In the limiting case, a continuous line of vehicles becomes a line source and the rate of sound level drop-off with distance approaches "cylindrical spreading," which produces a 3-dB drop-off rate for each doubling of distance. The effects of various traffic, ground cover, and geometric conditions on traffic noise propagation were evaluated in this study.

BACKGROUND

Considerable research has been completed in the past in an attempt to quantify the effect of various factors on noise propagation. Some of the results have not provided clear answers and some have been contradictory. The following is a summary of previous research dealing with noise propagation.

TRAFFIC VOLUME

The rate of noise propagation is theoretically a function of traffic volume. For a point source such as one vehicle, the sound level decreases by 6 dB for each doubling of distance away from the roadway. For a line source the drop-off of noise level is 3 dB per doubling of distance *(1)*. Data reported in one source tended to confirm this information *(2)*. For use in highway noise prediction models; a noise decline of 4.5 dB per doubling of distance is used for all volume conditions *(3, 4)*. This is referred to as a modified line source. One reference states that, for an average four-lane highway, the assumption of a line source will be true when the total traffic volume exceeds perhaps 1,000 vehicles per hour *(5)*. However, for traffic volumes less than this, the line-source assumption may not be completely correct.

The effect of traffic volume on the propagation loss factor was not found to be significant for volumes over 2,000 vehicles per hour (vph) based on data shown in NCHRP Report 173 *(6)*. The loss factor was thought possibly to be affected for volumes below 2,000 vph; however, ambient noise influence on the low-volume measurements prevented valid conclusions *(6)*. Additional research was needed to adequately define the effect of low-volume conditions on noise propagation.

GROUND COVER

The effect of the ground cover between the noise source and observer has been found to significantly affect noise propagation. In a Connecticut study completed in 1971, the transmission of random noise was measured through dense corn, a dense hemlock plantation, an open pine stand, dense hardwood brush, and cultivated soil. Bare ground was found to attenuate noise between 200-1,000 hertz (Hz). Tilling the soil reduced the frequency of peak attenuation from 700 to 350 Hz. All types of dense forests were about equally as effective in attenuating high-frequency noise *(7)*.

In another study, the difference in noise propagation from a loudspeaker was compared for grass and pavement surfaces. For distances of 3 to 30 feet (0.9 to 9.1 m), the noise levels were 2 to 3 dBA louder over pavement than grass covers. The meter and speaker were both centered at 4 feet (1.2 m) above the ground *(8)*.

A model for the attenuation of traffic noise, developed in England in 1974, considered various types of ground cover for distances of 26 to 1,300 feet (8 to 400 m). The difference in propagation increased with increasing distance from the roadway. At about 330 feet (101 m), the combined attenuation by distance and ground cover was least for hard ground (22 dBA) compared to the open site (26 dBA), farmland (30 dBA), and dense woodland (37 dBA) *(9)*.

The present design guide provides for excess noise attenuation due to vegetation. This factor applies when the vegetation is dense enough to break the line of sight between the roadway and observer and is at least 15 feet (4.6 m) high and 100 feet (30 m) deep. The maximum noise reduction allowable from vegetation alone is 10 dB based on 5 dB for every 100 feet (30 m) of dense trees *(3, 4, 5)*.

Also, the ground condition between the receiver and roadway is considered. The ground is defined as either absorbent or reflective *(5)*. Reflective ground means that the ground is flat and hard with very few or no obstructions. The design guide uses an attenuation of 3 dB per doubling of distance when the surface of the terrain is highly reflective, as with asphalt or concrete pavements *(6)*.

MEASUREMENT HEIGHT

Results from several studies have shown that sound levels increase with increasing measurement height due to ground attenuation. In a Canadian study, adjustment factors were developed for various heights and distances on short grass ground covers. For example, at 100 feet (30 m) from the road, adjustments for various heights (reference: 0 dBA at 4 feet (1.2 m)) were plus 5 dBA at 10 feet (3.0 m), plus 7 dBA at 20 feet (6.1 m), and plus 6 dBA at 40 feet (12 m). Corrections for 200 and 300 feet (61 and 91 m) from the road were also given *(10)*.

In a study by Scholes et al., in England in 1974, the L_{10} values at a site 75 feet (23 m) from a road were plotted for heights of 5 feet (1.5 m), 10 feet (3.0 m), 20 feet (6.1 m), and 30 feet (9.1 m). For conditions of no wind, L_{10} values for these heights were 74.5, 76, 79, and 80 dBA, respectively. Thus, heights above 5 feet (1.5 m) would cause noise increases of about 1.5 dBA at 10 feet (3.0 m), 4.5 dBA at 20 feet (6.1 m), and 5.5 dBA at 30 feet (9. 1 m) *(11)*.

The current design guide uses an attenuation factor depending on observer height *(4)*. For observers near the gound, an attenuation of 4.5 dB is used for each doubling of distance. However, for higher receivers (above 10 feet (3.0 m)), a reduction of 3 dB per doubling of distance is used.

A stated conclusion in NCHRP Report 173 was that the propagation loss factor was not significantly dependent on measurement height for heights up to 15 feet (4.6 m) above ground. However, propagation loss would be expected to fall as the height increased above 15 feet (5 m) over a lush ground cover *(6)*.

DISTANCE FROM ROADWAY

Another variable which may affect noise propagation is the distance of the observer from the roadway. The propagation loss factor (noise drop-off per doubling of distance) has been found to be a constant for distances of 50 to 1,600 feet (15 to 488 m). This applied to high traffic volumes (over a few thousand vph), but it was not necessarily applicable to low-volume sites *(6)*.

VEHICLE SPEEDS AND CHARACTERISTICS

Very little information is available concerning the effect of vehicle types and speeds on noise propagation. For automobiles, as speed increases, tire-roadway noise increased rapidly and becomes the controlling factor. Noise from medium and heavy trucks is controlled by engine and exhaust noise and is louder than car noise. As the speed of most vehicles increases, higher frequencies begin to dominate.

Most grassy ground covers reduce higher frequencies better than low frequencies. Since frequency generally increases as speed increases, more attenuation may be expected at higher speeds for cars in particular. Because of the many factors affecting truck noise, the effect of speed on noise propagation is not clear. The source height of noise from large trucks is assumed to be 8 feet (2.4 m). The noise source heights of different vehicles may also have an effect on noise propagation *(12)*.

PERCENTAGE LEVEL

The percentage level is a way of expressing noise levels over a period of time. Examples of percentage levels commonly used are L_{01}, L_{10}, L_{50}, and L_{90}. L_{10} is the noise level exceeded 10 percent of the time. The L_{eq}, or equivalent level, is an expression of the total noise energy over a time period. Values of L_{10} and L_{eq} are more commonly used in highway noise standards and in comparisons of highway noise levels *(12)*.

A relationship has been found between percentage levels and noise propagation *(6)*. At traffic volumes below 5,000 vph and at distances within 1,600 feet (488 m) of the roadway, the propagation loss factor varied significantly with percentage level. In such cases, more propagation loss was found in the smaller percentage levels (L_{01} and L_{10}) than higher percentage levels (L_{90}). This seems reasonable since L_{90} levels are usually quite low at low-volume sites (near ambient levels) and have little room for further decrease in propagation loss. At volumes above 5,000 vph, a common propagation loss factor could be applied for all percentage levels.

WIND AND TEMPERATURE

The direction and speed of wind affects the propagation of sound, although the effect is not always well known. In a calm environment, the sound-wave fronts are undistorted and sound propagates radially. In wind, the sound upward from the source refracts up and away from the ground, creating a shadow zone. This would have little effect for close distances to the source; but beyond the edge of the shadow zone, there may be a considerable reduction in noise. The downwind sound is refracted down towards the ground, so sound would be carried farther than for calm conditions *(13)*.

Irregular or gusty winds of 15 to 30 mph (6.7 to 13.4 m/s) may cause fluctuations in sound levels by an average of about 4 to 6 dBA per 300 feet (91 m). Short-term fluctuations may be much greater than average losses. However, changes in noise levels based on high wind speeds cannot be counted on for noise control for any extended period of time under normal circumstances *(2, 14)*.

In one study, reductions up to 20 dB were found upwind compared to calm conditions. Excess attenuation upwind exceeded downwind propagation by 25 dB (at 12 feet (3.7 m) heights) to 30 dB (at 5-foot (1.5-m) heights) *(15)*.

Air temperature can also have an effect on sound propagation. Under normal daytime situations, temperature decreases with height. This may result in temperature-created shadow zones upward and symmetrical from the noise source. During temperature inversions, the sound is refracted down towards the ground in all directions. Sometimes, irregularities in the temperature inversion profile can cause a focusing of sound, and the perceived noise level can be higher at some locations than others closer to the source *(13)*.

PROCEDURE

TYPES OF DATA

Data were collected to determine the effects of the following variables on traffic noise propagation:

(1) traffic volume,
(2) wind,
(3) ground cover,
(4) receiver height,
(5) distance,
(6) traffic speed,
(7) source height,
(8) percentage level, and
(9) type of vehicle.

DATA COLLECTION

There were two general methods of data collection. The first consisted of using as many as four sound-level meters and graphic-level recorders to take simultaneous recordings of the traffic stream. These data were taken at different distances and heights from the roadway. The distances were measured from the centerline of the near traffic lane. Ten-minute recordings were obtained using the A-weighting scale. Noise levels at intervals slightly greater than one second were determined in the laboratory utilizing a digital datareduction system where noise output was punched onto computer cards as described in a previous report *(16)* and analyzed. Figure 1 illustrates the various methods of data collection and analysis used at sites adjacent to the roadway. The setup to collect simultaneous data at four different heights is shown in Figure 2. A description of the sites at which measurements were taken is given in Table 1. Noise levels of individual vehicles were also obtained using the sound-level meter. The second method involved a constant noise source using a random noise generator. The output noise was input into a sound-level meter equipped with an octave band analyzer, amplified, and broadcast through a speaker. The resulting noise level was analyzed at different distances and heights from the speaker using a sound-level meter equipped with an octave band analyzer (Figure 3). Octave band analysis was set for center frequencies from 63 through 8,000 hertz. Pink noise (constant energy per octave bandwidth) was used for the octave band analysis while white noise (flat spectrum with constant energy per hertz bandwidth) was used for unweighted (linear) and A-weighted noise analysis. A photograph of the equipment used for this data collection is in Figure 4.

For the traffic stream locations, the data were generally analyzed in terms of the L_{10} or L_{eq} noise level. A computer program using the trapezoidal rule and Simpson's rule was used to determine L_{eq}. Following is a list of the terms used in the summaries of the data:

L_{10}	=	noise level exceeded 10 percent of the time,
L_{50}	=	noise level exceeded 50 percent of the time,
L_{90}	=	noise level exceeded 90 percent of the time,
L_{eq}	=	noise equivalent level,
L_{max}	=	maximum noise level,
L_{min}	=	minimum noise level,
AUTO	=	automobiles and light trucks,
MT	=	medium trucks, and
HT	=	heavy trucks.

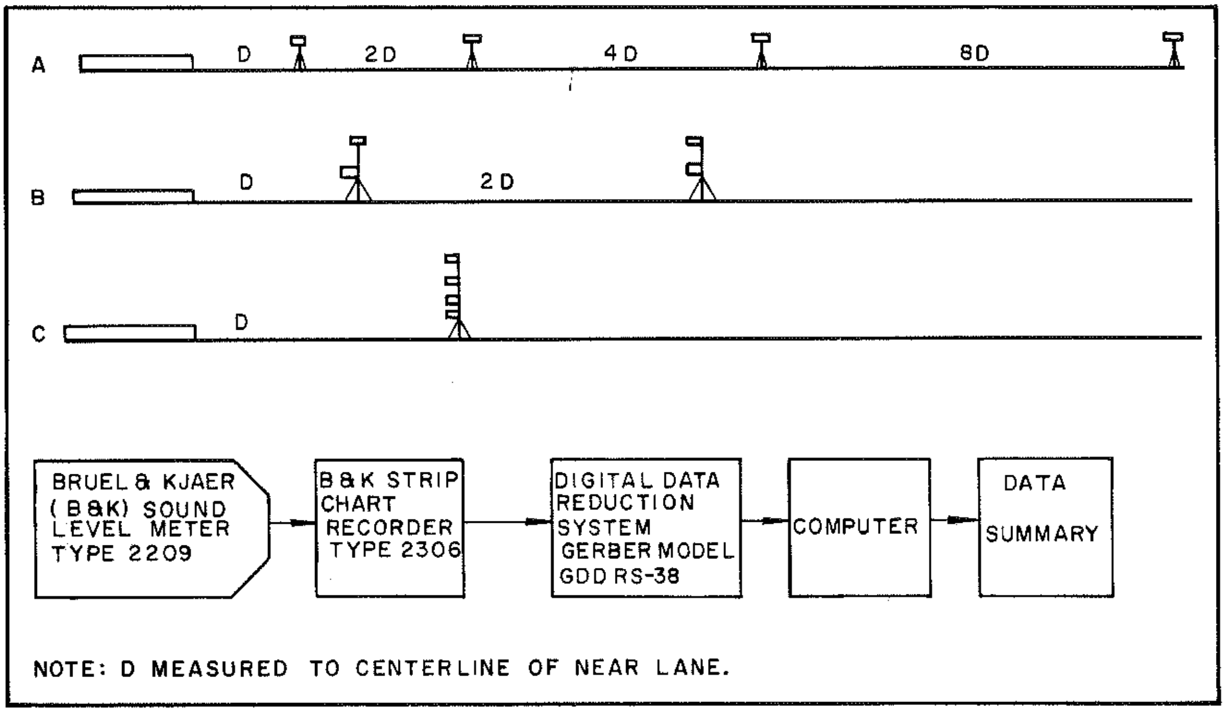
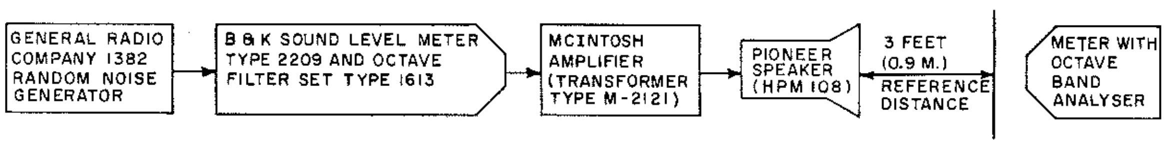


Figure 1. Data Collection and Analysis Used at Sites Adjacent to Roadway.

Figure 2. Photograph of Setup Used to Collect Data Simultaneously at Four Measurement Heights.

TABLE 1. TRAFFIC STREAM MEASUREMENT SITES

SITE NUMBER	ROUTE	LOCATION (CITY)	HIGHWAY NAME	TYPE OF LOCATION	SPEED LIMIT (MPH)	SPEED LIMIT (M/S)	AVERAGE SPEED (MPH)	AVERAGE SPEED (M/S)	TYPICAL HOURLY VOLUME	NUMBER OF NOISE RECORDINGS: 10-MINUTE MEASUREMENTS	NUMBER OF NOISE RECORDINGS: TOTAL PERIODS
1	US 27	Lexington	South Limestone Street	Urban	40	(18)	37	(17)	2150	244	78
2	US 68	Lexington	Harrodsburg Road	Rural	55	(25)	54	(24)	570	102	36
3	I 75	Lexington	Interstate 75	Rural	55	(25)	62	(28)	1800	203	75
4	I 264	Louisville	Watterson Expressway	Urban	55	(25)	48	(21)	3880	102	34
5	US 60	Lexington	Winchester Road	Rural	55	(25)	53	(24)	420	58	20
6	US 31W	Louisville	Dixie Highway	Urban	40	(18)	36	(16)	2500	51	17
7	US 60	Versailles	Versailles Road	Rural	50	(22)	56	(25)	820	80	22
8	US 68	Lexington	Harrodsburg Road	Urban	45	(20)	37	(17)	660	36	12
9	US 60	Lexington	Winchester Road	Urban	45	(20)	34	(15)	2130	15	5
Totals										891	299



NOTE:

1. RANDOM NOISE GENERATOR PROVIDES BOTH PINK AND WHITE NOISE.
2. OCTAVE BOND ANALYSIS FOR CENTER FREQUENCIES OF 63 THROUGH 8,000 ALSO LINEAR AND A-WEIGHTED.
3. USED PINK NOISE FOR OCTAVE BAND ANALYSIS.
4. USED WHITE NOISE FOR LINEAR AND A-WEIGHTED.
5. NOISE LEVEL AT REFERENCE DISTANCE WAS 95 dB FOR ALL DATA EXCEPT LINEAR NOISE (90 dB).

OCTAVE FREQUENCY RANGE (H_2)	GEOMETRIC MEAN FREQUENCY OF BAND (H_2)
22—44	31
44—88	63
88—175	125
175—350	250
350—700	500
700—1400	1000
1400—2800	2000
2800—5600	4000
5600—11200	8000

Figure 3. Data Collection Procedure Using Random Noise Generator.

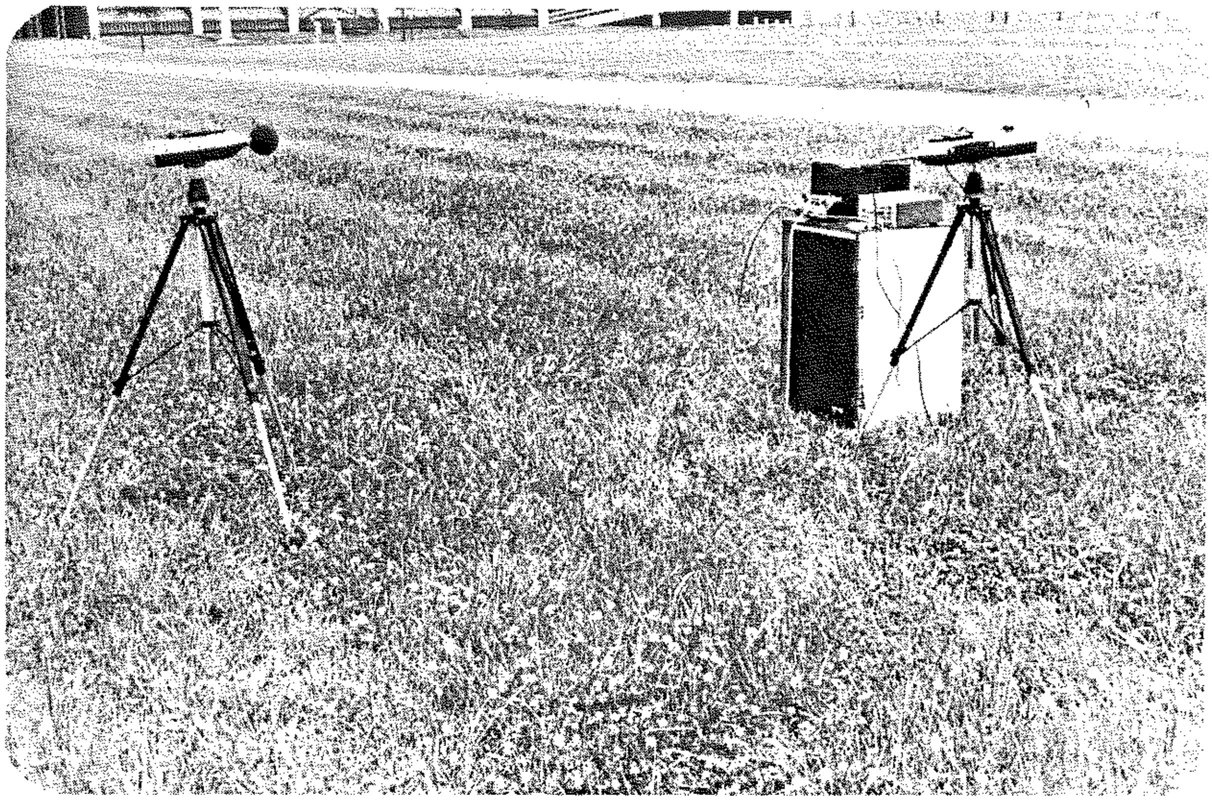


Figure 4. Photograph of Equipment Used with Random Noise Generator.

RESULTS

TRAFFIC VOLUME

One of the primary objectives of the study was to determine the effect of traffic volume on traffic noise propagation. Theory states that noise propagation will vary from 3 to 6 dB for a line or point source, respectively. The current design guide used a 4.5 dBA drop-off for all traffic volumes. This is termed a modified line source. A past study concluded that traffic volume did not influence noise propagation when the volume was over 2,000 vph *(6)*. However, it was stated that noise propagation might be significantly influenced by volumes lower than 2,000 vph. Since a large percentage of Kentucky highways have volumes less than 2,000 vph, a large amount of data was taken in an attempt to resolve this question.

The method of data collection involved taking simultaneous recordings of the traffic stream at different distances. All the data were taken at a 5-foot (1.5-m) height over short grass. Sites were chosen at locations with zero grade, with the observer level with the roadway, and with no shielding to reduce the number of variables which would alter the noise drop-off. Sites were chosen so that a large range in traffic volumes could be obtained. The wind speed and direction were obtained and data were not used in the analysis if the wind vector either toward or away from the roadway was over 10 knots. A summary of the data is given in APPENDIX A.

Results shown in Table 2 give the average noise reduction per doubling of distance for various traffic volumes. Two sets of data are given. One set of data represents all the data while the other excludes some data. Data were excluded from the modified set if the reduction per doubling of distance was greater than 6.5 dBA or less than 2.5 dBA. This allowed a one-half decibel variance from the theoretical limits which could have resulted from data collection and analysis errors. Considering the L_{10} noise level data, approximately four percent of the data showed a reduction less than 2.5 dBA; about 12 percent was greater than 6.5 dBA.

TABLE 2. REDUCTION IN TRAFFIC NOISE LEVEL PER DOUBLING OF DISTANCE FOR VARIOUS TRAFFIC VOLUMES

TRAFFIC VOLUME (VEHICLES PER HOUR)	NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE					
	ALL DATA			EXCLUDING SOME DATA[a]		
	L_{10}	L_{eq}	L_{50}	L_{10}	L_{eq}	L_{50}
Less than 1000	5.7	5.2	3.4	5.2	5.0	3.8
1000 - 1999	4.9	4.6	3.9	4.2	4.2	4.1
2000 - 2999	4.0	3.8	3.5	4.2	4.0	3.7
3000 - 4000	4.6	4.7	4.0	4.6	4.7	4.1
Over 4000	4.2	4.3	4.2	4.2	4.3	4.2

[a] Exclude data if the reduction per doubling of distance was greater than 6.5 dBA or less than 2.5 dBA.

The reduction in the L_{10} noise level per doubling of distance increased substantially when the volume was less than 1,000 vph. The reduction in the L_{eq} noise level also increased for volumes less than 1,000 vph; however, the increase was not quite as dramatic as for the L_{10} level. For both the L_{10} and L_{eq} noise levels, the average reduction for the various traffic volumes was very close to the 4.5-dBA drop-off per doubling of distance currently used in traffic noise prediction for all traffic volumes. The data summarized in Table 2 show this assumption to be very good, except for traffic volumes less than 1,000 vph where this drop-off increases to over 5 dBA. It should be noted that this is an average value for volumes less than 1,000 vph. In some cases, the drop-off was less than 5 dBA. However, considering all data, it is recommended that the reduction per doubling of distance used to predict L_{10} noise levels be increased to 5.0 dBA for volumes less than 1,000 vph.

The equivalent distance, which is basically the distance to the centerline of the roadway, is used rather than the distance to the near lane in the prediction procedure *(4)*. An analysis similar to that shown in Table 2 was done using the equivalent distance to determine if any significant difference occurred. As in Table 2, there was an increase in the noise reduction per doubling of distance for low-volume conditions, particularly using the L_{10} values. An analysis excluding data where the reduction per doubling of distance was greater than 6.5 dBA or less than 2.5 dBA found the L_{10} reduction varied from 4.5 dBA for volumes of 2,001 to 3,000 vph to 4.8 dBA for volumes between 1,000 and 2,000 to 5.1 for volumes less than 1,000 vph. For L_{eq}, the reduction per doubling of distance varied from 4.5 dBA for volumes of 2,001 to 3,000 vph to 4.7 dBA for volumes between 1,000 and 2,000 to 4.9 dBA for volumes less than 1,000 vph.

Current highway design criteria is based on L_{10}. For comparison purposes, the noise drop-off was also obtained for L_{eq} and L_{50}. Theoretically, when the L_{eq} noise level is considered, traffic volume should not have the influence reflected in the L_{10} value. However, the L_{eq} drop-off also increased for volumes less than 1,000 vph but not as much as that found for L_{10}. A different situation was found when the L_{50} was considered. The L_{50} experienced a lower drop-off compared to both L_{10} and L_{eq}. Also, the L_{50} drop-off was not significantly affected by traffic volume. The L_{50} reduction actually decreased slightly for lower traffic volumes.

In addition to using the actual volume count, a separate analysis was made using what was termed the "equivalent volume." This was a weighted volume based on the number of automobiles and medium and heavy trucks in the traffic stream. The formula for equivalent volume was as follows:

$$EV = A + 2M + 4H$$

where
- EV = equivalent volume (per hour),
- A = number of automobiles and light trucks,
- M = number of medium trucks, and
- H = number of heavy trucks.

Light trucks refer to two-axle, four-wheel vehicles. Medium trucks generally refer to gasoline-powered, two-axle, six-wheel vehicles. Heavy trucks refer generally to diesel-powered, three-or-more-axle truck combinations. There is a large difference in the noise levels emitted by these types of vehicles. Multiplying factors were applied to medium and heavy trucks to determine if this would alter the previous findings concerning the relationship between noise-level reduction per doubling of distance and traffic volume. However, when the data were summarized using equivalent volume very similar results were found.

WIND

Large fluctuations in noise drop-off were sometimes found at a site even when the traffic volumes were similar. These variations were partially explained by the effect of wind. The wind speed and direction for each measurement are given in APPENDIX B. These data were used to determine the component blowing either directly toward or away from the roadway. These components were then grouped according to speed. Data taken when the traffic volume was less than 1,000 vph were not used in these calculations, since the low traffic volume influenced the data. The measurement height was 5 feet (1.5 m) and the ground cover was short grass. Results are shown in Table 3.

TABLE 3. REDUCTION OF TRAFFIC NOISE LEVEL PER DOUBLING OF DISTANCE FOR VARIOUS WIND VECTORS

DIRECTION	WIND VELOCITY (KNOTS)[a]	TRAFFIC NOISE REDUCTION PER PER DOUBLING OF DISTANCE L_{10}[b]	L_{eq}[c]
	Greater than 10	8.6	8.3
Away from roadway	5 - 10	5.0	4.8
	1 - 4.9	5.0	4.9
	0 - 4.9	4.2	4.1
Toward roadway	5 - 10	3.8	3.6
	Greater than 10	2.7	2.7

[a] Wind vector blowing either directly away from or toward roadway. Calculated using wind speed and direction given in Table B-1.

[b] The equation for the relationship between the L_{10} reduction per doubling of distance and wind vector was $y = 4.78 - .21\,x$ where x is the wind vector and y is the L_{10} noise dropoff. The r^2 was 0.93. A wind vector away from the roadway was negative; toward the roadway positive; parrallel to the roadway was zero.

[c] The equation for the relationship between the L_{eq} reduction per doubling of distance and wind victor was $y = 4.63 - .20\,x$ where x is the wind vector and y is the L_{eq} noise dropoff. The r^2 was 0.93.

When the component speed was over 10 knots (11.5 mph (5 m/s)), the noise drop-off was influenced significantly. When the wind was blowing away from the roadway, the noise was spread by the wind, and the noise drop-off was small. Conversely, when the wind was blowing toward the roadway, the spreading of the noise was inhibited and the drop-off was increased. The results showed that reliable data cannot be taken when the speed of the wind component is greater than 10 knots (11.5 mph (5 m/s)). Also, even at speeds less than 10 knots (11.5 mph (5 m/s)), the wind speed and direction should be considered.

GROUND COVER

The effect of ground cover on noise propagation was investigated using both types of data sources -- noise generated by the traffic stream and a random noise generator. The traffic-stream data were collected at a low-volume location (Harrodsburg Road (US 68) near Lexington) and a high-volume location (Dixie Highway in Louisville). Summaries of the data used in this analysis plus other traffic-stream noise data taken on a ground cover other than short grass are given in APPENDIX C. The random noise generator was used at numerous sites such as parking lots, grass fields, and agricultural areas isolated from highways. Reference noise levels (at a distance of 3 feet (0.9 m)) from the random noise generator was 95 dB for all measurements except linear noise where a 90 dB reference was used.

A summary was made of the traffic stream data as shown in Table 4. The drop-off in L_{10} and L_{eq} are given per doubling of distance for various ground covers. On short grass, the L_{10} dropped off 5.0 dBA compared to 4.7 dBA for L_{eq} at the high-volume site. The L_{10} reduction per doubling of distance dropped off 5.8 dBA over tall grass (5.4 dBA for L_{eq}) compared to a drop-off of only 2.9 dBA over pavement (2.8 dBA for L_{eq}). For the low-volume site, the L_{10} noise level dropped off 5.9 dBA over short grass and a plowed field compared to 3.1 dBA over pavement. The effect of a reflective surface (pavement) on noise attenuation is clearly demonstrated.

TABLE 4. NOISE LEVEL DROP-OFF PER DOUBLING OF DISTANCE FOR VARIOUS GROUND COVERS AND TRAFFIC VOLUMES (TRAFFIC STREAM DATA)

		NOISE DROP-OFF PER DOUBLING OF DISTANCE (dBA)	
	GROUND COVER	L_{10}	L_{eq}
High volume	Short grass	5.0	4.7
Location	Tall grass	5.8	5.4
(Site 6)	Pavement	2.9	2.8
Low volume	Short grass	5.9	5.2
Location	Pavement	3.1	3.1
(Sites 2 and 8)	Plowed field	5.9	5.1

The random noise generator was utilized for determining the difference in noise attenuation (A-weighted noise levels) between short grass and other ground covers as plotted in Figure 5. A plowed field produced the same attenuation as short grass. Attenuations per doubling of distance for medium and high grass, snow, and smooth dirt ground covers were within 1 dBA compared to short grass. Pavement, followed by gravel, provided the least attenuation. High weeds provided much more attenuation than any other ground cover. A comparison of the attenuation provided by pavement compared to high weeds showed that ground cover can have a significant effect on noise propagation. However, comparison of various heights of grass showed that typical right-of-way ground covers do not show a large range in attenuation.

A series of plots were made to show noise levels over pavement, short grass, and high weeds for distances of 25 to 200 feet (7.6 to 61 m) using the random noise generator data. The relationship for A-weighted noise (Figure 6) shows that noise over pavement decreased from about 85 dBA at 25 feet (7.6 m) to about 63 dBA at 200 feet (61 m). Over short grass, noise levels decreased from about 84 dBA at 25 feet (7.6 m) to 50 dBA at 175 feet (53 m). Noise levels dropped off much more over high weeds. A decrease from 80 dBA at 25 feet (7.6 m) to about 56 dBA at 100 feet (30 m) was found. A plot of noise levels for other ground covers versus distances showed no great differences (Figure 7).

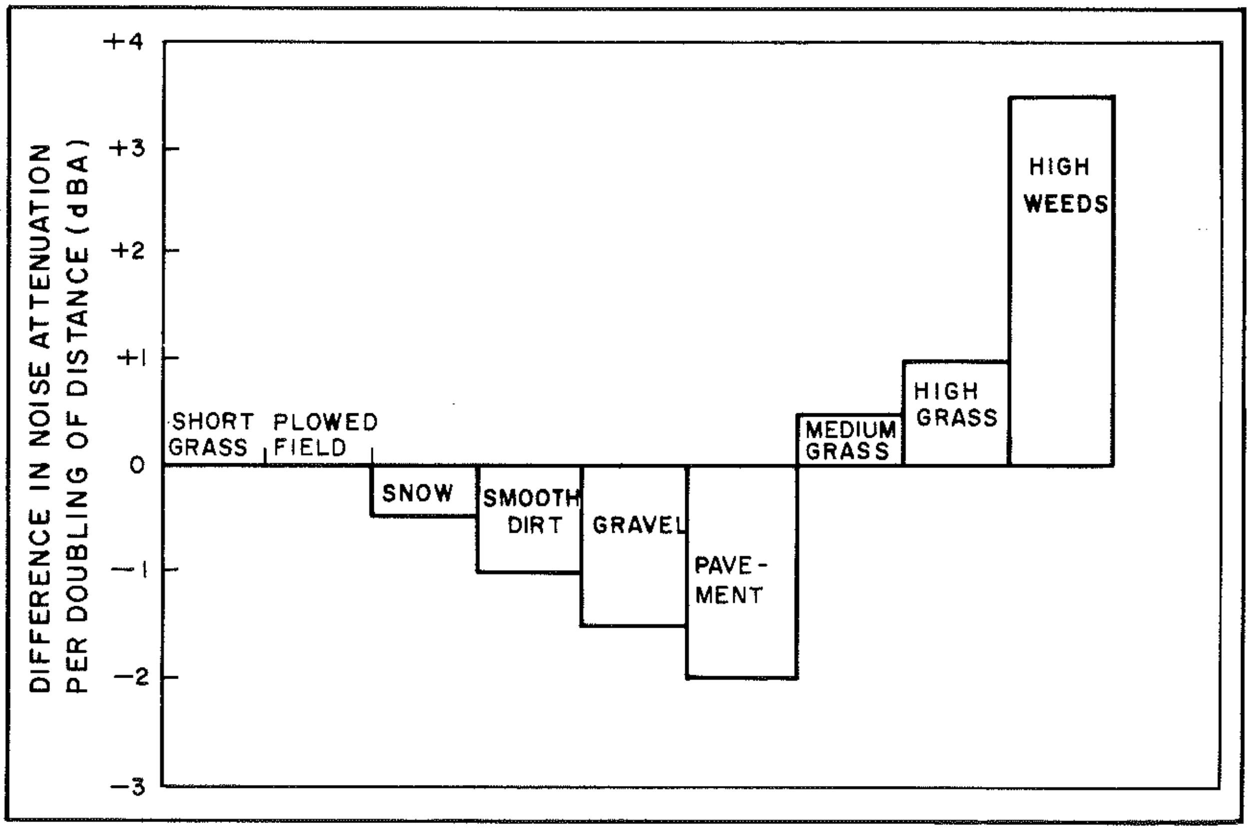
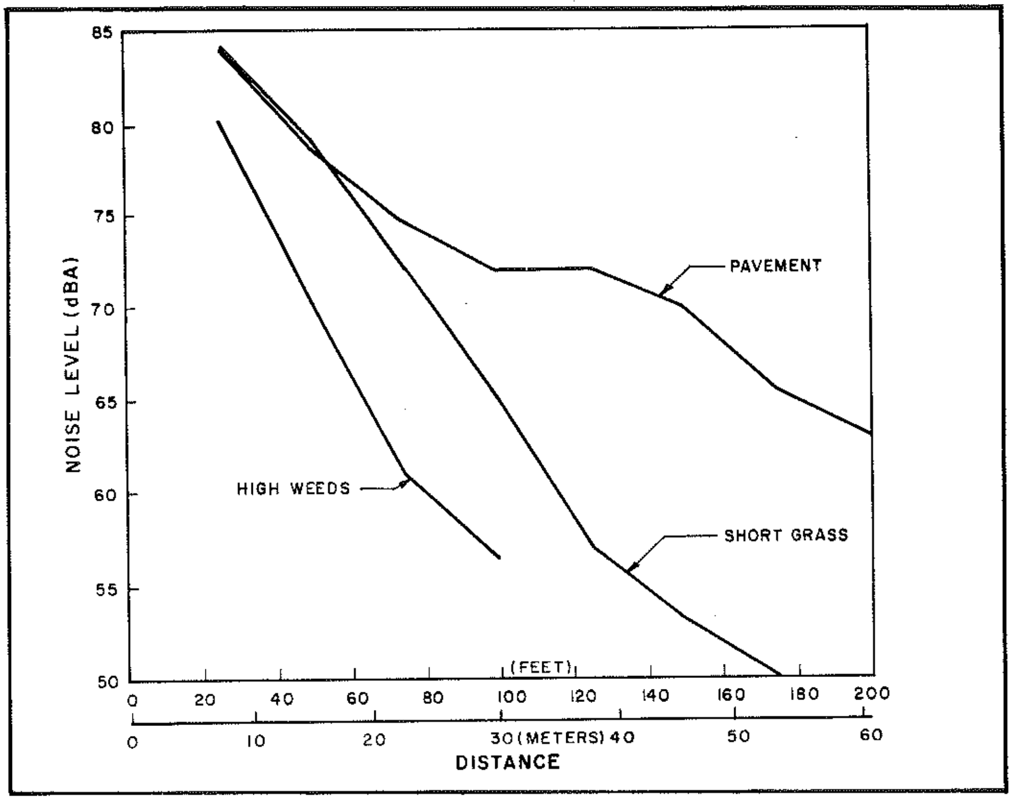


Figure 5. Noise Attenuation per Doubling of Distance for Various Ground Covers Compared to Short Grass (A-weighted Noise Level).

Figure 6. **Effect of Short Grass, Pavement, and High Weeds on Noise Levels (A-weighted) for Various Distances from the Random Noise Generator.**



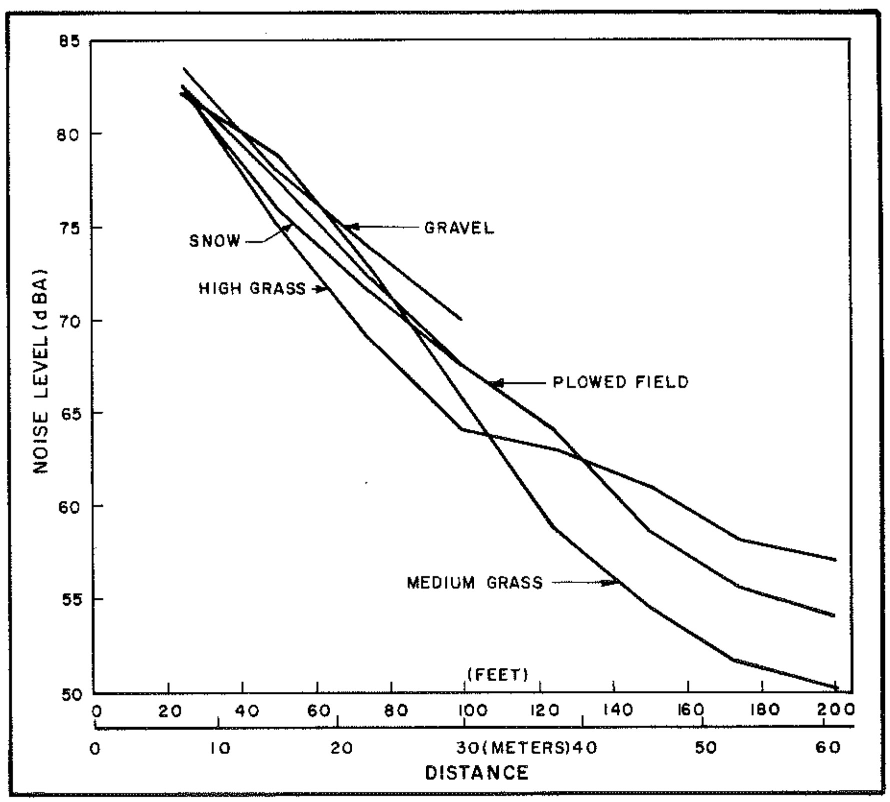


Figure 7. **Effect of Other Ground Covers on Noise Levels (A-weighted) for Various Distances from the Random Noise Generator.**

Similar plots of noise level (dB) versus distances were made for short grass, pavement, and high weeds for octave-band, center frequencies of 63, 125, 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz and linear (unweighted) noise (see APPENDIX D). Noise attenuations over the three ground covers were less for low frequencies (centered on 63, 125, and 250 Hz octave bands) than for high frequencies; low-frequency noise was affected very little by ground cover. Ground covers had a greater effect on noise levels for the 500 and 2,000 Hz center frequencies. At 1,000 Hz, noise levels on high weeds and short grass were almost identical but were considerably lower than noise levels over bituminous pavements. At 4,000 Hz, noise levels were higher on short grass than pavement up to a distance of 100 feet (30 m). At 8,000 Hz, a difference of nearly 20 dB was found between bituminous pavements (63 dB) and high weeds (44 dB) at a distance of 100 feet (31 m).

For unweighted (linear) noise, drop-offs could be detected only to about 100 feet (30 m); this was due to the high ambient (background) levels. Tables show average noise levels for all frequencies (in A-weighted and unweighted) for each distance; the data are given in APPENDIX D.

The noise drop-off per doubling of distance for the other ground covers are shown in Table 5. Using short grass as the reference cover, the difference in noise attenuation per doubling of distance was plotted for octave-band center frequencies of 62.5 to 8,000 Hz (APPENDIX E). The difference in propagation for the ground covers varied in different octave-band center frequencies. For example, a plowed field or smooth soil provided higher attenuation than short grass at 500 Hz but less at 2,000 Hz. The higher attenuation over high weeds compared to short grass varied from 1 dB at 250 hertz to 6 dB at 8,000 Hz. The attenuation over pavement was 7 dB less than over short grass at 2,000 Hz. Medium grass had lower noise drop-offs of about 1.5 dB at 500 and 8,000 Hz compared to short grass. The noise drop-off on snow was greater than on short grass at 125 through 1,000 Hz but was lower at the higher frequencies. The lower attenuation on gravel and pavement was due primarily to a low attenuation of the higher frequencies. Attenuation over high grass was higher than over short grass at 4,000 and 8,000 Hz.

TABLE 5. NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE FOR VARIOUS GROUND COVERS[a]

GROUND COVER	NOISE REDUCTION PER DOUBLING OF DISTANCE (dB)								
	A-WEIGHTED NOISE	OCTAVE - BAND CENTER FREQUENCY (HZ)							
		63	125	250	500	1,000	2,000	4,000	8,000
Pavement	6.0	5.5	6.0	6.5	6.5	6.5	3.0	6.5	9.0
Gravel	6.5	6.0	6.0	6.0	6.0	7.5	7.0	6.5	8.5
Smooth ground (No grass)	7.0	6.0	6.5	6.5	8.5	8.0	9.0	8.0	8.0
Snow	7.5	6.0	8.0	9.5	10.0	9.5	9.0	8.5	8.0
Plowed field	8.0	6.5	7.0	8.0	9.5	9.0	8.5	8.5	11.0
Short grass[b]	8.0	6.0	6.0	6.0	6.5	9.0	10.0	9.0	9.0
Medium grass[c]	8.5	6.0	6.0	7.0	8.0	8.0	10.5	10.0	10.5
High grass[d]	9.0	6.0	6.0	6.0	6.5	8.0	9.5	10.5	11.0
High weeds[e]	11.5	6.5	6.0	7.0	9.5	10.0	12.0	13.5	15.0

a Reference noise level of 95 dB at distance of 3 feet (0.9 m) from speaker for each test. Microphone height of 4 feet (1.2 m). Distances of 25 (7.6 m), 50 (15 m), 75 (2.3 m), and 100 feet (30 m) from reference point were used. White random noise used for A-weighted. Pink random noise used for various frequencies.
b About 1 inch (2.5 cm) high.
c About 3 (7.6) to 5 (13) inches (cm) high.
d About 9 (23) to 12 (30) inches (cm) high.
e About 3 (0.8) to 4 (1.0) feet (m) high.

RECEIVER HEIGHT

Traffic stream noise data were measured along with the random noise generator to determine the relationship between noise propagation and measurement (receiver) height. The major objective was to determine the height above the ground where the effect of ground cover becomes negligible. Measurements were made at receiver heights of 5 to 30 feet (1.5 to 9.1 m) above the ground. Distance from the roadway (measured from the centerline of the near lane) ranged from 25 to 600 feet (7.6 to 183 m). The data are given in APPENDIX F. The data collected at an urban location are given in Tables 6 and 7. Both the L_{10} and L_{eq} noise levels showed a reduction in drop-off per doubling of distance for the 20-foot (1.5-m) and 10-foot (3.0-m) heights. This relationship was also found for a high-speed interstate location which had a high volume of heavy trucks (see Table 8). The data support the present procedure of using a different noise reduction per doubling of distance depending on receiver height. Also, the current level of 10 feet (3.0 m) appears to be the point at which the drop-off changes.

Results obtained with the random noise generator confirmed findings obtained from measurement of the traffic stream. The reduction per doubling of distance for short grass and pavement were compared at different heights. Data were taken with the noise source at ground level to represent car noise (Table 9) and at an 8-foot (2.4-m) height to represent truck noise (Table 10). With the noise source at ground level, the difference in propagation over grass compared to pavement almost dissipated at a 9-foot (2.7 m) measurement height and completely dissipated at the 15-foot (4.6-m) height. This agreed with data from the traffic stream which showed that a change in the propagation loss occurs above a measurement height of 10 feet (3.0 m). At this height above the ground, the ground cover no longer has a significant influence on noise propagation.

TABLE 6. L_{10} NOISE LEVEL FOR VARIOUS RECEIVER HEIGHTS AND DISTANCES FROM ROADWAY (URBAN ROADS) (SITE 1)

DISTANCE FROM ROADWAY (FEET (M))	AVERAGE L_{10} NOISE LEVEL — HEIGHT ABOVE GROUND (FEET (M)): 5 (1.5)	10 (3.0)	20 (6.1)	30 (9.1)
25 (7.6)	74.0	74.6	73.6	74.2
50 (15.2)	67.8	69.9	71.6	71.4
100 (30.5)	65.1	66.8	68.7	69.3
200 (61.0)	61.4	61.6	64.1	65.7
400 (122.0)	54.0	55.2	58.3	60.8
Average reduction per doubling of distance	5.0	4.8	3.8	3.4

TABLE 7. L_{eq} NOISE LEVEL FOR VARIOUS RECEIVER HEIGHTS AND DISTANCES FROM ROADWAY (URBAN LOCATION) (SITE 1)

DISTANCE FROM ROADWAY (FEET (M))	AVERAGE L_{eq} NOISE LEVEL — HEIGHT ABOVE GROUND (FEET (M)) 5 (1.5)	10 (3.0)	20 (6.1)	30 (9.1)
25 (7.6)	71.1	71.5	70.8	71.3
50 (15.2)	65.3	67.4	69.0	69.8
100 (30.5)	62.6	64.3	66.1	67.2
200 (61.0)	59.0	59.4	61.8	63.5
400 (122.0)	51.7	53.2	57.5	58.9
Average reduction per doubling of distance	4.8	4.6	3.3	3.1

TABLE 8. REDUCTION IN NOISE LEVEL (L_{10}) FOR VARIOUS RECEIVER HEIGHTS AND DISTANCES FROM THE ROADWAY (INTERSTATE ROADS) (SITE 3)

MEASUREMENT HEIGHT (FEET (M))	DECREASE IN NOISE LEVEL (L_{10}) BETWEEN GIVEN DISTANCES — 80 FEET (24.4 M) TO 300 FEET (91.4 M)	80 FEET (24.4 M) TO 600 FEET (183 M)
5 (1.5)	15.9	25.7
10 (3.0)	15.3	23.7
20 (6.1)	9.7	20.0
30 (9.1)	7.9	18.6

TABLE 9. NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE FOR GRASS COMPARED TO PAVEMENT (NOISE SOURCE AT GROUND LEVEL)[a]

	NOISE REDUCTION PER DOUBLING OF DISTANCE (dB)													
			OCTAVE-BAND CENTER FREQUENCY (HZ)											
MEASUREMENT HEIGHT	A-WEIGHTED NOISE		125		250		500		1,000		2,000		4,000	
(FEET) (M)	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT
5 (1.5)	8.5	5.5	5.5	5.5	6.5	6.5	7	5	7.5	4	5	3.5	5.5	5.5
9 (2.7)	6	5	5.5	5.5	5.5	6	7.5	4.5	2	2.5	4.5	4	6.5	6
15 (4.6)	4.5	4.5	5	5	5	4	4	1.5	6.5	2.5	2	5	5	4.5
20 (6.1)	3.5	3.5	4.5	5	3.5	3.5	2.5	0	5.5	3	3.5	4	3	3.5

[a] Reference noise level taken at distance of 3 feet (0.9 m) from speaker for each test. Reference levels varied slightly for different frequencies. Distances of 25 (7.6 m), 50 (15 m), 75 (23 m), and 100 feet (30 m) from the reference point were used. White random noise was used for A-weighted measurements, and pink random noise was used for the various frequencies.

TABLE 10. NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE FOR GRASS COMPARED TO PAVEMENT (NOISE SOURCE AT 8-FOOT (2.4 M) HEIGHT)

	NOISE REDUCTION PER DOUBLING OF DISTANCE (dB)													
			OCTAVE-BAND CENTER FREQUENCY (HZ)											
MEASUREMENT HEIGHT	A-WEIGHT NOISE		125		250		500		1,000		2,000		4,000	
(FEET) (M)	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT
5 (1.5)	5.5	5.5	2.5	2.5	6	3.5	7.5	6	4.5	5	4.5	4.5	5.5	5.5
9 (2.7)	5.5	5.5	4	4	8	7	5.5	6.5	5.5	4.5	6	5.5	6	6
15 (4.6)	5.5	5.5	7.5	6	6.5	7	5.5	5	5	4.5	5	4.5	7	6.5
20 (6.1)	5	4.5	7	6	4	4.5	5.5	4.5	5	3.5	3	2.5	5.5	6

[a] Reference noise level taken at distance of 3 feet (0.9 m) from speaker for each test. Reference levels varied slightly for different frequencies. Distances of 25 (7.6), 50 (15), 75 (23), and 100 feet (30 m) from the reference point were used. White random noise was used for A-weighted measurements, and pink random noise was used for the various frequencies.

Data on noise reduction in various octave bands are also given in Table 9. The major differences in noise reduction between grass and pavement surfaces occurs in the octave bands centered on 500 and 1,000 Hz. The results (Table 10) show no difference in noise reduction per doubling of distance at any measurement height when the noise source was put at a height of 8 feet (2.4 m). This was found for A-weighted noise and all octave bands.

Also considered was the change in noise level at any given measurement distance as a function of measurement height. Except at locations close to the roadway or noise source, noise increases as measurement height increases. Simultaneous recording of the traffic stream showed that noise levels kept increasing to the highest point of measurement (30 feet (9.1 m)).

A plot of the L_{10} noise levels as a function of receiver height and distance from the roadway for the urban location is given in Figure 8. At 50 feet (15.2 m) from the roadway, the increase in noise level with increased height above the ground ceased at the 20-foot (6.1-m) height. At 25 feet (7.6 m) from the roadway, the noise level was the same at all measurement heights. At 100 feet (30.5 m) from the roadway, the noise level increased very little above the 20-foot (6.10-m) height. However, as the distance from the roadway increased, the noise level increased more with height. Also, the height at which the increase ceased kept increasing as the distance from the roadway increased. At 200 feet (61 m), the noise level appeared to be leveling at the 30-foot (9.1-m) height. Also, at 400 feet (122 m), the increase in noise level from the 20-foot (6.1-m) to 30-foot (9 1-m) height was less than from the 10-foot (3.0-m) to 20-feet (6.1-m) height.

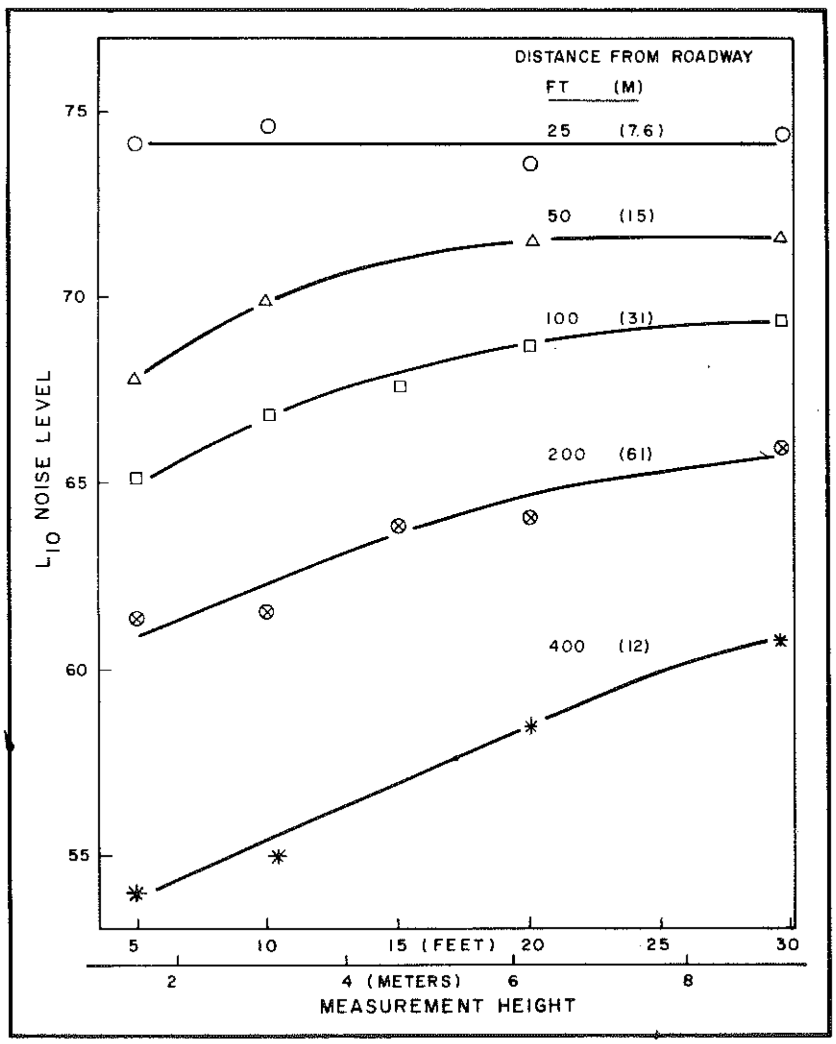


Figure 8. L_{10} Noise Level as a Function of Receiver Height and Distance from Roadway (Site 1).

DISTANCE

Measurements were made to determine how noise drops off as distance increases for a microphone height of 5 feet (1.5 m). Distances ranged from 25 to 400 feet (7.6 to 122 m) for most measurements, and three or four distances were monitored simultaneously to determine noise drop-off per doubling of distance.

On a low-speed urban road (Nicholasville Road in Lexington), data for L_{10}, L_{50}, L_{90}, and L_{eq} were obtained as cited in Table 11. Measurements were made at 25, 50, 100, 200, and 400 feet (7.6, 15, 30, 61, and 122 m) over short grass. The data were used to calculate the drop-off in noise per doubling of distances for L_{10} and L_{eq} (Table 12). The average drop-off per doubling of distance was 3.3 dBA for L_{10} and 3.1 dBA for L_{eq}. Noise drop-offs remained relatively constant per doubling of distance, but dropped slightly between 200 and 400 feet (61 and 122 m). This was probably caused by the low noise levels at 400 feet (122 m) (approached ambient (background) noise).

Plots of L_{10}, L_{eq}, L_{50}, and L_{90} were made for various distances as shown in Figure 9. A linear relationship was found using a log scale of distance. All L_{eq} levels were about halfway between L_{50} and L_{10} values at each distance.

TABLE 11. NOISE LEVELS AT VARIOUS DISTANCES (SITE 1)

DISTANCE FT (M)	NUMBER DATA POINTS	AVERAGE NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}
25 (7.6)	2	70.9	65.6	58.2	67.7
50 (15)	28	67.2	62.6	57.7	64.7
100 (31)	25	63.6	59.8	55.8	61.5
200 (61)	27	59.9	56.4	53.1	57.5
400 (122)	11	57.8	54.3	51.0	55.5

TABLE 12. NOISE LEVEL DROP-OFF PER DOUBLING OF DISTANCE (SITE 1)

DISTANCE FT	M	DROP-OFF PER DOUBLING DISTANCE L_{10}	L_{eq}
25 to 50	8 to 15	3.7	3.0
50 to 100	15 to 31	3.6	3.2
100 to 200	31 to 61	3.7	4.0
200 to 400	61 to 122	2.1	2.0
Average		3.3	3.1

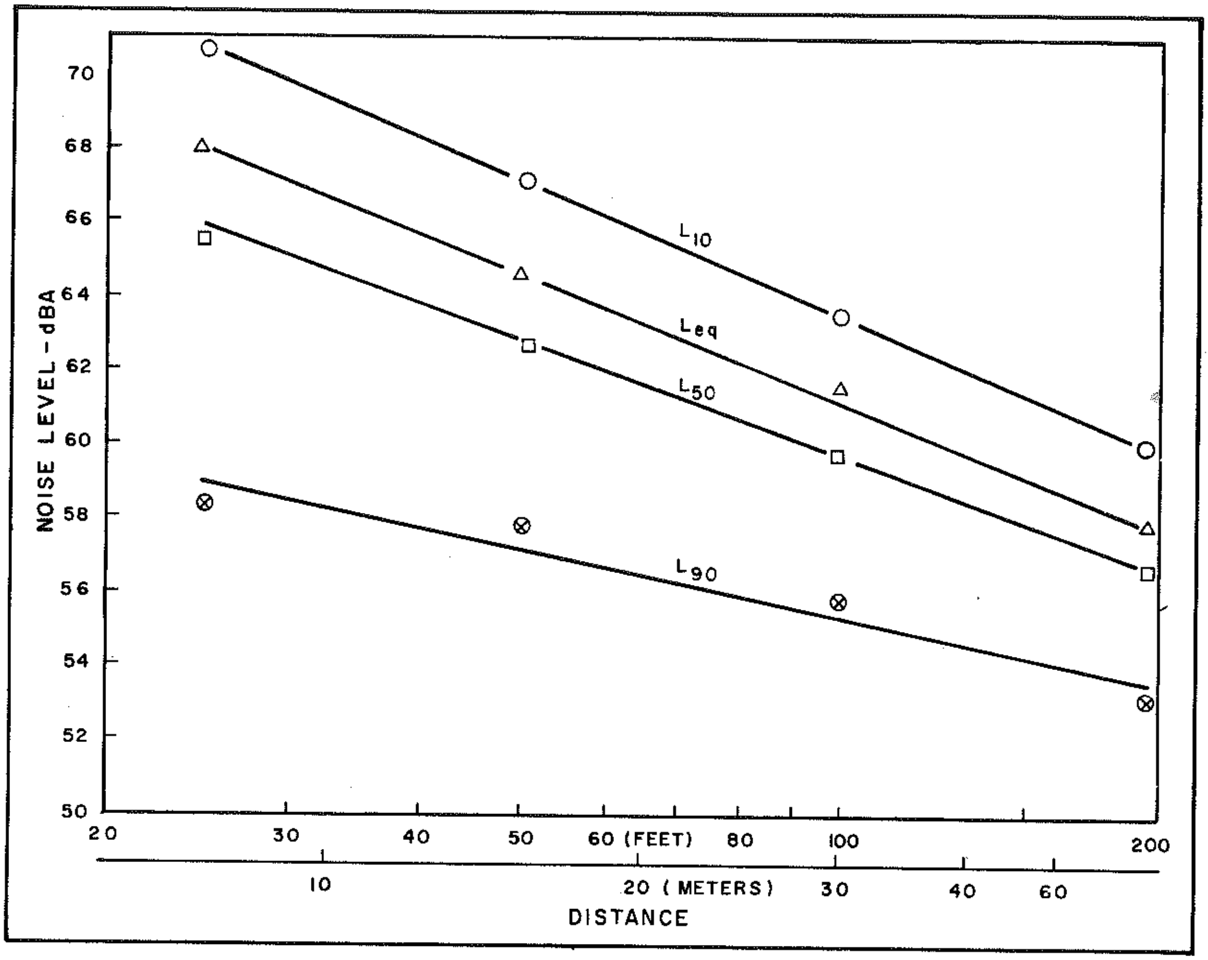


Figure 9. Effect of Distance on Noise Level (Site 1).

Similar data were collected and summarized on a high-speed rural road (US 68 in Fayette County). Distances of 25, 50, 100, and 200 feet (7.6, 15, 30, and 61 m) were used over short grass. Values of L_{10} ranged from 71.9 dBA at 25 feet (7.6 m) to 54.8 dBA at 200 feet (61 m) (Table 13). Drop-offs per doubling of distance averaged 5.7 dBA (L_{10}) and 5.5 dBA (L_{eq}) (Table 14). These average drop-offs were higher than at the urban site, probably because of lower volumes and higher speeds. Plots of L_{10}, L_{eq}, L_{50}, and L_{90} are shown in Figure 10 for various distances. Similar summaries and plots for other locations are given in APPENDIX G.

The equivalent distance was also used to verify these results. When the equivalent distance was used, the noise drop-off increased at distances close to the roadway (less than 50 feet (15 m) from the centerline of the near lane). Using the equivalent distance also increased the noise drop-offs at each distance.

The dual effect of distance and measurement height on noise propagation was then analyzed. Noise data were collected on Nicholasville Road at heights of 5, 10, 20, and 30 feet (1.5, 3.0, 6.1, and 9.1 m) and distances of 25 to 400 feet (7.6 to 122 m). A plot of these data for the L_{10} level is shown in Figure 11. At a distance of 25 feet (7.6 m), noise levels were about the same regardless of height. As distance increased, noise levels were definitely higher at greater measurement heights. At 400 feet (122 m), noise levels at the 30-foot (9-m) height were about 62 dBA compared to 60 dBA at 20 feet (6.1 m), 56 dBA at 10 feet (3.0 m), and 55 dBA at 5 feet (1.5 m). Values of r^2 ranged between 0.96 to 0.99 for all relationships. Similar findings are shown in a plot of L_{eq} values in Figure 12.

The very high correlation found between noise level and distance from the roadway indicated the validity of the assumption that traffic noise attenuation is constant per doubling of distance. Results show that this assumption, which was questioned in a past report *(6)*, is also valid at low-volume locations.

TABLE 13. NOISE LEVELS AT VARIOUS DISTANCES (SITE 2)

DISTANCE FT (M)	NUMBER DATA POINTS	AVERAGE NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}
25 (7.6)	8	71.9	59.2	47.2	68.7
50 (15)	35	66.7	55.8	47.4	63.3
100 (31)	28	60.4	52.4	45.3	57.6
200 (61)	30	54.8	49.9	45.4	52.3

TABLE 14. NOISE LEVEL DROP-OFFS PER DOUBLING OF DISTANCE (SITE 2)

DISTANCE FT	M	DROP-OFF PER DOUBLING DISTANCE L_{10}	L_{eq}
25 to 50	8 to 15	5.2	5.4
50 to 100	15 to 31	6.3	5.7
100 to 200	31 to 61	5.6	5.3
Average		5.7	5.5

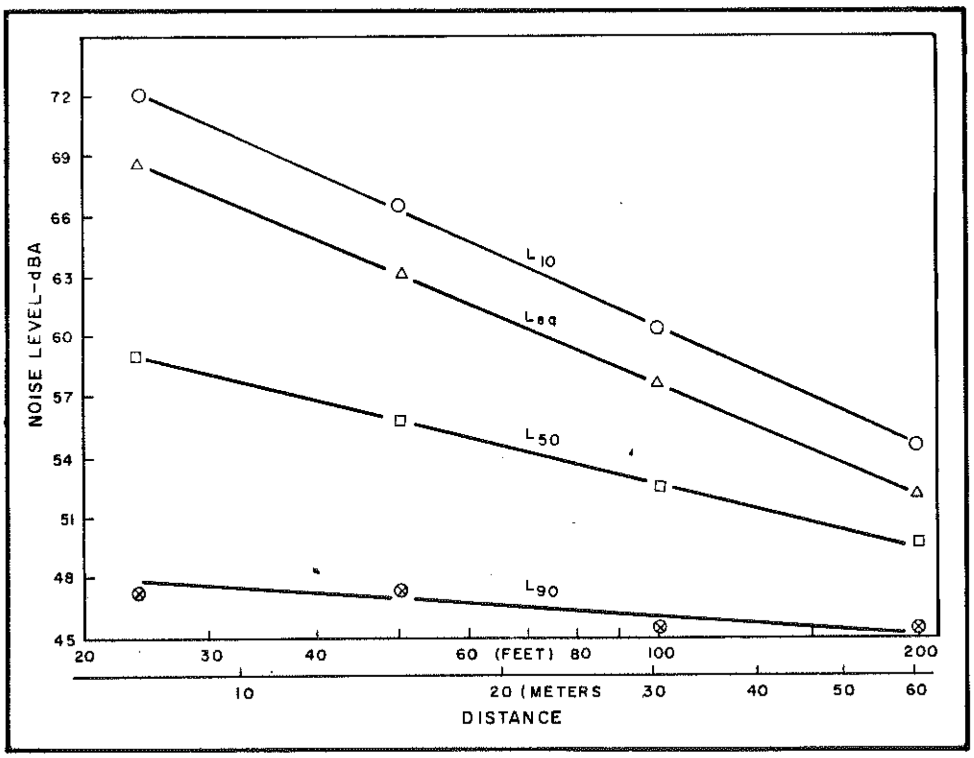


Figure 10. Effect of Distance on Noise Level (Site 2).

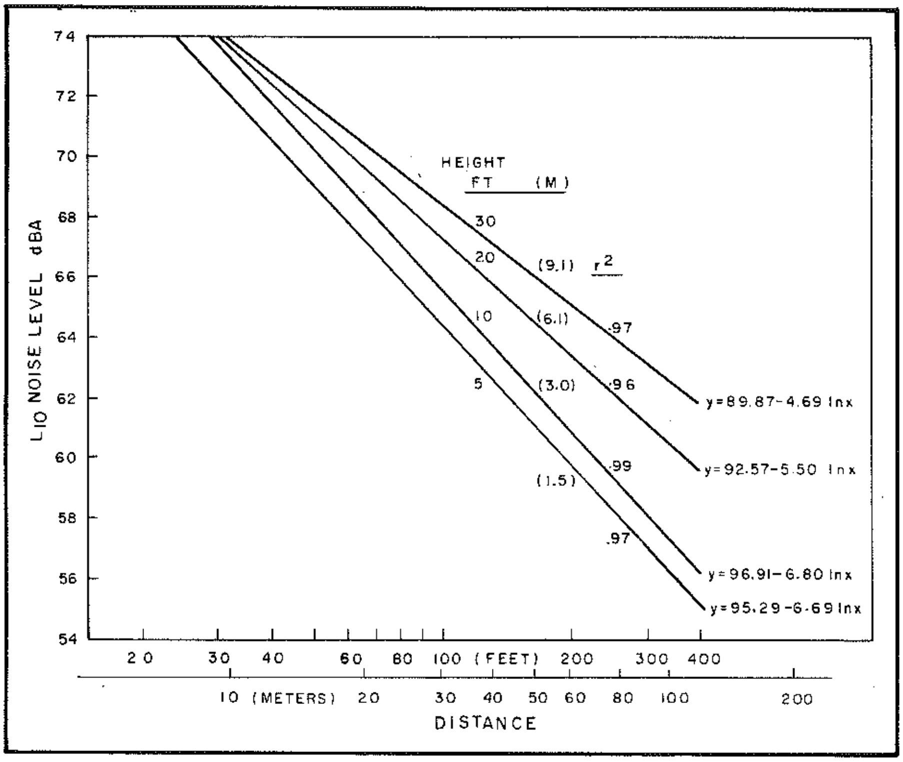


Figure 11. L_{10} Noise Levels for Various Distances and Receiver Heights.

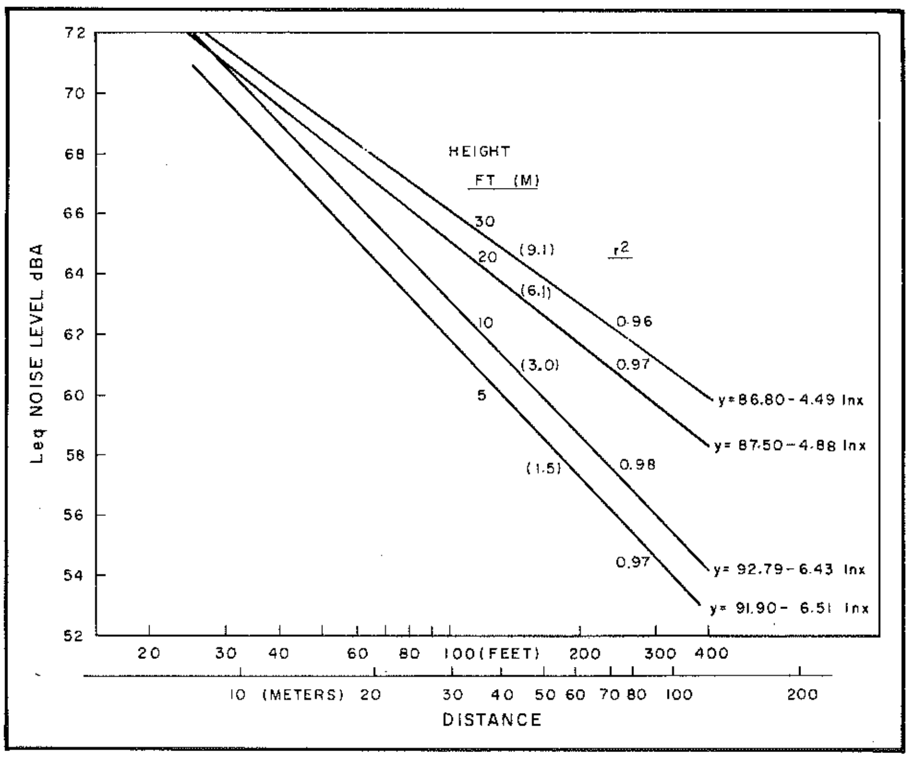


Figure 12. L_{eq} Noise Levels for Various Distances and Receiver Heights.

SPEED

To determine if vehicle speed is related to noise propagation, measurements were taken using a test car. Simultaneous measurements were made as the car was driven by at a constant speed. Data were taken at 25 feet (7.6 m) and 50 feet (15.2 m) from the centerline of the driving lane. Noise from other vehicles caused problems when distances greater than 50 feet (15.2 m) were used. The speeds used were 30, 40, and 50 miles per hour (13.4, 17.9, and 22.4 m/s). Also, data were collected on various ground covers including pavement and short and tall grasses.

The variation in noise propagation as a function of ground cover is illustrated in Table 15. The average reduction for all speeds for a doubling of distance varied from 5.2 dBA for pavement to 8.2 dBA for tall grass. The noise propagation varied with the speed of the test car for short and tall grass ground covers; the noise drop-off increased as vehicle speed increased. The drop-off remained relatively constant over pavement. As speeds increase, tire-pavement noise increases rapidly and becomes the controlling factor in automobile noise. The tire-pavement noise which predominates at higher speeds has a higher frequency than engine noise. Thus, the noise at higher speeds is made up of higher frequencies which were found to have a high drop-off with distance compared to low frequencies.

SOURCE HEIGHT

The random noise generator was used to determine the effect of source height on noise propagation. The speaker was set at ground level and then at 8 feet (2.4 m). The ground level source represented automobile noise. The 8-foot (2.4-m) height represented the noise height for trucks. Microphone heights of 2.5 to 25 feet (0.8 to 7.6 m) were obtained by connecting the microphone to a surveying level rod and adjusting the measurement heights. Distances of 25 to 300 feet (7.6 to 91 m) from the speaker were used.

The first series of measurements were taken with a zero height above grass and pavement. The results for grass are given in Table 16 and for pavement in Table 17.

For a microphone height of 2.5 feet (0.8 m), noise levels over grass were reduced by 11 dBA per doubling of distance compared to only 6 dBA over pavement. As height increased to 10 feet (3 m), the drop-off per doubling of distance over grass decreased sharply to about 5 dBA and then was very similar to pavement from 10 to 25 feet (3 to 9 m). The drop-offs for grass and pavement both approached about 3.0 to 3.5 dBA. The curves in Figure 13 show that the noise drop-off per doubling of distance decreased for both ground covers as measurement height increased. This drop-off is greater for grass than pavement at measurement heights up to 10 feet (3.0 m). Drop-offs per doubling of distance ranged from about 11 dBA to 3 dBA, depending on measurement height.

The other source height used was 8 feet (2.4 m), obtained by mounting the speaker on a platform in the bed of a pickup truck. Data were collected over grass and pavement at heights of 2.5 to 25 feet (0.8 to 7.6 m). Results of these data are given in Tables 18 and 19.

TABLE 15. NOISE PROPAGATION FOR VARIOUS VEHICLE SPEEDS (TEST CAR) AND GROUND COVERS

	NOISE REDUCTION FROM 25 (7.6) TO 50 FEET (15 m)		
SPEED (MPH) (M/S)	SHORT GRASS	PAVEMENT	TALL GRASS
30 (13.4)	4.9	5.3	7.5
40 (17.9)	6.8	4.7	8.1
50 (22.4)	7.5	5.7	9.0
Average (all speeds)	6.4	5.2	8.2

TABLE 16. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (GRASS GROUND COVER AND NOISE SOURCE AT GROUND LEVEL)[a]

DISTANCE FEET (m)[b]	NOISE LEVEL (dBA) HEIGHT, FEET (m) 2.5 (.8)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	88.5	88	88.5	83	81	79
50 (15)	83	84	82	80.5	79.5	77.5
75 (23)	77	79	79	79	77	75.5
100 (30)	69	76	76	76	75	74
125 (38)	63	71	74	74	74	73
150 (46)	56	63	72	72	72.5	73
175 (53)	c	61	70	71	71	71
200 (61)	c	59	67	68.5	69	69
225 (69)	c	c	62	67.5	67.5	68
250 (76)	c	c	60	64	64.5	64.5

[a] Reference noise level was 95 dBA at 3 feet (.9 m) from speaker at 5-foot (1.5-m) height.
[b] Distance from reference point which was 3 feet (.9 m) from speaker.
[c] Noise level was too close to the ambient.

TABLE 17. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (PAVEMENT GROUND COVER AND NOISE SOURCE AT GROUND LEVEL)[a]

DISTANCE FEET (M)[b]	NOISE LEVEL (dBA) HEIGHT, FEET (m) 2.5 (.8m)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	89.5	88.5	87	84	82	79.5
50 (15)	84.5	83	82.5	81	80.5	79
75 (23)	82	81.5	80.5	79	78	76.5
100 (30)	80	78.5	77.5	76.5	75.5	74.5
125 (38)	77	77.5	76.5	74	74	74
150 (46)	75	76.5	76	72	72	72.5
175 (53)	71	74.5	74	71.5	71	71.5
200 (61)	67.5	72	72	71	70	69.5
225 (69)	64	71	71	70.5	69.5	68.5
250 (76)	63	66	68	69	68.5	68
275 (84)	60	65	67	67	68	67.5
300 (91)	58	61	63.5	64	67	67

[a] Reference noise level was 95dBA at 3 feet (.9 m) from speaker at 5 foot (1.5-m) height.
[b] Distance from reference point which was 3 feet (.9 m) from speaker.

Figure 13. Noise Level Reduction per Doubling of Distance for Grass Compared to Pavement (Noise Source at Ground Level) (A-weighted Noise).

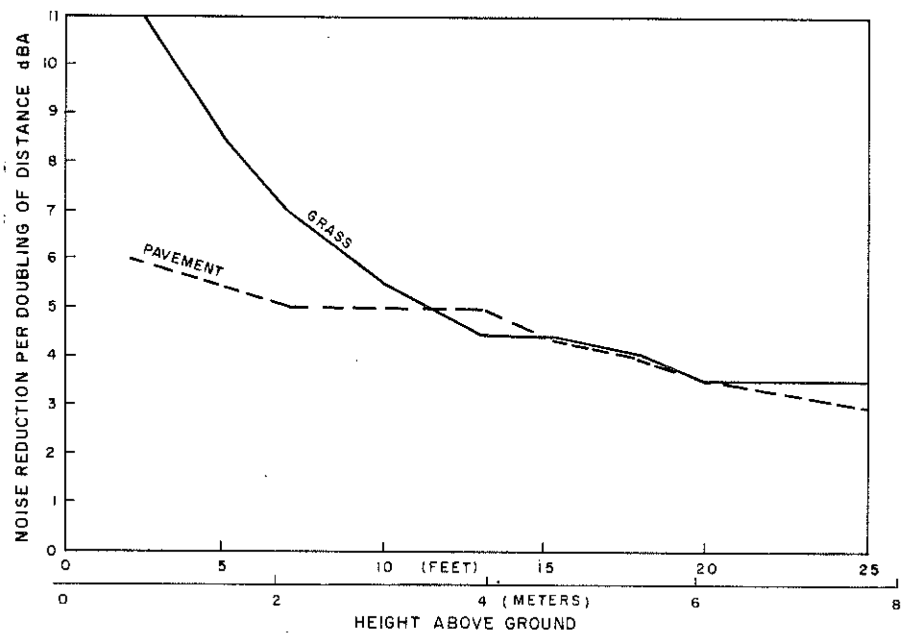


TABLE 18. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (GRASS GROUND COVER AND NOISE SOURCE AT 8-FOOT (2.4-M) HEIGHT)[a]

DISTANCE FEET (M)[b]	NOISE LEVEL (dBA) HEIGHT, FEET (m)					
	2.5 (.8)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	87	88	87	86.5	85	82
50 (15)	83.5	83.5	82	81.5	80	80
75 (23)	80.5	80	79	77	77	77
100 (30)	77	77.5	76	75	75	75
125 (38)	76	74.5	74.5	74	73	73
150 (46)	75	73	72.5	72	71.5	70.5
175 (53)	74	73	71.5	71	70.5	69.5
200 (61)	72.5	72.5	71	70	69.5	68.5
225 (69)	71.5	72	69	69	68.5	67.5
250 (76)	67.5	70.5	68	68	67.5	66.5
275 (84)	64	68	66	66	65.5	66
300 (91)	59	66	66	65	64.5	65

[a] Reference noise level was 93 dBA at 3 feet (.9 m) from speaker at 5-foot (1.5-m) height.

[b] Distance from reference point which was 3 feet (.9 m) from speaker.

TABLE 19. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (PAVEMENT GROUND COVER AND NOISE SOURCE AT 8-FOOT (2.4-M) HEIGHT)[a]

	NOISE LEVEL (dBA)					
	HEIGHT, FEET (m)					
DISTANCE FEET (M)[b]	2.5 (.8)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	86.5	88.5	88	86.5	85	82.5
50 (15)	84	84	82.5	82	81.5	80.5
75 (23)	82	81	79.5	79	79	78.5
100 (30)	79	79	77.5	76.5	76	76
125 (38)	76	76	75	75	74	73.5
150 (46)	74	74	73.5	73.5	73.5	72.5
175 (53)	73.5	73	72	72.5	72	71.5
200 (61)	73	71	71	71	70.5	70
225 (69)	69	69	68.5	69	67.5	67.5
250 (76)	69	69	68.5	69	67.5	67.5
275 (84)	66	68	67.5	68	67	66.5
300 (91)	65	67.5	66	66	65.5	65

[a] Reference noise level was 93 dBA at 3 feet (.9 m) from speaker at 5-foot (1.5-m) height.
[b] Distance from reference point which was 3 feet (.9 m) from speaker.

For the 8-foot (2.4-m) source height, the noise reduction per doubling of distance was plotted for grass and pavement surfaces for various measurement heights (Figure 14). For both ground covers, the noise reduction per doubling of distance remained at 5.5 dBA for measurement heights up to 15 feet (4.6 m). Above 15 feet (4.6 m), reductions dropped to 3.5 dBA over pavement and 4.0 dBA over grass. Thus, ground cover has little if any effect on noise propagation for 8-foot (2.4-m) source heights. Also, the drop-off per doubling of distance is nearly constant at around 5.5 dBA for an 8-foot (2.4-m) source height at measurement heights up to 15 feet (4.6 m).

In summary, ground cover had very little influence on noise propagation when the source height was 8 feet (2.4 m). When the noise source was at ground level, ground cover influenced noise propagation up to a receiver height of about 10 feet (3 m).

PERCENTAGE LEVEL

Noise reduction per doubling of distance was found for L_{10}, L_{50}, L_{90}, and L_{eq} at these locations. The locations included a low-volume location (hourly volume below 1,000) on Harrodsburg Road, a medium-volume location (hourly volume around 2,000) on Nicholasville Road, and a high-volume location on I 264 in Louisville (hourly volumes above 3,000) (Table 20).

The average drop-off per doubling of distance for all sites was 4.5 dBA for L_{10} and 4.4 dBA for L_{eq}. At the low-volume location, drop-offs were 5.7 and 5.5 dBA for L_{10} and L_{eq}. At the high-volume site, drop-offs of 4.6 dBA were observed for both L_{10} and L_{eq}. At the medium-volume site, lower drop-offs in L_{10} (3.3 dBA) and L_{eq} (3.1 dBA) were found. These could have resulted from the lower speeds and low truck volumes.

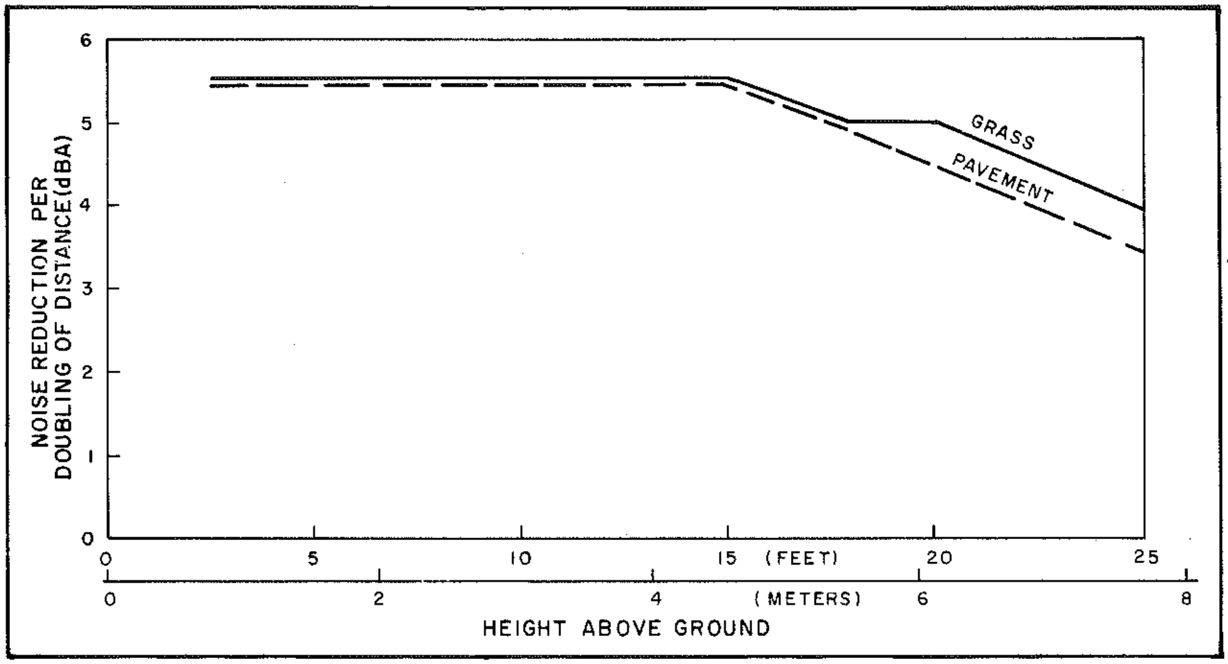


Figure 14. Noise Level Reduction per Doubling of Distance for Grass Compared to Pavement (Noise Source at 8-Foot (2.4-m) Height) (A-weighted Noise).

TABLE 20. TRAFFIC NOISE REDUCTION PER DOUBLING OF DISTANCE FOR VARIOUS VOLUMES OF TRAFFIC AND NOISE DESCRIPTIONS

NOISE DESCRIPTOR	TRAFFIC NOISE REDUCTION PER DOUBLING OF DISTANCE			
	LOW VOLUME LOCATION (<1000 VPH)[a]	MEDIUM VOLUME LOCATION (≈2000 VPH)[b]	HIGH VOLUME LOCATION (>3000 VPH)[c]	AVERAGE
L_{10}	5.7	3.3	4.6	4.5
L_{50}	3.1	2.8	4.1	3.3
L_{90}	0.9	1.8	3.5	2.1
L_{eq}	5.5	3.1	4.6	4.4

[a] US 68 (Harrodsburg Road) in Fayette County
[b] Nicholasville Road in Lexington
[c] Watterson Expressway (I-264) in Louisville

The drop-offs in L_{50} averaged 3.3 dBA for all sites. The L_{90} drop-offs averaged only 2.1 dBA, since these levels often approach ambient levels, especially at low volume sites. The L_{90} drop-offs were lowest (0.9 dBA) at the low-volume site and highest (3.5 dBA) at the high-volume location. Drop-offs in L_{50} at the sites varied between 2.8 and 4.1 dBA.

A distribution of noise levels (dBA) was plotted by percentage level for all six locations in Figure 15. The graph shows that, at 100 feet (30 m), noise levels were highest on I 75 and lowest on Harrodsburg Road. Values of L_{max}, L_{10}, L_{50}, L_{90}, and L_{min} were plotted for each location to show this noise distribution.

Plots were also made to show the distribution of noise levels for various heights at distances of 50 feet (15 m) (Figure 16), 100 feet (30 m) (Figure 17), 200 feet (61 m) (Figure 18), and 400 feet (122 m) (Figure 19). These distributions were based on data collected on Nicholasville Road at measurement heights of 5, 10, 20, and 30 feet (1.5, 3.0, 6.1, and 9.1 m). Again, L_{max}, L_{10}, L_{50}, L_{90}, and L_{min} noise levels were used to determine these distributions. At 100 feet (30 m), the curves are evenly spaced. The 5- and 10-foot (1.5 and 3.0-m) receiver-height curves are closely spaced for 200 and 400 feet (61 and 122 m). At 50 feet (15 m), the 5-foot (1.5-m) curve is considerably lower than the others, and all curves have large ranges between minimum and maximum values.

The data showed that the noise drop-off varies with the percentage level used to describe the noise. In general, as the percentage level becomes smaller, the noise drop-off increased. However, the difference in drop-off between the various percentage levels decreased as the traffic volume increased. At volumes over 4,000 vph, the difference in the noise drop-off disappeared.

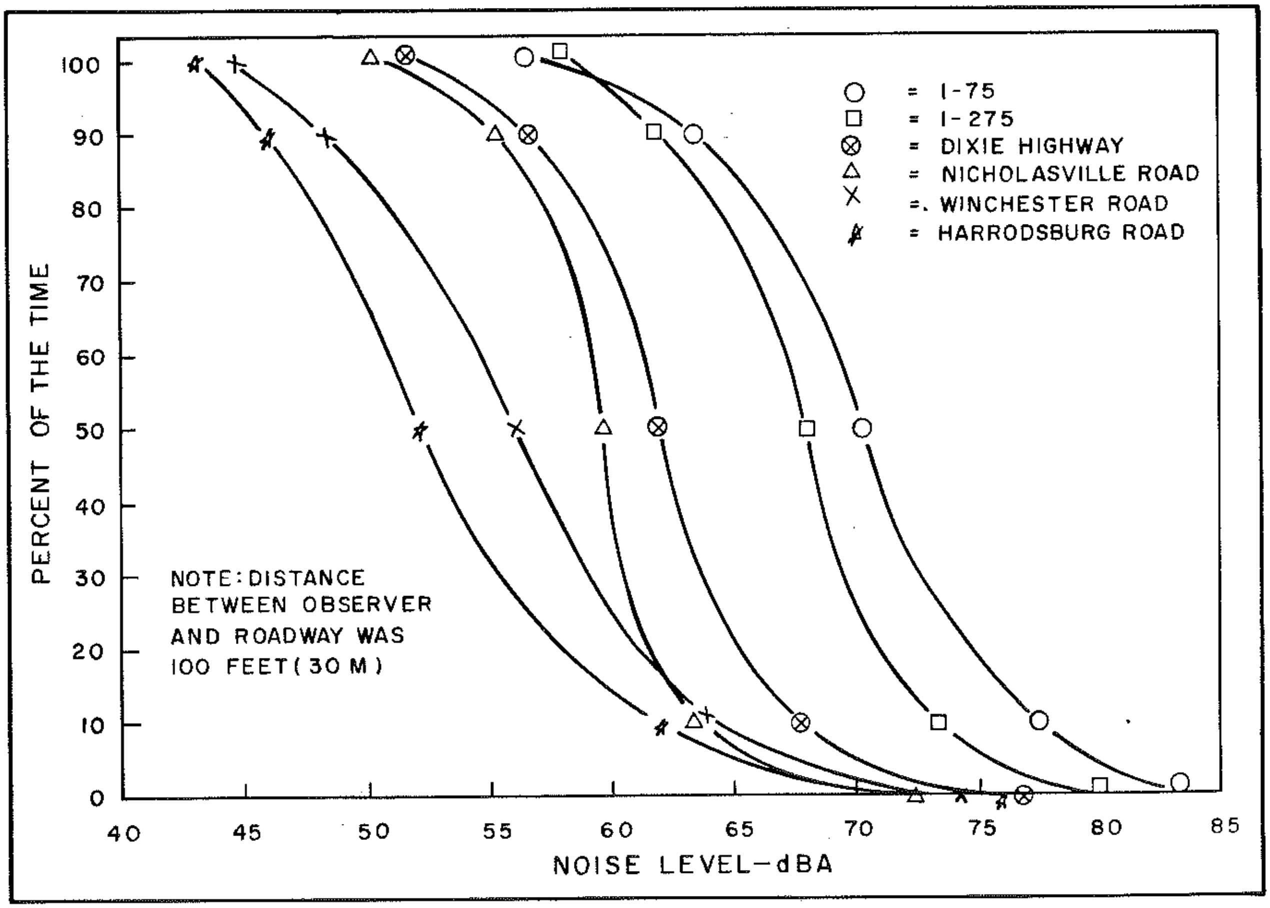


Figure 15. Distribution of Noise Levels at Six Test Locations.

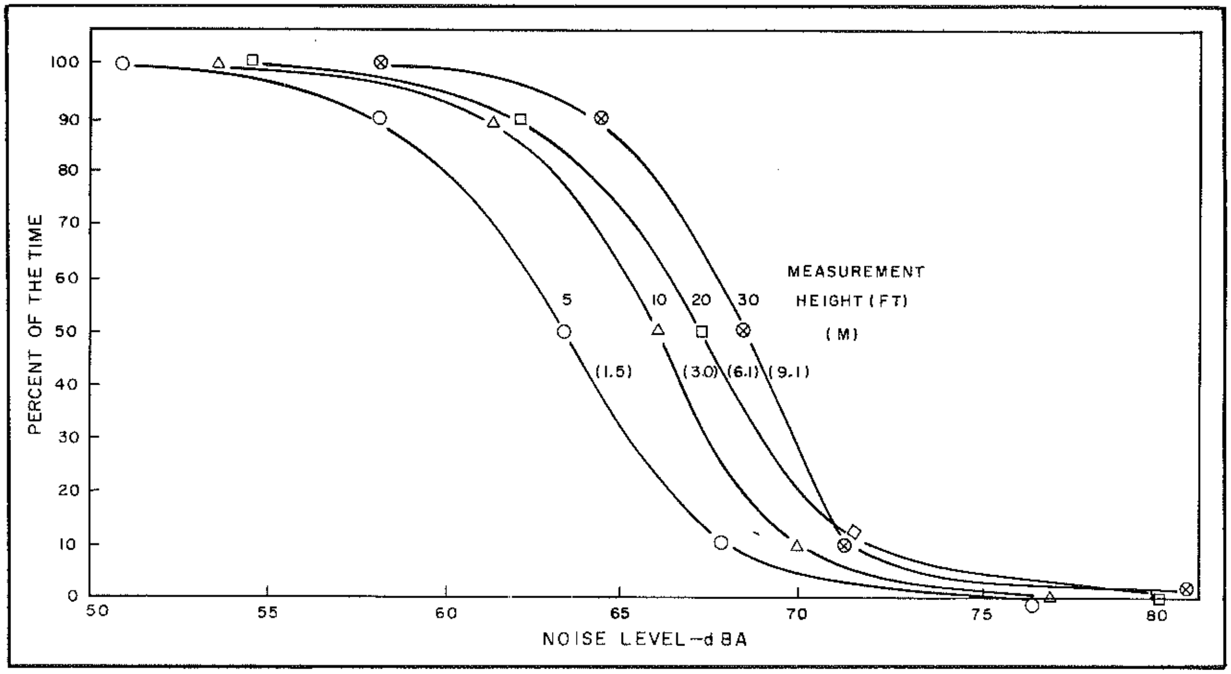


Figure 16. Distribution of Noise Levels for Various Receiver Heights at a Distance of 50 Feet (15.2 m) (Site 1).

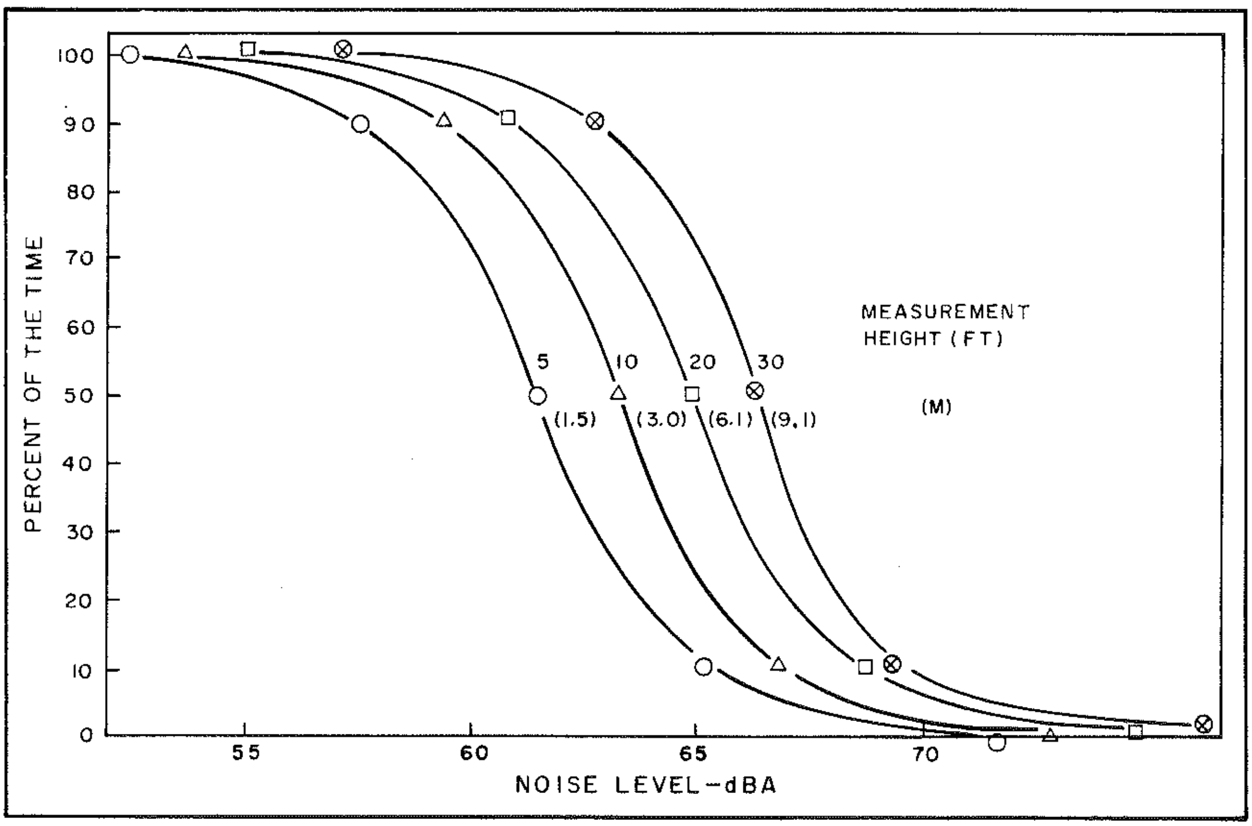


Figure 17. Distribution of Noise Levels for Various Reciever Heights at a Distance of 100 Feet (30.5 m) (Site 1).

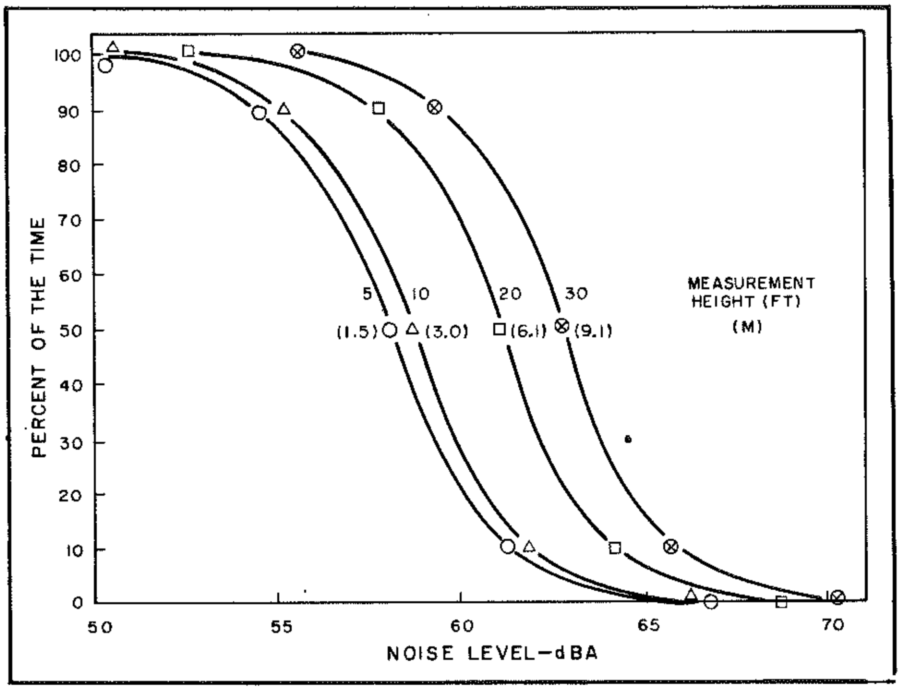


Figure 18. Distribution of Noise Levels for Various Receiver Heights at a Distance of 200 Feet (61.0 m) (Site 1).

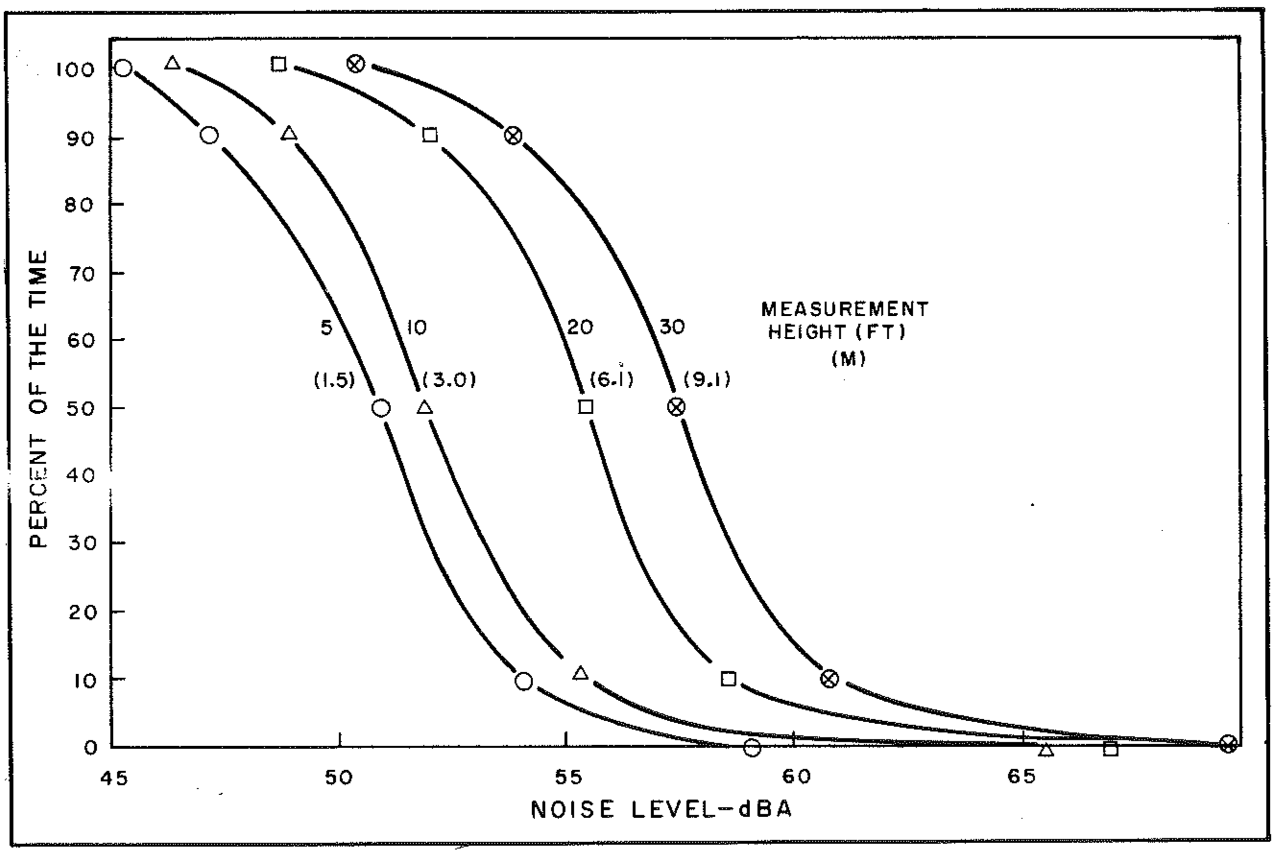


Figure 19. Distribution of Noise Levels for Various Receiver Heights at a Distance of 400 Feet (121.9 m) (Site 1).

TYPE OF VEHICLE

Measurements were made of individual automobile and truck noise levels with a sound-level meter employing the A-weighting network. Measurements were taken at 50 feet (15 m) and 100 feet (30 m) from the center of the traffic lane and approximately 4 feet (1.2 m) above ground. The vehicle type and noise level were recorded manually as a vehicle passed. Measurements were taken only when the noise emitted by a single vehicle could be clearly isolated or distinguished from the noise of the traffic stream.

Results from this analysis are given in Table 21. The data were taken at several locations which were classified as urban, interstate, and rural non-interstate roads. These road categories were based primarily on traffic speeds. Average automobile speeds ranged from 40 mph (18 m/s) on the urban roads to 54 mph (24 m/s) at the rural non-interstate roads, and 62 mph (28 m/s) on the interstate roads. Three different vehicle types were used to represent the various types of vehicles on the highway. These categories corresponded to those types listed in the new noise prediction design guide *(4)*. Noise data obtained from single-unit, two-axle, six-tire trucks were used to represent the medium truck category. Noise readings were obtained for over 8,000 vehicles which included approximately 6,000 automobiles, 1,000 medium trucks, and 1,000 heavy trucks.

Results indicated that the noise drop-off with distance for automobiles was slightly higher for the high-speed locations. This agrees with the findings shown in Table 15.

The noise drop-off with distance for heavy trucks was also higher at the high-speed locations. The average speeds for the heavy-truck category ranged from 35 mph (16 m/s) on the urban roads to 51 mph (23 m/s) on the rural non-interstate roads and 61 mph (27 m/s) on the interstate roads. The reason for the increase in noise drop-off may be attributable to a change in the frequency distribution of the noise to a higher proportion of high-frequency noise at higher speeds. This change occurs for automobiles *(2)*. The higher frequencies have a higher drop-off with distance. At higher speeds, tire noise may constitute a large proportion of the noise; this would lower the overall source height which also would lead to a larger drop-off. When all locations were considered, the noise reduction was close to 6.0 dBA per doubling of distance for both automobiles and heavy trucks.

At urban locations where the speed is low, automobiles had a larger drop-off with distance compared to heavy trucks; however, on the high-speed, interstate roads, heavy trucks had a larger drop-off than automobiles. The medium truck category had the largest overall drop-off. Inconsistancy in the data made generalized conclusions difficult.

TABLE 21. PROPAGATION OF NOISE FROM VARIOUS TYPES OF VEHICLES AND DISTANCES FROM THE ROADWAY

	NOISE REDUCTION FROM 50 FEET (15 M) TO 100 FEET (30 M)[a]		
	VEHICLE TYPE		
TYPE OF ROAD	AUTOMOBILE	MEDIUM TRUCK[b]	HEAVY TRUCK[c]
Urban	5.8	6.8	4.6
Rural, Non-Interstate	6.5	5.5	6.4
Interstate	6.3	8.3	7.6
All	6.0	6.9	6.2

[a] The distances were measured from the centerline of the traffic lane.
[b] Single-unit, two-axle, six-tire truck.
[c] Combination, five-axle truck.

SUMMARY AND CONCLUSIONS

TRAFFIC VOLUME

1. The L_{10} noise level reduction per doubling of distance increased substantially when traffic volume was less than 1,000 vph. For the peak volumes experienced in Kentucky, the noise reduction did not decrease significantly below 4.5 dBA per doubling of distance.

2. The L_{eq} noise level reduction increased for traffic volumes less than 1,000 vph; however, the increase was not quite as dramatic as the L_{10} level.

3. When L_{50} levels were considered, the drop-off in noise was not significantly affected by traffic volume.

4. Truck volumes did not alter findings concerning the relationship between noise level reduction per doubling of distance and traffic volumes.

WIND

1. Large fluctuations in noise drop-off at a given site for similar traffic volumes were found to be partially explained by the effect of wind. Very good relationships were found between noise drop-off and wind vector (component of the wind blowing either directly toward or away from the roadway).

2. Reliable data could not be obtained when the wind vector speed was greater than 10 knots (11.5 mph (5 m/s)).

GROUND COVER

1. Based on traffic stream data, drop-offs in L_{10} noise per doubling of distance were 5.0 dBA over short grass, 2.9 dBA over pavement, and 5.8 dBA over tall grass for high-volume roads. Slightly larger drop-offs were found on low-volume roads.

2. Data obtained using a random noise generator showed that ground cover can have a significant effect on noise attenuation. Using short grass as a reference surface, higher noise attenuation per doubling of distance was found for high weeds (3.5 dBA). Attenuation over high grass, medium grass, smooth dirt, snow, and plowed field was within 1.0 dBA of short grass. Attenuation per doubling of distance was lower on gravel (1.5 dBA) and pavement (2.0 dBA) compared to short grass.

3. Low frequency noise (octave-bands centered at 63, 125, and 250 hz) was affected very little by ground cover. Compared to short grass, high grass and weeds have higher attenuations at high frequencies (above 1,000 Hz); plowed field and smooth ground had attenuation of 2 to 3 dB higher at 500 Hz; pavement had a decrease in attenuation of about 7 dB at 2,000 Hz; and snow had 3.5 dB higher attenuation at 250 and 500 Hz.

4. A comparison of the attenuation provided by pavement and high weeds showed that ground cover can have a significant effect on noise propagation. However, various heights of grass showed that typical right-of-way ground covers did not significantly affect noise attenuation.

RECEIVER HEIGHT

1. Data from both traffic stream and random noise generator showed that changes in noise attenuation occurred at heights above 10 feet (3.0 m); the drop-off per doubling of distance decreased from about 4.5 dBA for receiver heights of 10 feet (3.0 m) or below to slightly over 3.0 dBA for heights above 10 feet (3.0 m).

2. For receivers heights above 10 feet (3.0 m), ground cover had no significant influence on attenuation.

3. The major differences in propagation loss between grass and pavement occurred in the octave bands with center frequencies of 500 and 1,000 Hz.

4. No difference in noise reduction per doubling of distance was found at any measurement height when the noise source was at a height of 8 feet (2.4 m).

5. Except at locations close to the roadway (closer than about 50 feet (15 m)), noise increased as height of the receiver increased.

6. Up to 400 feet (122 m) from the roadway, the noise level increased with height of the receiver. Also, the height at which the increase in noise level ceased increased with distance from the roadway.

DISTANCE

1. Up to about 400 feet (122 m), noise drop-offs (dBA) remained constant per doubling of distance. When the equivalent distance was used, the noise drop-off increased at distances close to the roadway (less than 50 feet (15 m) from the centerline of the near lane).

2. Logarithmic best-fit curves for L_{10} and L_{eq} were determined for heights of 5 to 30 feet (1.5 to 9.1 m) and distances of 25 to 400 feet (8 to 22 m) (one site). Values of r^2 ranged from 0.96 to 0.99.

3. The very high correlation between noise level and distance from the roadway validated the assumption that traffic noise attenuation is constant per doubling of distance.

SPEED

Using a test car driven at various speeds, noise drop-off with distance increased over grass as vehicle speed increased. No changes with speed were noted over pavement surfaces.

SOURCE HEIGHT

1. For a ground level noise source over grass, noise drop-off per doubling of distance varied from 11 at a 2.5-feet (0.8-m) receiver height to 3.5 dBA at a 25-foot (7.6-m) height. Over pavement, the drop-off per doubling of distance varied from 6 dBA at 2.5 feet (0.8 m) to 3 dBA at 25 feet (7.6 m).

2. For an 8-foot (2.4-m) source height, the drop-off per doubling of distance was found to be constant at 5.5 dBA over grass and pavement for receiver heights up to about 15 feet (4.6 m). Above 15 feet (4.6 m), the drop-offs decreased to about 4 dBA at 25 feet (2.6 m).

3. Ground cover had very little influence on noise propagation when the source height was 8 feet (2.4 m). When the noise source was at ground level, ground cover influenced noise propagation up to measurement heights of about 10 feet (3.0 m).

PERCENTAGE LEVEL

1. At three locations with varying traffic volumes and speeds, the average drop-off in noise level per doubling of distance was 4.5 dBA for L_{10}, 4.4 for L_{eq}, 3.3 for L_{50}, and 2.1 dBA for L_{90}.

2. In general, as the percentage level became smaller, the noise drop-off per doubling of distance increased. The difference in drop-off between the various percentage levels decreased as the traffic volume increased. At volumes over 4,000 vph, this difference disappeared.

TYPE OF VEHICLE

Individual noise readings indicated that noise propagation was influenced by vehicle type and speed. This was related to the differences in frequency distribution and source height of different vehicles and the changes that occur at different speeds. Noise attenuation generally increased with increased vehicle speed. On urban roads, automobile noise showed a larger drop-off with distance compared to heavy trucks; however, on high-speed interstate roads, heavy trucks had a larger drop-off than automobiles. Inconsistencies in the data made general conclusions difficult.

RECOMMENDATIONS

1. The reduction per doubling of distance used to predict L_{10} noise levels should be increased to 5.0 dBA for volumes less than 1,000 vph.

2. For receiver heights of 10 feet (3.0 m) or below, a noise drop-off of 3.0 dBA per doubling of distance should be used for reflective ground covers (pavement); a 4.5-dBA reduction should be used for normally absorptive ground covers; and a 6.0-dBA reduction should be used for extremely absorptive ground covers (high weeds).

3. For receiver heights above 10 feet (3.0 m), a 3.0-dBA drop-off per doubling of distance should be used regardless of the type of ground cover.

4. The noise propagation factor should be constant per doubling of distance.

5. Traffic noise data should not be taken when the component of the wind either blowing toward or away from the roadway exceeds 10 knots (11.5 mph (5/m)).

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APPENDIX A

SUMMARY OF
TRAFFIC STREAM NOISE
(8 SITES AT 5-FOOT (1.5-m) HEIGHT ON SHORT GRASS

TABLE A1. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 1) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
2-24-76	1	50(15)	70.5	65.8	59.2	67.6	75.9	54.1	2184	36	6	2226	2280
		100(30)	65.6	62.9	56.7	63.4	72.1	52.6					
		400(122)	57.4	54.7	51.8	55.4	62.6	49.2					
	2	50(15)	71.0	66.9	62.6	68.0	75.6	54.4	1824	30	12	1866	1932
		100(30)	66.4	63.1	59.2	64.1	73.1	52.8					
		400(122)	61.0	56.2	52.8	57.4	56.6	50.3					
	3	50(15)	70.5	66.3	61.0	67.6	75.9	50.8	2484	42	0	2526	2568
		100(30)	65.1	62.1	58.2	63.0	70.3	49.7					
		400(122)	59.0	55.5	52.6	56.2	64.1	49.0					
	4	50(15)	70.5	67.2	63.3	68.2	76.4	56.9	2328	42	12	2382	2460
		100(30)	66.2	63.1	59.7	63.9	71.8	54.9					
		400(122)	58.7	55.6	52.8	56.5	65.1	50.8					
	5	50(15)	70.0	66.1	61.0	67.5	75.9	54.6	2382	24	12	2418	2478
		100(30)	66.2	62.6	58.2	63.6	73.6	53.8					
		400(122)	56.4	54.0	51.3	54.8	63.3	48.5					
6-29-76	6	50(15)	68.2	65.1	61.3	66.1	76.2	55.6	2766	24	0	2790	2814
		100(30)	64.1	60.5	57.2	61.5	71.3	52.3					
		400(122)	58.5	54.1	50.8	56.0	70.3	42.3					
	7	50(15)	68.2	64.9	61.5	65.9	74.6	53.3	2904	6	0	2910	2916
		100(30)	63.1	60.2	57.4	60.8	67.7	51.5					
		400(122)	56.9	53.2	49.0	54.4	63.6	46.4					
	8	50(15)	67.9	64.2	60.5	65.5	76.7	49.5	2862	12	6	2880	2910
		100(30)	63.1	59.8	56.7	60.8	70.5	47.7					
		400(122)	56.9	53.7	50.8	54.5	62.6	47.4					
	9	50(15)	67.7	63.6	59.0	67.5	88.7	48.5	2676	24	0	2700	2724
		100(30)	62.6	59.3	55.1	64.6	85.6	47.2					
		400(122)	57.4	53.4	49.7	56.9	73.3	44.9					
11-3-77	1	50(15)	65.4	59.4	54.6	62.4	76.4	50.0	1794	60	12	1866	1962
		200(61)	58.7	55.2	51.8	56.4	66.2	49.7					
	2	50(15)	64.1	58.7	53.6	61.0	76.4	48.7	1818	42	0	1860	1902
		200(61)	57.2	54.3	51.5	55.0	65.4	48.5					
	3	50(15)	64.6	58.4	52.1	60.7	70.8	48.2	1662	18	6	1686	1722
		200(61)	56.9	53.6	50.5	54.3	62.3	46.7					
	4	50(15)	63.8	58.2	52.8	60.4	72.8	47.4	1806	30	6	1842	1890
		200(61)	56.7	53.4	50.5	54.0	59.2	47.9					
11-9-77	1	200(61)	67.6	58.2	54.0	60.0	73.1	51.5	2046	6	0	2052	2058
	2	200(61)	61.3	57.0	53.1	58.3	68.5	49.7	1806	48	0	1854	1902
	3	200(61)	59.5	56.4	53.3	57.2	66.9	49.2	1692	0	0	1692	1692
	4	200(61)	59.7	57.2	54.9	57.6	63.3	51.0	1650	0	0	1650	1650
4-10-78	1	50(15)	69.7	65.3	61.5	66.3	71.5	55.6	1464	30	18	1512	1596
		100(30)	64.1	60.5	56.4	61.7	73.6	51.3					
		200(61)	62.3	58.9	55.1	60.1	68.5	43.3					
	2	50(15)	67.7	63.7	59.5	64.8	71.0	55.6	1524	48	30	1602	1740
		100(30)	63.6	60.1	56.4	61.0	70.0	51.0					
		200(61)	61.3	58.4	55.4	59.0	65.9	50.8					
	3	75(23)	65.4	61.6	57.4	62.8	74.1	50.8	1992	60	24	2076	2208
		150(46)											
		300(91)	60.8	58.1	55.6	58.6	63.3	48.7					
	4	75(23)	64.4	60.8	56.9	62.0	72.6	51.5	1956	24	12	1992	2052
		150(46)											
		300(91)	58.5	56.5	54.4	56.8	61.0	50.0					
6-13-78	1	50(15)	63.6	59.2	53.1	60.9	69.7	47.7	1560	18		1578	1596
		100(30)	60.3	55.7	50.8	57.6	69.7	47.7					
		200(61)	57.9	54.4	50.8	56.0	69.7	47.7					

TABLE A1. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
10-11-76	1	50(15)	68.2	63.8	58.5	65.7	77.9	53.8	1656	60	12	1728	1824
		100(30)	64.1	60.1	55.9	61.7	74.4	52.1					
		200(61)	59.5	56.4	53.6	57.2	67.4	50.3					
	2	50(15)	67.9	63.8	59.2	65.2	75.6	53.1	1932	42	6	1980	2040
		100(30)	63.6	60.3	56.9	61.2	70.0	52.6					
		200(61)	60.0	56.7	53.8	57.5	65.9	49.7					
	3	50(15)	67.9	63.3	57.2	66.2	80.0	52.8	1431	26	0	1457	1483
		100(30)	64.1	59.9	55.4	63.2	81.3	52.8					
		200(61)	61.3	56.9	53.3	58.6	69.0	47.4					
	4	50(15)	67.7	63.5	58.2	68.4	88.7	52.6	2034	60	0	2094	2154
		100(30)	61.8	59.3	56.4	59.7	62.8	52.8					
		200(61)	59.2	56.7	53.3	58.3	71.5	48.2					
	5	50(15)	66.7	63.1	59.0	69.0	93.6	53.1	1884	36	6	1926	1960
		100(30)	61.8	59.6	56.7	64.5	87.7	53.1					
		200(61)	58.7	56.1	53.8	57.5	75.6	50.0					
4-13-77	1	25(7.6)	70.3	64.8	57.7	67.0	78.7	49.0	1806	66	6	1878	1912
		50(15)	67.7	62.6	56.4	64.6	79.0	50.3					
		100(30)	65.6	61.0	56.4	62.6	72.8	50.8					
		200(61)	61.7	56.9	52.8	58.3	69.0	48.7					
	2	25(7.6)	71.5	66.3	58.7	68.4	76.4	51.5	1722	42	0	1764	1806
		50(15)	67.2	62.5	56.2	64.2	72.1	49.5					
		100(30)	65.6	61.4	56.2	62.7	69.5	48.2					
		200(61)	61.5	57.6	54.0	58.5	64.2	49.5					
	3	35(11)	67.7	64.0	58.7	66.7	82.1	44.6	2088	36	6	2130	2184
		80(24)	65.9	61.9	56.9	64.7	79.7	46.4					
		160(49)	63.3	59.5	54.9	62.3	76.4	47.9					
		320(98)	59.6	56.0	52.8	58.8	72.3	48.4					
	4	35(11)	67.2	63.1	56.9	64.6	75.6	49.5	2148	60	0	2208	2268
		80(24)	64.6	61.1	55.6	62.5	76.9	48.7					
		160(49)	63.1	59.0	54.6	60.2	69.0	48.7					
		320(98)	58.7	55.7	52.1	56.5	65.9	47.8					
	5	60(18)	66.4	63.4	60.3	64.1	69.5	53.1	2016	96	12	2124	2256
		120(37)	65.4	61.9	57.7	62.9	71.5	53.1					
		240(78)	60.0	57.1	54.4	57.7	65.6	51.0					
	6	60(18)	66.4	63.7	60.8	64.2	70.0	54.9	2334	42	12	2382	2466
		200(61)	64.4	61.2	58.2	62.0	73.8	54.1					
		240(73)	60.0	57.7	55.1	58.2	69.7	52.3					
		480(146)	56.7	54.6	52.6	55.0	63.5	49.7					
	7	60(18)	65.1	61.7	58.2	62.8	75.9	44.6	2112	48	6	2166	2232
		200(61)	62.8	59.6	56.2	60.4	68.5	50.3					
		300(91)	59.5	56.5	53.3	57.1	67.4	50.5					
		400(122)	58.7	55.9	53.1	56.4	64.2	50.8					
10-18-77	1	50(15)	64.9	59.7	54.4	61.6	76.9	51.0	1920	84	0	2004	2088
		100(30)	62.3	57.8	54.1	59.2	68.2	50.0					
		200(61)	60.0	56.3	53.1	57.4	68.2	49.0					
	2	50(15)	64.6	59.1	53.6	61.1	74.4	50.5	1518	42	6	1566	1626
		100(30)	61.5	57.1	53.1	58.8	70.8	50.3					
		200(61)	60.5	57.1	53.8	58.4	69.7	50.3					
	3	50(15)	64.6	60.4	56.2	62.0	78.7	52.1	1968	48	0	2016	2064
		100(30)	61.8	58.1	54.6	59.2	71.8	50.3					
		200(61)	60.3	57.1	54.6	57.7	65.4	52.1					
10-20-77	1	50(15)	66.4	61.2	56.2	63.5	77.7	49.7	2208	60	12	2280	2376
		200(61)	57.9	54.1	49.7	55.3	64.1	46.4					
	2	100(30)	64.4	59.5	55.1	61.5	73.1	49.0	2496	54	6	2502	2628
		200(61)	58.2	54.5	51.5	55.5	65.1	46.9					
6-13-78	2	50(15)	63.3	58.1	52.8	59.9	68.7	49.5	1482	30		1512	1542
		100(30)	60.3	55.2	50.5	57.0	66.2	34.4					
		200(61)	57.4	54.0	50.3	54.7	60.8	47.2					
	3	100(30)	62.3	56.7	51.5	59.6	74.6	45.4	1626	48		1674	1722
		200(61)	60.3	55.0	50.8	57.2	70.5	44.1					
		400(122)	55.1	50.6	46.4	52.0	59.2	39.5					

TABLE A2. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 2) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
10-11-76	1	50(15)	65.6	55.5	48.5	66.0	85.9	46.4	426	24	18	468	546
		100(30)	57.9	52.1	47.4	58.8	77.9	45.4					
		200(61)	54.6	51.8	48.7	53.4	65.9	46.9					
	2	50(15)	65.4	56.5	50.0	63.5	83.6	47.7	396	18	12	426	480
		100(30)	59.0	53.1	47.7	52.6	71.3	45.9					
		200(61)	56.7	52.2	49.2	53.7	65.6	46.4					
	3	50(15)	66.2	55.3	49.2	63.0	83.1	47.7	528	18	6	552	588
		100(30)	56.9	51.3	47.2	55.8	75.1	45.9					
		200(61)	52.8	50.9	48.7	51.7	64.4	47.2					
	4	50(15)	66.7	56.9	48.7	64.6	81.8	47.7	528	12	36	576	696
		100(30)	61.8	53.7	48.2	58.8	75.1	46.7					
		200(61)	56.7	52.1	48.5	54.2	65.6	46.9					
	5	50(15)	66.7	56.5	50.3	61.0	81.0	48.5	450	24	12	486	524
		100(30)	59.5	52.2	47.2	56.7	75.1	44.9					
		200(61)	54.1	50.9	47.7	52.6	66.2	41.3					
	6	50(15)	66.7	56.6	50.0	63.8	80.5	47.7	474	24	12	510	570
		100(30)	59.2	52.0	46.7	56.8	71.3	45.1					
		200(61)	54.6	50.0	47.2	51.8	63.3	46.4					
	7	50(15)	67.7	57.6	50.8	64.4	80.3	47.9	594	24	24	642	738
		100(30)	59.7	53.1	47.9	56.6	70.0	46.2					
		200(61)	54.1	50.1	47.7	51.2	63.3	46.4					
	8	50(15)	67.9	57.1	49.0	62.9	77.4	46.4	684	54	12	750	840
		100(30)	59.5	53.3	47.9	56.0	67.2	46.2					
		200(61)	54.4	50.1	47.2	51.6	65.1	45.6					
12-15-76	1	25(7.6)	71.3	59.3	48.6	68.8	84.2	42.9	318	24	24	336	438
		50(15)	65.1	55.3	44.9	62.4	80.0	39.2					
		100(30)	59.5	51.3	42.6	55.8	69.7	40.8					
		200(61)	54.4	48.4	42.1	50.9	62.8	36.7					
	2	25(7.6)	76.2	62.6	51.4	71.4	85.0	44.6	504	42	30	576	708
		50(15)	69.5	58.6	48.2	67.1	83.8	41.3					
		100(30)	62.8	53.9	45.9	60.1	75.9	40.8					
	3	25(7.6)	73.2	59.1	47.2	69.6	84.4	43.2	618	18	18	654	726
		50(15)	66.4	55.5	45.6	65.4	85.9	41.0					
		100(30)	58.7	51.0	43.8	61.4	83.6	---					
		200(61)	54.6	48.4	42.1	57.5	40.5	39.2					
	4	25(7.6)	72.7	58.4	46.4	68.6	84.0	41.7	438	18	6	462	498
		50(15)	65.1	54.8	45.4	62.8	81.0	40.5					
		100(30)	57.4	49.6	41.8	55.4	73.8	41.0					
		200(61)	52.1	46.8	42.3	49.5	62.1	35.4					
4-14-77	1	25(7.6)	69.5	59.4	47.2	65.5	82.8	41.8	462	54	6	522	594
		50(15)	67.9	56.1	44.6	65.0	84.6	40.0					
		100(30)	59.7	51.1	42.6	56.4	73.6	38.7					
	2	25(7.6)	71.5	58.9	46.4	69.2	91.3	39.5	408	12	36	456	576
		50(15)	67.2	54.2	43.3	63.3	79.0	37.9					
		100(30)	58.2	48.9	40.5	56.0	77.8	32.8					
	3	25(7.6)	70.5	57.5	46.2	68.6	86.4	39.7	318	36	24	378	486
		50(15)	68.5	54.9	44.6	66.7	86.9	39.7					
		100(30)	56.7	48.4	41.0	57.2	77.4	56.7					
	4	25(7.6)	70.3	58.0	44.1	67.7	85.6	40.0	468	24	18	510	588
		50(15)	65.1	53.3	42.8	63.6	82.6	40.0					
		100(30)	60.3	49.9	40.8	58.5	76.7	37.9					
10-20-76	1	50(15)	66.7	60.4	53.3	62.8	72.8	46.9	1260	12	6	1278	1332
		100(30)	67.6	57.5	52.6	59.3	69.2	47.7					
11-9-77	1	50(15)	63.8	57.1	49.2	61.0	75.4	39.2	1206	18	12	1236	1290
		200(61)	54.4	51.3	48.7	51.9	58.5	38.2					
	2	50(15)	64.9	56.9	49.2	61.4	75.6	39.7	1278	60	12	1350	1446
		200(61)	55.9	52.2	48.5	53.2	60.5	41.5					
	3	50(15)	65.1	57.9	51.0	61.6	75.1	37.9	1188	18	30	1236	1344
		200(61)	55.4	52.0	49.2	52.7	59.5	45.6					
	4	50(15)	64.1	57.3	51.3	60.9	74.9	44.1	1134	18	6	1158	1194
		200(61)	54.6	51.5	48.7	52.3	60.5	40.0					

TABLE A2. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
12-2-77	1	50(15)	66.7	56.8	47.7	62.8	77.4	44.6	384	42	30	456	588
		200(61)	53.6	48.0	43.1	50.4	61.3	39.2					
	2	50(15)	69.0	58.0	51.0	65.5	83.8	45.6	318	12	12	342	390
		200(61)	51.8	46.7	43.3	54.7	76.9	38.7					
	3	50(15)	63.3	54.0	46.7	59.6	74.1	45.1	348	12		360	372
		200(61)	48.7	44.5	41.0	45.8	55.6	38.7					
	4	50(15)											
		200(61)	49.2	45.2	42.3	46.5	57.9	37.5	390	24	12	426	486
8-17-78	1	50(15)	68.7	54.4	45.4	63.6	77.9	42.8	354	30	6	354	402
		100(30)	62.6	54.1	46.2	59.6	74.1	42.6					
		200(61)	55.6	50.2	45.1	52.8	63.8						
	2	50(15)	68.7	53.9	45.4	64.6	79.5	43.3	282	48	12	342	426
		100(30)	62.6	51.1	43.8	58.3	72.8	41.8					
		200(61)	56.2	49.1	44.4	52.7	65.6	42.1					
	3	50(15)	67.9	55.6	45.9	62.4	71.5	43.1	324	42	6	372	432
		100(30)	63.3	53.6	45.6	58.8	72.1	43.3					
		200(61)	57.9	51.4	45.1	54.4	67.2	41.8					
	4	50(15)	69.2	55.9	47.7	63.7	77.4	43.6	288	0	18	306	360
		100(30)	64.6	54.1	45.9	60.8	75.4	43.1					
		200(61)	57.2	50.6	44.4	54.2	69.2	41.8					
	5	50(15)	68.2	52.9	43.8	63.7	82.1	41.3	312	6	12	330	372
		100(30)	63.1	53.2	45.4	58.6	71.3	43.1					
		200(61)	55.9	49.9	44.4	53.7	71.5	42.6					
	6	50(15)	64.4	50.5	42.8	59.8	74.6	41.3	258	6	0	264	270
		100(30)	60.0	50.6	44.9	55.3	66.7	42.8					
		200(61)	53.8	48.5	44.1	50.4	60.5	---					
8-17-78	1	50(15)	65.9	54.5	45.9	62.5	76.9	41.3	324	24	18	366	444
		100(30)	61.5	52.8	45.4	59.2	78.7	41.8					
		200(61)	58.7	52.2	45.9	55.2	69.7	41.8					
	3	50(15)	67.2	56.6	46.4	62.2	72.3	42.1	474	36	18	528	618
		100(30)	60.8	52.8	45.4	56.7	67.7	39.0					
		200(61)	58.2	51.3	44.4	54.6	66.7	40.5					
	4	50(15)	65.4	54.9	46.9	60.8	73.1	42.6	420	30	18	468	522
		100(30)	59.2	52.2	45.9	55.6	71.0	41.8					
		200(61)	54.9	49.6	44.4	52.3	68.2	39.0					
	5	50(15)	66.7	56.0	46.9	62.9	79.5	43.8	528	12	12	552	600
		100(30)	59.5	52.2	44.9	56.3	70.8	42.1					
		200(61)	52.6	46.5	40.8	49.2	61.3	39.2					
	6	50(15)	69.7	57.3	45.1	68.2	87.9	42.1	462	18	42	522	834
		100(30)	63.6	53.4	43.1	60.7	76.4	39.5					
		200(61)	59.0	49.5	41.5	55.2	71.3	39.5					

TABLE A3. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 3) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
8-5-76	1	150(46)	75.6	69.3	64.6	71.4	79.7	56.9	1746	78	246	2070	2886
		300(91)	72.1	67.2	62.8	68.7	76.9	58.5					
		600(183)	69.5	64.5	60.3	66.1	74.9	55.9					
	2	150(46)	75.4	69.7	64.6	72.1	84.4	60.3	1794	120	306	2220	3258
		300(91)	72.3	67.9	63.1	69.7	82.3	51.8					
		600(183)	70.0	65.4	61.0	66.9	75.6	56.7					
	3	150(46)	78.2	70.7	64.6	73.8	84.4	58.2	1728	108	282	2118	3072
		300(91)	74.4	68.6	62.6	71.0	83.1	51.3					
		600(183)	71.0	65.8	60.3	68.3	78.5	54.9					
	4	150(46)	76.9	70.0	63.8	72.9	83.3	57.4	2280	168	336	2784	3960
		300(91)	73.6	68.3	62.8	70.2	79.7	55.6					
		600(183)	69.2	64.7	59.2	66.2	72.6	53.1					
12-15-76	1	300(91)	69.5	63.1	55.9	66.2	79.0	52.1	1080	66	312	1458	2460
	2	300(91)	68.2	62.0	54.9	64.6	74.4	49.0	996	66	258	1320	2160
	3	75(23)	77.1	68.7	59.6	72.6	82.9	52.1	924	114	336	1374	2496
		300(91)	67.9	61.7	54.4	64.1	73.1	50.3					
		600(183)	62.8	57.9	52.8	59.4	67.9	49.0					
	4	75(23)	77.3	68.4	60.1	72.8	86.2	51.9	816	84	216	1116	1848
		300(91)	66.4	60.3	53.8	67.3	69.2	50.5					
		600(183)	60.0	56.2	51.8	57.2	63.6	49.5					
	5	100(30)	75.4	67.0	59.0	71.3	84.9	51.8	1038	60	264	1362	2214
		400(122)	65.1	59.3	53.6	62.0	76.7	48.5					
		800(244)	63.3	57.3	52.6	59.4	70.5	48.5					
	6	100(30)	74.1	66.8	59.0	70.0	79.7	51.8	972	78	318	1368	2400
		400(122)	63.8	58.9	53.6	60.4	67.4	50.5					
		800(244)	60.3	60.3	52.8	57.1	65.6	50.0					
11-2-77	1	75(23)	82.1	74.4	66.9	78.3	89.0	59.5	1876	36	240	1248	2004
		300(91)	66.9	62.9	59.0	64.4	75.6	56.2					
	2	75(23)	81.0	71.9	63.6	76.8	88.2	51.4	1020	24	276	1320	2172
		300(91)	65.6	61.6	57.2	62.7	69.0	54.9					
	3	75(23)	82.6	72.8	64.6	78.3	92.3	57.2	1044	24	306	1374	2316
		300(91)	65.9	62.0	57.7	63.1	70.3	53.1					
	4	75(23)	81.3	72.6	64.9	76.6	87.2	57.7	1002	24	354	1380	2466
		300(91)	65.9	54.9	56.9	62.9	70.0	54.9					
11-9-77	1	300(91)	67.2	62.6	57.7	64.0	72.6	49.7	972	132	492	1596	3204
	2	75(23)	80.5	74.6	68.7	76.9	90.3	61.0	1224	120	600	1944	3864
		300(91)	66.2	61.7	56.9	63.3	75.4	52.6					
	3	75(23)	80.0	73.2	67.9	76.0	86.9	62.8	1374	54	474	1902	3378
		300(91)	66.2	60.8	56.2	62.6	72.8	53.1					
	4	75(23)	78.7	72.3	65.9	75.4	87.2	56.7	1230	54	522	1806	3426
10-20-77	1	75(23)	82.3	75.4	68.5	78.4	89.0	61.0	648	24	246	918	1680
		300(91)	67.4	62.7	57.7	64.0	70.3	55.6					
	2	75(23)	81.5	74.7	68.5	77.7	87.9	60.0	930	66	318	1314	2334
		300(91)	66.4	61.2	56.9	62.9	73.1	54.1					
	3	75(23)	81.3	74.8	68.5	77.5	88.2	57.9	1212	84	294	1590	2556
		150(46)	73.1	67.3	61.5	69.4	77.9	55.4					
		300(91)	63.8	59.9	51.2	60.9	66.9	52.3					
	4	150(46)	75.4	67.9	61.3	71.2	82.6	38.7	1060	96	348	1512	2652
		300(91)	66.7	60.3	54.9	62.5	71.0	52.3					
		600(183)	60.3	56.3	52.8	57.1	62.6	51.5					
10-31-77	1	75(23)	80.0	74.0	68.2	76.8	88.7	67.6	1218	96	240	1554	2370
		300(91)	71.8	66.1	61.0	67.8	75.6	57.2					
	2	75(23)	82.1	75.3	68.5	78.5	89.2	62.3	1344	90	384	1818	3060
		300(91)	72.3	67.9	62.6	69.4	77.9	54.4					
	3	75(23)	79.2	74.4	69.0	76.8	89.7	62.1	1152	96	252	1500	2352
		300(91)	71.3	66.8	62.3	68.1	75.6	46.7					
	4	75(23)	80.0	74.5	69.2	77.0	89.0	62.6	1200	66	228	1494	2244
		300(91)	71.3	66.9	63.1	68.1	75.6	55.1					
	5	75(23)	80.5	75.1	70.0	77.1	88.5	63.6	1164	54	258	1476	2304
		300(91)	71.5	68.3	65.1	69.0	75.4	62.6					
	6	75(23)	80.0	74.2	68.5	76.6	84.9	63.8	1194	48	204	1446	2106
		300(91)	67.7	64.7	61.8	65.5	74.9	59.2					

TABLE A3. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
4-5-78	1	75(23)	80.8	74.4	67.2	76.8	83.8	74.4	1956	156	372	2484	3756
		300(91)	73.3	68.6	63.3	70.7	84.4	49.7					
	2	75(23)	80.5	73.3	65.1	76.0	82.8	54.4	1980	150	420	2550	3960
		300(91)	72.6	68.0	63.3	71.0	83.0	56.4					
	3	75(23)	80.8	73.2	66.2	76.1	83.6	53.3	2028	78	324	2430	3480
		300(91)	72.8	67.4	63.1	69.4	82.3	59.2					
	4	75(23)	79.7	73.3	66.7	75.6	83.3	60.5	2154	78	360	2592	4470
		300(91)	71.5	67.1	63.1	68.4	76.7	60.5					
12-2-77	1	75(23)	83.8	77.1	70.3	80.4	91.0	61.0	1182	114	324	1620	2706
		300(91)	71.3	68.2	64.4	69.2	77.7	56.7					
	2	75(23)	83.8	77.1	70.3	79.9	91.5	61.0	1128	96	270	1494	2400
		300(91)	70.8	67.5	62.3	68.5	77.7	58.5					
	3	75(23)	82.1	75.9	70.0	78.6	89.2	63.3	1170	108	276	1554	2490
		300(91)	69.2	64.6	60.3	65.8	72.1	55.6					
	4	75(23)	82.6	75.6	69.0	78.8	89.2	54.1	1218	120	246	1584	2442
		300(91)	70.6	65.4	60.0	67.0	75.9	70.0					
12-16-76	1	25(7.6)	83.1	74.2	65.1	79.7	95.6	57.2	864	54	282	1200	2100
		50(15)	80.3	72.8	65.1	77.0	90.5	56.9					
		100(30)	79.6	72.3	65.5	75.1	83.5	57.8					
		200(61)	76.7	69.9	64.1	72.3	80.5	56.2					
	2	25(7.6)	81.5	73.0	64.9	78.7	94.4	53.3	1200	84	168	1452	2040
		50(15)	78.5	71.5	64.6	75.9	89.7	55.4					
		100(30)	76.7	70.8	65.3	73.4	82.9	57.1					
		200(61)	74.4	69.0	64.1	71.3	81.5	59.0					
	3	25(7.6)	84.9	75.6	66.4	81.5	95.4	58.5	1062	102	306	1470	2490
		50(15)	81.5	73.4	65.4	77.7	90.5	58.5					
		100(30)	79.7	72.6	65.9	75.5	83.6	60.8					
		200(61)	75.7	70.0	64.4	72.3	82.3	59.5					
	4	25(7.6)	82.8	73.6	64.9	79.9	94.4	54.6	1230	48	222	1500	2214
		50(15)	80.3	71.7	64.1	76.6	92.6	55.1					
		100(30)	79.0	71.0	64.5	74.4	84.2	57.6					
		200(61)	76.2	68.8	63.3	71.6	80.5	57.9					
	5	25(7.6)	85.1	76.7	68.5	82.0	95.6	59.2	1212	96	294	1602	2388
		50(15)	81.8	74.4	67.7	78.4	91.3	59.7					
		100(30)	79.9	73.7	67.9	76.0	83.8	60.5					
		200(61)	76.9	71.1	65.4	73.2	83.1	60.5					
	6	20(6.1)	84.6	76.1	67.4	82.2	95.4	54.6	1188	54	282	1524	2424
		40(12)	81.0	72.6	64.6	77.8	94.9	54.4					
		80(24)	79.6	72.4	66.3	75.4	83.7	55.8					
		160(49)	77.2	70.3	64.6	73.5	84.9	57.4					
	7	20(6.1)	84.9	77.0	68.2	82.0	98.2	60.0	1212	66	168	1446	2016
		40(12)	81.3	73.3	66.4	77.8	93.3	61.3					
		80(24)	80.0	72.8	67.1	75.3	84.0	62.7					
		160(49)	76.7	70.3	64.9	73.2	87.2	56.2					
	8	20(6.1)	83.1	75.4	65.9	80.1	94.6	53.3	1272	78	138	1488	1980
		40(12)	77.7	71.8	64.1	75.6	89.7	52.8					
		80(24)	76.4	70.6	64.6	72.8	81.7	55.5					
		160(49)	76.7	69.1	62.3	72.2	82.1	54.6					
	9	20(6.1)	84.6	76.4	68.2	81.8	96.7	60.5	1344.	78	180	1602	2220
		40(12)	81.3	73.0	65.9	77.8	93.8	59.0					
		80(24)	78.7	72.1	66.0	74.6	83.7	59.9					
		160(49)	76.9	70.5	64.9	73.2	84.6	60.5					
	10	20(6.1)	82.8	74.5	65.9	80.4	95.6	53.3	1349	72	192	1608	2256
		40(12)	77.7	70.8	63.3	75.1	89.0	53.6					
		80(24)	77.1	70.3	63.8	73.1	82.7	57.1					
		160(49)	74.1	68.6	64.1	70.6	79.7	53.9					

TABLE A3. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
4-11-78	1	75(23)	74.4	66.2	58.7	73.0	89.0	54.1	786	30	180	996	1566
		150(46)	66.2	60.5	55.1	66.6	84.9	50.0					
		300(91)	64.9	55.8	47.9	57.1	81.0						
	2	75(23)	73.3	65.4	56.9	71.0	86.4	50.0	840	42	120	1002	1404
		150(46)	68.7	61.0	54.4	66.2	83.8	45.4					
		300(91)	65.6	54.7	42.6	67.8	89.5						
	3	75(23)	75.1	65.2	55.6	71.7	84.9	47.4	852	54	240	1146	1920
		150(46)	67.4	60.1	52.6	64.0	75.9	44.9					
		300(91)	64.9	54.7	43.8	60.6	73.3						
4-24-78	1	75(23)	71.5	63.2	54.2	68.3	85.4	48.2	936	36	126	1098	1512
		150(46)	67.2	59.9	52.3	64.0	78.7	45.6					
		300(91)	61.8	55.8	49.2	58.4	67.9	45.1					
	2	75(23)	74.9	64.6	55.1	71.4	85.9	43.3	780	24	192	996	1596
		150(46)	70.0	61.5	52.6	66.7	80.8	46.4					
		300(91)	65.4	57.3	50.3	60.6	69.2	43.8					
	3	75(23)	71.5	63.7	55.1	68.6	82.1	45.9	954	48	150	1152	1650
		150(46)	67.9	60.1	52.1	64.3	75.6	44.1					
		300(91)	62.3	55.4	49.0	58.2	66.9	42.3					
6-9-78	1	150(46)	69.7	60.9	52.3	64.6	72.8	46.4	1020	24	192	1236	1428
		300(91)	62.3	56.3	50.3	58.8	69.2	45.4					
	2	200(61)	68.5	59.8	52.3	65.4	83.8	43.6	996	60	168	1224	1788
		400(122)	64.9	55.1	47.3	61.0	73.6	42.1					
	3	250(76)							1026	102	198	1326	2022
		500(152)	58.5	53.4	48.2	55.2	64.9	42.1					

TABLE A4. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 4) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
6-19-78	1	50(15)	75.9	71.6	67.9	73.4	88.5	61.8	5382	126	138	5646	6186
		100(30)	69.0	66.1	63.6	66.8	72.6	57.9					
		200(61)	68.2	64.1	60.5	65.7	78.5	56.2					
	2	50(15)	75.9	71.7	67.9	74.1	87.9	63.8	4164	102	144	4398	4944
		100(30)	70.3	66.5	63.6	67.3	72.8	60.8					
		200(61)	67.7	63.5	60.0	65.3	77.4	56.7					
	3	50(15)	75.6	71.9	68.5	74.2	90.3	65.6	4770	102	174	5046	5670
		100(30)	72.3	68.4	65.1	69.2	74.6	61.0					
		200(61)	69.2	64.7	60.5	66.6	79.7	57.4					
	4	50(15)	74.6	71.2	67.9	72.4	86.2	64.4	4968	114	168	5250	5868
		100(30)	68.5	63.3	57.4	65.0	72.1	53.6					
		200(61)	66.2	62.6	59.7	63.8	76.4	57.7					
	5	50(15)	75.1	71.4	67.9	72.8	84.9	64.4	5118	102	150	5334	5922
		100(30)	70.3	66.9	63.8	67.6	72.8	59.2					
		200(61)	67.9	63.4	50.5	65.6	80.8	56.4					
	6	50(15)	75.9	71.7	67.7	74.1	86.7	63.3	5268	108	102	5448	5892
		100(30)	68.7	65.4	62.6	66.2	72.6	59.0					
		200(61)	66.9	63.3	60.0	64.9	76.9	57.4					
	7	50(15)	75.1	72.2	69.0	74.6	91.8	64.4	5064	66	108	5232	5628
		100(30)	69.7	67.0	64.6	67.7	77.9	58.5					
		200(61)	68.5	64.7	61.0	66.9	82.1	57.2					
	8	50(15)	74.4	71.3	68.2	72.1	82.6	63.3	5106	126	84	5316	5694
		100(30)	69.2	66.4	63.8	67.0	72.3	54.4					
		200(61)	65.9	62.8	60.0	63.7	76.7	51.9					
7-18-78	1	50(15)	75.9	70.4	64.9	72.6	84.6	57.9	3138	228	162	3528	4242
		100(30)	74.6	69.5	64.9	71.3	82.3	59.7					
		200(61)	63.8	59.6	55.9	60.8	67.7	50.5					
	2	50(15)	77.7	70.9	64.4	73.8	85.1	59.7	3012	150	222	3384	4200
		100(30)	77.9	71.2	65.1	74.2	87.4	61.3					
		200(61)	67.2	61.6	56.7	63.4	72.3	52.6					
	3	50(15)	75.9	70.1	64.9	73.0	86.2	57.9	2688	204	168	3050	3768
		100(30)	75.6	70.1	65.1	72.4	86.2	59.5					
		200(61)	66.9	61.6	56.9	63.6	72.6	51.5					
	4	50(15)	76.4	70.0	64.1	72.6	84.1	56.2	2106	210	198	2514	3319
		100(30)	76.2	69.8	64.4	72.2	83.3	58.2					
		200(61)	65.1	60.5	55.9	62.1	70.0	50.5					
	5	50(15)	78.5	71.5	65.4	74.6	86.7	56.7	2706	156	300	3162	4218
		100(30)	77.7	71.0	64.9	74.8	88.7	57.7					
		200(61)	67.7	62.0	56.7	64.0	72.1	47.9					
	6	50(15)	76.7	70.8	65.4	73.4	86.4	61.0	3096	120	168	3384	4008
		100(30)	75.9	70.2	65.1	73.0	85.4	60.8					
		200(61)	67.7	62.1	57.9	63.8	72.8	53.3					
	7	50(15)	76.9	71.3	66.2	74.2	88.5	60.5	3558	156	210	3924	4710
		100(30)	75.1	70.0	65.1	72.4	84.1	59.2					
		200(61)	66.2	61.0	56.4	62.5	69.7	52.3					
	8	50(15)	79.2	72.6	66.9	76.6	91.8	60.5	3798	192	168	4158	4854
		100(30)	77.7	70.7	65.4	73.8	87.7	61.5					
		200(61)	67.2	62.0	57.7	63.6	72.6	54.4					
	9	50(15)	76.4	70.8	65.6	73.9	89.5	62.3	4308	132	186	4626	5316
		100(30)	75.4	69.2	64.6	72.9	89.2	61.0					
		200(61)	66.9	61.7	57.9	63.4	73.3	52.8					
	10	50(15)	76.4	71.4	66.7	73.8	86.2	61.0	4506	84	234	4824	5610
		100(30)	74.9	69.1	64.6	71.5	84.9	60.0					
		200(61)	65.9	60.9	56.7	62.3	71.5	51.5					

TABLE A4. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
8-2-78	1	50(15)	77.4	71.1	65.1	75.0	92.3	56.7	3060	180	162	3402	4068
		100(30)	71.8	66.0	60.5	69.2	85.1	54.4					
		200(61)	67.2	62.9	58.7	64.4	76.7	54.1					
	2	50(15)	76.4	70.8	64.4	74.0	87.4	56.7	3030	216	210	3456	4302
		100(30)	73.3	66.6	60.5	69.6	80.5	55.1					
		200(61)	69.0	64.0	59.2	65.5	73.1	54.1					
	3	50(15)	76.4	70.6	65.1	73.6	88.5	57.9	3006	198	186	3390	4146
		100(30)	72.3	66.0	60.5	68.8	81.5	54.1					
		200(61)	68.7	64.0	59.7	65.6	75.1	53.8					
	4	50(15)	76.9	70.9	65.4	73.9	87.9	60.3	2982	174	126	3282	3834
		100(30)	72.8	66.2	61.0	69.4	81.5	56.7					
		200(61)	69.0	61.6	55.4	64.9	77.9	46.7					
	5	50(15)	77.2	71.3	65.6	74.2	85.9	59.0	3138	126	228	3492	4302
		100(30)	72.3	66.5	61.3	69.3	79.7	55.9					
		200(61)	66.9	61.6	57.4	64.0	76.9	53.3					
	6	50(15)	77.7	71.5	65.6	74.6	89.0	56.4	2856	132	234	3222	4056
		100(30)	72.1	65.8	60.8	68.5	82.1	55.4					
		200(61)	66.9	61.3	56.9	63.8	76.9	51.5					
	7	50(15)	77.7	72.1	65.9	75.2	88.5	59.5	2814	132	126	3072	3582
		100(30)	73.3	68.4	63.8	70.5	83.1	56.4					
		200(61)	70.0	65.1	61.0	66.5	76.4	56.2					
	8	50(15)	76.9	71.5	65.9	74.0	88.5	56.9	3054	210	162	3426	4122
		100(30)	73.8	68.8	64.1	70.6	83.8	56.9					
		200(61)	68.7	64.5	61.0	65.6	76.4	54.9					
	9	50(15)	76.4	71.6	66.2	73.7	86.2	57.7	3564	186	168	3918	4608
		100(30)	72.1	68.2	63.8	69.7	80.8	59.0					
		200(61)	68.2	64.9	61.8	65.8	73.8	52.8					
	10	50(15)	79.0	72.7	66.4	76.0	89.0	56.4	3078	144	240	3462	4326
		100(30)	74.4	69.2	64.9	71.2	82.6	56.2					
		200(61)	70.5	65.9	62.1	67.4	77.9	45.1					
	11	50(15)	77.9	72.1	66.4	75.0	87.2	59.0	3438	168	192	3798	4542
		100(30)	74.9	69.3	69.6	71.4	82.1	58.7					
		200(61)	70.0	65.1	61.0	66.7	75.9	52.3					
	12	50(15)	77.4	71.9	66.2	74.2	85.4	57.2	3546	180	222	3948	4794
		100(30)	73.3	68.4	63.8	70.2	80.0	56.4					
		200(61)	68.7	64.8	61.3	66.5	81.0	57.9					
	13	50(15)	77.7	72.6	67.4	74.8	86.2	59.5	3168	150	198	3516	4260
		100(30)	72.8	68.5	64.4	69.9	80.5	57.9					
		200(61)	68.7	65.2	61.8	66.2	74.1	57.9					
10-3-78	1	50(15)	79.3	73.2	66.7	75.7	85.9	60.5	2646	120	192	2958	3654
		100(30)	73.3	68.7	64.1	70.3	81.1	60.3					
		200(61)	68.7	65.7	62.3	66.4	75.4	59.0					
	2	50(15)	79.0	73.0	66.2	75.8	88.7	59.5	2184	144	126	2454	2976
		100(30)	74.4	69.4	64.4	72.3	85.9	60.5					
		200(61)	69.5	65.7	62.3	66.5	71.5	58.7					
	3	50(15)	80.8	74.4	68.5	77.1	86.9	60.3	2520	144	246	2910	3792
		100(30)	76.7	70.8	66.2	73.0	83.6	60.0					
		200(61)	70.5	67.3	63.6	68.1	75.1	60.8					

TABLE A5. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 5) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
9-15-76	1	25(7.6)	72.1	59.9	51.8	67.6	80.5	49.0	312	24	0	336	360
		50(15)	66.7	57.4	48.7	63.6	79.2	45.6					
		100(30)	60.0	53.7	47.9	56.4	66.7	45.1					
	2	25(7.6)	70.0	60.4	52.1	66.2	79.2	48.7	522	12	0	534	546
		50(15)	65.9	58.1	51.3	62.0	76.2	48.2					
		100(30)	58.5	54.3	50.0	55.9	67.9	46.7					
	3	25(7.6)	71.8	60.3	50.5	67.6	82.6	48.7	492	12	12	516	540
		50(15)	67.7	58.2	49.0	64.9	81.3	46.9					
		100(30)	60.3	54.2	47.9	58.7	75.4	45.9					
	4	25(7.6)	71.0	58.8	50.0	66.4	85.1	48.5	438	12	6	456	510
		50(15)	66.7	56.7	48.7	62.3	79.5	45.4					
		100(30)	58.7	52.7	47.4	56.0	73.6	43.8					
7-13-78	1	50(15)	68.5	58.5	49.0	66.4	83.6	43.8	342	6	6	354	378
		100(30)	64.4	56.4	49.2	61.1	76.4	45.1					
		200(61)	60.0	53.6	47.2	58.2	76.4	42.8					
	2	50(15)	66.9	57.4	48.2	62.8	74.9	44.6	354	6	0	360	366
		100(30)	62.6	55.3	49.2	58.5	70.3	46.9					
		200(61)	59.0	53.0	47.4	55.2	64.1	45.6					
	3	75(23)	66.7	57.8	48.5	63.8	80.5	43.8	318	18	0	336	354
		150(46)	62.3	55.7	49.2	59.1	72.8	45.1					
		300(91)	56.4	49.6	42.6	53.2	65.1	---					
	4	75(23)	66.4	56.6	47.7	62.2	75.4	42.8	378	6	0	384	390
		150(46)	61.0	54.5	47.9	58.0	71.3	42.1					
		300(91)	52.8	47.5	43.1	49.4	60.0	41.0					
	5	100(30)	62.8	54.6	46.2	61.7	81.3	38.7	366	12	12	390	462
		200(61)	60.8	54.4	47.7	57.3	66.9	44.1					
		400(122)	54.1	49.3	45.1	51.1	64.4	42.8					
	6	100(30)	62.8	54.7	46.4	59.0	71.3	43.8	426	6	0	432	438
		200(61)	60.5										
		400(122)	52.8	47.8	43.3	54.3	75.1	39.5					
	7	125(38)	60.3	53.1	45.9	60.8	79.7	39.5	396	24	6	426	480
		450(137)	53.6	48.0	43.1	52.4	67.2	40.5					
	8	125(38)	59.7	52.9	45.9	56.2	69.7	40.0	432	18	6	456	504
		450(137)	50.8	46.8	42.6	48.0	59.2	39.2					
8-4-78	1	25(7.6)	74.6	63.5	52.8	70.6	85.1	50.8	426	18	6	450	486
		50(15)	69.5	61.7	52.3	66.0	78.7	48.5					
		100(30)	65.6	57.3	48.5	61.6	75.9	43.8					
	2	25(7.6)	74.1	62.0	51.3	71.2	91.5	50.5	288	48	0	336	384
		50(15)	71.0	60.9	49.7	67.0	83.6	48.7					
		100(30)	67.4	57.7	48.2	63.2	76.7	44.1					
	3	25(7.6)	75.1	63.2	51.0	70.8	83.8	50.8	426	24	0	450	474
		50(15)	71.3	62.6	52.6	67.4	79.0	48.7					
		100(30)	67.2	58.8	49.2	63.3	75.1	44.9					
	4	100(30)	66.2	58.2	49.0	62.8	77.9	45.9	414	42	0	456	498
		200(61)	62.3	56.8	50.3	59.2	69.7	36.9					
		400(122)	56.4	50.7	44.9	53.0	64.4	40.0					
	5	100(30)	65.9	57.5	48.7	61.4	71.8	44.9	450	6	0	456	462
		200(61)	61.5	55.6	50.0	57.8	71.3	44.6					
		400(122)	54.1	49.4	44.4	51.0	59.2	41.3					
	6	100(30)	66.7	57.3	47.2	63.3	77.9	43.3	396	36	12	444	516
		200(61)	62.8	56.3	49.2	59.8	72.8	45.9					
		300(91)	58.7	52.6	46.4	55.9	69.5	42.6					
8-14-78	1	50(15)	67.2	57.7	49.5	62.4	73.1	44.9	390	30	0	420	450
		100(30)	65.6	57.4	49.0	62.4	75.9	45.1					
		200(61)	59.5	53.6	48.2	55.9	66.7	45.4					
	2	50(15)	68.5	58.4	48.2	65.0	79.2	43.8	450	12	0	462	474
		100(30)	66.2	57.5	48.2	62.1	71.3	42.3					
		200(61)	60.0	53.9	47.4	56.5	67.9	44.9					

TABLE A6. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 6) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
10-3-78	1	50(15)	72.8	68.5	63.3	70.0	80.0	59.5	3084	84	24	3192	3348
		100(30)	67.2	62.6	58.7	63.9	72.1	53.6					
		200(61)	62.6	58.8	55.4	59.9	69.2	51.3					
	2	50(15)	72.8	68.4	62.3	70.8	84.1	55.1	3054	90	102	3246	3642
		100(30)	67.4	62.6	57.2	65.4	79.2	51.5					
		200(61)	63.3	58.6	54.1	60.4	69.7	51.0					
	3	50(15)	72.6	68.3	62.8	70.4	83.1	56.4	3084	126	48	3258	3528
		100(30)	66.9	61.9	57.4	64.4	77.7	53.6					
		200(61)	62.1	58.3	54.9	59.8	70.0	51.8					
	4	50(15)	73.6	62.6	58.7	70.2	72.1	53.6	3018	186	24	3228	3486
		100(30)	67.4	62.5	57.2	64.3	72.6	53.6					
		200(61)	62.8	59.3	54.9	60.3	67.4	51.5					
10-10-78	1	50(15)	72.1	66.2	59.5	69.4	82.3	51.0	2004	138	60	2202	2720
		100(30)	67.7	60.9	55.4	63.5	72.6	48.4					
		200(61)	62.3	57.6	53.1	60.0	72.8	48.4					
	2	50(15)	72.8	66.0	57.2	70.6	85.6	52.1	1674	144	72	1890	2250
		100(30)	70.0	61.8	54.9	67.0	84.6	49.2					
		200(61)	63.6	58.2	53.1	64.6	82.0	49.7					
	3	50(15)	73.6	66.6	59.0	70.1	82.1	53.8	2016	120	126	2262	2640
		100(30)	70.2	63.0	56.1	65.7	72.6	51.5					
		200(61)	65.4	59.7	54.8	61.9	71.0	52.0					
	4	50(15)	71.0	65.0	57.9	68.7	87.4	49.0	2532	102	48	2682	2928
		100(30)	66.7	60.3	54.6	64.3	80.0	48.7					
		200(61)	60.5	55.4	51.3	58.3	74.4	47.4					
	5	50(15)	72.8	67.8	62.6	69.9	80.5	53.6	2490	168	96	2754	3210
		100(30)	69.0	62.3	57.2	64.9	77.2	53.6					
		200(61)	62.3	57.4	53.6	60.5	75.1	49.5					
	6	50(15)	70.5	66.2	61.0	67.9	81.0	51.8	2574	132	54	2760	3054
		100(30)	66.9	61.8	57.2	63.8	77.4	53.8					
		200(61)	60.0	56.7	53.6	58.1	70.8	51.0					
	7	50(15)	70.0	65.4	58.2	67.5	79.7	51.0	2682	102	78	2862	3178
		100(30)	66.7	60.8	55.6	63.2	77.7	51.0					
		200(61)	59.7	56.2	52.1	57.5	69.7	47.9					

APPENDIX B

WEATHER CONDITION DATA

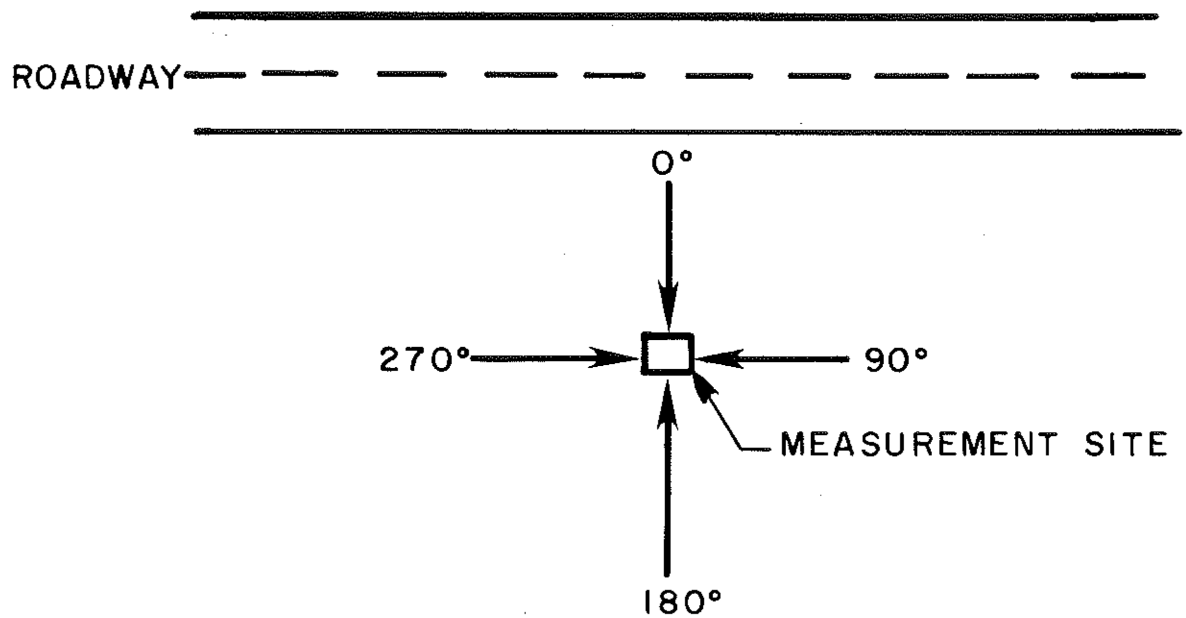

Figure B1. Wind Direction Parameter (Degrees).

TABLE B-1. WEATHER CONDITIONS DATA

DATE	SITE NUMBER	WIND SPEED (KNOTS)	WIND DIRECTION (DEGREES)	WIND VECTOR SPEED[a] (KNOTS)	TEMPERATURE (°F)	RELATIVE HUMIDITY
2-24-76	1	12.5	270°	0	54	41
6-29-76	1	10	300°	-5	85	57
10-11-76	1	7.5	200°	+7	59	50
4-3-76	1	6	0°	-6	77	45
10-18-77	1	10.5	300°	-5	59	52
10-20-77	1	5	190°	+5	58	62
11-3-77	1	7.5	200°	+7	73	66
11-9-77	1	12	250°	+4	69	70
4-10-78	1	13	300°	-7	76	56
6-13-77	1	9	70°	-3	68	54
10-11-76	2	5	200°	+5	59	70
10-20-76	2	8	330°	-7	45	96
12-15-76	2	5	255°	+1	69	54
4-14-77	2	2	45°	-1	81	34
11-9-77	2	12	220°	+9	69	70
12-2-77	2	9	260°	+2	39	86
8-17-78	2	5	290°	-2	83	65
8-17-78	2	5	160°	+5	85	61
8-5-76	3	12	340°	-11	81	58
12-15-76	3	7	30°	-6	46	54
12-16-76	3	12	0°	-12	36	75
10-20-77	3	5	180°	+5	58	62
10-31-77	3	12	290°	-4	65	62
11-2-77	3	7	210°	+6	66	57
11-9-77	3	11	280°	-2	71	65
12-2-77	3	8	340°	-7	44	76
4-5-78	3	6	210°	+5	61	56
4-11-78	3	15	180°	+15	63	48
4-24-78	3	5	120°	+2	68	39
6-9-78	3	8	230°	+5	67	56
6-17-78	4	3	345°	-3	72	79
7-18-78	4	2	190°	+2	80	45
8-2-78	4	9	235°	+5	81	60
10-3-78	4	3	135°	+2	66	75
9-15-76	5	5	320°	-4	74	57
7-13-78	5	8	250°	+3	74	86
8-4-78	5	9	50°	-6	69	68
8-14-78	5	1	350°	-1	78	77
10-3-77	6	5	300°	-2	66	75
10-10-78	6	4	230°	+3	65	56

[a] A wind vector away from the roadway was negative; toward the roadway, positive; parallel to the roadway was zero.

APPENDIX C

TRAFFIC STREAM NOISE DATA TAKEN ON DIFFERENT GROUND COVERS

TABLE C1. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 6) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
10-10-78[a]	1	50(15)	69.7	63.8	55.6	66.8	82.1	51.0	1494	186	24	1704	1962
		100(30)	62.8	58.2	52.1	61.2	77.7	47.7					
		200(61)	56.9	54.0	51.0	54.9	63.1	46.7					
	2	50(15)	70.0	63.9	56.4	67.2	82.6	51.0	1752	108	36	1896	2112
		100(30)	64.1	58.6	53.6	61.8	77.2	45.1					
		200(61)	59.0	55.0	51.0	56.6	67.2	46.9					
	3	50(15)	70.5	64.8	58.2	67.2	79.7	52.3	1842	138	54	2034	2334
		100(30)	64.9	60.2	54.9	62.4	76.7	49.5					
		200(61)	60.0	56.6	53.6	57.7	66.4	47.7					
10-10-78[b]	1	50(15)	71.8	68.5	61.5	71.0	86.4	56.2	2184	84	48	2316	2544
		100(30)	73.1	66.8	59.0	72.5	93.1	53.6					
		200(61)	67.4	61.9	56.7	68.4	87.2	53.6					
	2	50(15)	66.7	58.7	51.8	61.8	70.8	43.6	2136	78	48	2262	2484
		100(30)	72.8	66.3	58.5	69.4	80.0	53.6					
		200(61)	67.2	61.1	56.4	63.2	73.6	51.0					
	3	50(15)	71.8	67.3	60.8	70.0	83.6	54.6	1974	132	48	2154	2430
		100(30)	72.6	65.8	58.5	69.9	84.4	53.8					
		200(61)	66.9	60.8	56.2	63.0	73.3	53.6					

[a] Ground cover was tall grass
[b] Ground cover was pavement

TABLE C2. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 7)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	HEIGHT (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
				L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
3-18-76[a]	1	50 (15)	5 (1.5)	65.1	58.6	53.1	65.0	84.6	51.5	510	30	12	552	618
		100 (30)	5 (1.5)	59.5	54.4	49.0	59.6	75.9	44.9					
		200 (61)	5 (1.5)	55.6	52.0	48.7	55.8	74.1	45.6					
	2	50 (15)	5 (1.5)	70.5	59.4	50.5	65.7	76.4	45.4	456	48	72	576	840
		100 (30)	5 (1.5)	63.8	55.8	48.7	61.1	76.2	45.4					
		200 (61)	5 (1.5)	59.5	53.1	47.4	56.1	65.9	44.4					
	3	50 (15)	5 (1.5)	65.6	57.7	49.2	61.9	75.6	44.1	738	0	12	750	786
		100 (30)	5 (1.5)	59.0	53.3	47.9	55.4	70.5	44.6					
		200 (61)	5 (1.5)	55.4	51.3	47.7	52.4	62.1	41.5					
	4	50 (15)	5 (1.5)	71.0	63.0	54.5	68.1	84.2	44.5	636	36	18	690	780
		100 (30)	5 (1.5)	63.1	57.7	53.3	61.2	76.9	51.8					
		200 (61)	5 (1.5)	59.5	53.0	47.2	56.8	72.1	42.3					
		400 (122)	5 (1.5)	55.9	50.4	45.9	52.9	64.9	39.7					
	5	50 (15)	5 (1.5)	71.0	63.8	55.8	69.0	84.5	50.1	612	54	24	690	816
		100 (30)	5 (1.5)	63.6	56.5	48.7	61.4	76.7	44.1					
		200 (61)	5 (1.5)	59.5	53.7	47.4	57.5	73.1	43.6					
		400 (122)	5 (1.5)	55.9	51.4	46.7	53.4	63.8	41.0					
	6	50 (15)	5 (1.5)	71.9	64.1	55.4	68.2	82.7	47.4	630	36	12	678	750
		100 (30)	5 (1.5)	65.1	57.6	49.2	62.2	75.4	44.9					
		200 (61)	5 (1.5)	61.8	55.5	49.0	60.4	74.9	44.1					
		400 (122)	5 (1.5)	61.0	53.8	48.7	56.9	65.4	43.1					
	7	100 (30)	5 (1.5)	66.3	60.6	53.8	63.9	76.5	48.2	732	12	12	756	804
		100 (30)	10 (3.0)	65.6	58.9	50.3	62.7	75.1	44.9					
		200 (61)	5 (1.5)	60.3	54.4	47.9	57.7	71.0	45.4					
		200 (61)	10 (3.0)	62.3	56.7	50.0	60.0	74.1	45.9					
	8	100 (30)	5 (1.5)	68.3	62.7	56.5	65.8	78.3	52.6	780	36	30	846	972
		100 (30)	15 (4.6)	68.5	61.7	54.1	65.2	75.1	47.9					
		200 (61)	5 (1.5)	61.8	56.6	51.3	59.4	72.6	47.4					
		200 (61)	15 (4.6)	65.1	59.7	54.4	62.4	74.4	49.5					
	9	100 (30)	5 (1.5)	65.1	57.6	49.2	62.2	75.4	44.9	678	24	18	720	798
		100 (30)	20 (6.1)	68.5	62.3	55.9	65.0	74.9	48.7					
		200 (61)	5 (1.5)	62.1	56.3	50.8	59.8	74.9	46.2					
		200 (61)	20 (6.1)	65.9	60.1	54.6	62.8	76.2	50.0					
	10	200 (61)	5 (1.5)	64.1	59.3	55.1	61.0	70.3	50.0	906	54	18	978	1086
		200 (61)	10 (3.0)	63.3	57.9	53.1	60.0	70.5	47.4					
		200 (61)	15 (4.6)	65.9	60.6	55.4	62.6	72.6	48.7					
		200 (61)	20 (6.1)	66.7	60.8	55.4	63.1	73.8	46.7					
	11	100 (30)	5 (1.5)	69.1	64.0	58.6	66.2	76.8	53.1	1218	54	36	1308	1470
		100 (30)	10 (3.0)	69.7	63.7	57.7	66.5	76.9	50.3					
		100 (30)	15 (4.6)	70.0	63.9	57.9	66.6	76.4	49.2					
		100 (30)	20 (6.1)	71.8	65.3	60.0	67.9	76.9	51.3					

TABLE C2. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	HEIGHT (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
4-6-76	1	100[b] (30)	10 (3.0)	66.7	58.9	51.0	63.3	75.1	43.6	780	48	30	858	996
		100[a] (30)	5 (1.5)	65.9	56.6	45.9	62.1	76.2	41.5					
		100[a] (30)	10 (3.0)	68.5	60.4	48.7	65.4	76.9	43.1					
	2	100[b] (30)	5 (1.5)	68.5	58.9	51.2	64.8	79.2	41.7	648	54	36	738	900
		100[b] (30)	15 (4.6)	68.2	59.2	50.3	64.5	75.6	43.6					
		100[a] (30)	5 (1.5)	66.2	55.2	44.9	63.4	77.9	42.6					
		100[a] (30)	15 (4.6)	69.7	59.6	46.9	65.8	76.2	42.1					
	3	100[b] (30)	5 (1.5)	66.8	58.8	49.2	64.4	79.0	44.2	732	36	30	798	924
		100[a] (30)	5 (1.5)	63.3	54.8	45.6	61.6	76.2	40.5					
		100[a] (30)	20 (6.1)	69.7	62.0	53.6	65.8	75.4	42.8					
	4	100[b] (30)	5 (1.5)	66.5	59.0	48.1	64.4	80.1	42.4	948	24	24	996	1092
		100[b] (30)	10 (3.0)	64.9	57.9	47.2	62.4	75.1	42.8					
		100[a] (30)	5 (1.5)	63.3	55.7	46.2	61.0	75.6	41.8					
		100[a] (30)	10 (3.0)	67.4	59.9	50.5	64.2	75.6	43.3					
	5	50[b] (15)	5 (1.5)	69.7	61.4	52.7	67.5	84.4	42.3	1044	24	42	1110	1260
		100[b] (30)	5 (1.5)	65.6	57.6	49.0	62.8	74.9	43.1					
		50[a] (15)	5 (1.5)	71.3	62.4	53.1	67.1	76.4	43.8					
		100[a] (30)	5 (1.5)	65.4	58.3	50.0	63.1	75.9	43.3					
	6	50[b] (15)	5 (1.5)	69.4	59.5	48.8	65.9	80.5	43.3	762	54	42	858	1038
		200[b] (61)	5 (1.5)	61.5	53.4	45.6	58.2	70.8	43.1					
		50[a] (15)	5 (1.5)	69.5	59.1	46.7	65.6	75.4	43.1					
		200[a] (61)	5 (1.5)	58.5	49.7	42.1	54.8	65.9	37.7					
	7	50[b] (15)	5 (1.5)	67.6	60.0	52.3	64.4	78.8	45.9	1128	54	24	1206	1332
		300[b] (91)	5 (1.5)	58.2	50.6	44.6	54.6	65.4	39.2					
		50[a] (15)	5 (1.5)	68.5	59.3	52.6	65.7	81.0	51.0					
		300[a] (91)	5 (1.5)	49.7	44.2	38.7	48.4	64.9	35.4					
	8	50[b] (15)	5 (1.5)	69.0	58.6	44.5	66.0	81.5	40.1	1068	36	24	1128	1236
		400[b] (122)	5 (1.5)	52.8	46.1	39.2	48.8	60.0	36.7					
		50[a] (15)	5 (1.5)	70.0	59.2	47.7	65.7	75.6	42.1					
		400[a] (122)	5 (1.5)	47.9	43.3	39.2	45.2	56.4	35.4					
	9	100[b] (30)	5 (1.5)	65.4	57.9	49.0	61.8	73.7	42.3	900	30	12	942	1008
		200[b] (61)	5 (1.5)	57.9	51.4	44.9	54.6	66.7	43.1					
		100[a] (30)	5 (1.5)	63.6	54.5	45.4	59.4	74.4	42.1					
		200[a] (61)	5 (1.5)	55.4	49.0	43.3	51.8	64.6	40.3					
	10	400[b] (122)	5 (1.5)	49.5	46.2	43.8	47.0	46.2	43.8	No Data				
		200[a] (61)	5 (1.5)	54.9	48.3	42.6	51.3	64.4	38.2					
		400[a] (122)	5 (1.5)	50.0	46.1	42.8	47.2	57.9	38.2					
	11	200[b] (61)	5 (1.5)	58.8	52.0	44.7	56.6	70.6	40.3	804	25	18	847	926
		400[b] (122)	5 (1.5)	50.3	43.9	38.3	46.6	56.7	35.6					

[a] Ground cover was plowed field
[b] Ground cover was short grass

TABLE C3. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 8) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
10-13-76[a]	1	60(18)	66.2	57.8	49.7	64.2	82.8	45.6	576	42	12	630	708
		120(37)	60.0	54.6	48.5	60.1	81.8	45.6					
		240(73)	55.4	51.3	47.2	54.0	69.5	43.8					
	2	60(18)	65.4	57.0	49.2	62.2	77.7	43.1	546	48	16	600	666
		120(37)	59.5	53.5	47.9	56.2	68.7	44.6					
		240(73)	53.3	49.6	46.4	50.6	60.3	44.9					
	3	60(18)	66.2	55.9	47.4	63.2	82.8	43.1	570	24	6	600	642
		120(37)	59.2	52.7	47.2	57.5	78.5	43.1					
		240(73)	52.6	48.7	45.1	50.9	66.9	43.1					
	4	60(18)	64.1	54.6	46.4	61.8	80.0	43.3	444	18	0	462	480
		120(37)	56.9	51.6	46.2	55.4	71.5	43.8					
		240(73)	52.6	49.0	45.6	51.9	67.7	39.7					
	5	60(18)	66.7	57.4	49.2	62.8	77.4	43.6	582	36	12	630	702
		120(37)	60.3	53.8	47.9	56.9	70.8	39.7					
		240(73)	55.1	50.7	46.7	52.6	66.9	40.5					
	6	60(18)	66.7	57.5	48.7	62.9	78.7	44.9	546	72	0	618	690
		120(37)	60.0	53.8	47.4	57.0	68.5	42.8					
		240(73)	54.6	50.4	46.2	55.3	74.1	43.6					
10-13-76[b]	1	25(7.6)	71.3	63.8	57.7	67.3	79.7	53.6	696	36	36	768	912
		50(15)	65.6	61.2	56.9	62.9	74.4	52.3					
		100(30)	64.6	60.7	57.2	61.8	70.3	54.1					
	2	25(7.6)	72.1	63.6	56.7	68.0	82.8	52.1	714	12	12	737	785
		50(15)	65.4	59.8	55.4	62.0	74.4	51.0					
		100(30)	64.4	59.3	55.4	60.8	70.8	53.1					
	3	25(7.6)	70.3	62.2	56.2	66.2	79.5	53.3	624	24	0	648	672
		50(15)	64.4	59.1	54.4	61.1	73.8	47.4					
		100(30)	61.8	58.2	54.1	59.2	70.3	50.5					
	4	25(7.6)	71.0	62.6	56.2	67.5	85.4	51.8	546	48	24	618	738
		50(15)	66.2	60.3	55.4	63.5	80.5	53.3					
		100(30)	65.6	59.9	55.4	62.3	75.6	51.8					
	5	25(7.6)	70.3	63.0	56.7	67.1	82.3	51.8	720	30	0	750	780
		50(15)	64.9	59.8	55.6	62.6	80.3	48.2					
		100(30)	64.1	59.5	55.9	61.1	74.1	51.8					
	6	25(7.6)	70.3	62.8	56.9	66.2	77.9	52.3	792	30	18	840	924
		50(15)	64.4	59.6	55.4	61.4	74.4	51.3					
		100(30)	62.3	58.7	55.4	59.8	70.3	52.1					

[a] Ground cover was plowed field
[b] Ground cover was pavement

TABLE C4. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 9) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
10-23-76[a]	1	20(6.1)	76.4	71.2	65.9	73.4	87.4	59.0	1962	78	12	2052	2166
		40(12)	73.3	68.8	63.8	70.6	82.8	58.2					
		80(24)	72.8	68.2	63.6	70.4	85.1	56.9					
	2	20(6.1)	76.2	71.3	65.9	73.2	86.9	53.3	2070	60	12	2142	2238
		40(12)	73.1	69.0	64.6	70.6	82.6	52.1					
		80(24)	72.3	67.6	63.3	69.8	82.8	52.8					
	3	20(6.1)	76.7	71.4	65.4	73.6	85.4	58.5	2058	90	42	2180	2406
		40(12)	73.8	69.2	64.1	71.0	82.6	57.7					
		80(24)	73.3	68.6	63.3	70.6	83.6	56.7					
	4	15(4.6)	79.2	72.8	66.2	81.3	104.1	60.0	2068	66	12	2142	2244
		30(9.1)	79.7	73.9	68.2	76.6	90.5	61.8					
		60(18)	72.3	67.9	63.3	69.9	83.3	58.2					
	5	15(4.6)	78.7	72.9	66.9	75.3	87.2	56.9	2064	78	12	2154	2268
		30(9.1)	78.5	73.6	68.5	75.7	88.2	59.2					
		60(18)	72.3	67.9	63.3	69.2	78.5	56.9					

[a] Ground cover was pavement

APPENDIX D

EFFECT OF GROUND COVER ON NOISE LEVELS FOR VARIOUS OCTAVE BANDS (USING RANDOM NOISE GENERATOR)

TABLE D1. SUMMARY OF NOISE DATA ON SHORT GRASS

				NOISE LEVEL (dB)									
				DISTANCE (FEET) (M)									
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)	225(69)	250(76)
White Noise	A-Weighted	95	48.0	84.1	79.0	72.0	65.0	57.0	53.0	50.0			
	Linear	90	65.0	86.2	81.7	77.5	72.5						
	Octave Band Geometric Mean Frequency (Hertz)												
	63	95	61.0	79.0	73.5	70.2	68.0						
	125	95	61.0	82.7	77.0	74.2	70.5	72.0	69.7	68.0	66.0		
	250	95	48.0	84.1	79.0	74.5	72.0	72.0	69.5	66.5	66.0	63.3	61.5
Pink Noise	500	95	36.0	87.5	81.2	74.5	72.5	66.5	63.0	62.0	56.0	52.5	52.0
	1000	95	40.0	80.2	71.7	64.0	59.5	54.0	50.0				
	2000	95	38.0	86.6	77.5	71.0	63.0	60.0	51.0	48.0			
	4000	95	30.0	83.0	78.0	73.0	67.7	68.0	65.0	60.5			
	8000	95	30.0	77.5	71.5	65.5	59.7						

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D2. SUMMARY OF NOISE DATA ON PAVEMENT

		NOISE LEVEL (dB)									
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White	A-Weighted	95	51.5	83.8	78.3	74.5	72.0	72.0	70.0	65.5	63.0
Noise	Linear	90	62.0	82.3	75.0	73.5	70.5	70.0	68.5	66.0	65.0
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	60.5	79.5	77.5	70.0	67.0	68.0	66.0	64.0	
	125	95	58.0	82.5	76.0	72.5	67.5	70.5	68.5	67.0	66.0
	250	95	52.0	85.0	78.8	75.5	72.0	73.0	71.0	69.0	67.5
Pink	500	95	47.5	87.7	81.7	78.0	73.3	73.5	72.5	70.0	67.0
Noise	1000	95	45.0	84.3	79.0	73.5	70.3	72.5	70.0	69.5	67.0
	2000	95	40.0	80.7	80.5	77.5	73.7	76.0	74.0	72.0	70.0
	4000	95	35.5	81.0	71.8	67.0	64.0	70.0	68.0	63.0	58.0
	8000	95	32.5	86.5	77.3	68.0	63.0	67.0	64.5	63.0	56.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D3. SUMMARY OF NOISE DATA ON HIGH WEEDS

		NOISE LEVEL (dB)					
				DISTANCE (FEET) (M)			
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)
White Noise	A-Weighted	95	45.0	80.0	70.0	61.0	56.5
	Linear	90	57.0	72.0	65.0		
	Octave Band Geometric Mean Frequency (Hertz)						
Pink Noise	63	95	49.0	78.5	72.0	69.0	66.0
	125	95	54.0	79.0	73.5	70.0	67.5
	250	95	42.0	84.0	76.5	74.0	70.5
	500	95	34.0	80.5	72.0	66.0	62.0
	1000	95	34.0	77.5	70.5	63.0	57.5
	2000	95	33.0	81.5	73.0	61.0	57.5
	4000	95	26.0	80.0	69.5	58.0	53.5
	8000	95	42.0	74.5	56.0	53.0	44.5

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D4. SUMMARY OF NOISE DATA ON GRAVEL

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	49	83.5	78.0	74.0	70.0				
	Linear	90	64	79.0	74.0	72.0	70.0	68.5	67.0	65.0	63.0
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	63	79.5	75.5	71.5	68.5	66.0	64.5	63.0	
	125	95	58	81.7	76.2	72.5	70.0	68.0	65.0	63.5	62.0
	250	95	49	87.0	82.0	78.0	75.0	74.5	72.5	70.5	68.5
Pink Noise	500	95	46	86.0	81.0	76.2	73.5	72.0	70.5	68.0	66.0
	1000	95	42	81.5	76.0	71.5	66.5	61.0	59.0	57.5	56.0
	2000	95	37	87.0	79.0	71.2	66.7	68.0	62.0	59.0	55.0
	4000	95	35	81.5	77.5	74.5	70.0	70.5	66.0	62.0	58.0
	8000	95	37	83.5	76.5	71.0	66.5	68.0	62.0	55.0	47.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D5. SUMMARY OF NOISE DATA ON HIGH GRASS

		NOISE LEVEL (dB)									
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	46.0	82.5	75.0	69.0	64.0	63.0	61.0	58.0	57.0
	Linear	90	66.0	79.0	73.0	72.0	70.0	68.0	66.0		
	Octave Band Geometric Mean Frequency (Hertz)										
Pink Noise	63	95	59.0	81.0	76.0	72.0	70.0	69.0	67.0	65.0	64.0
	125	95	60.0	83.0	78.0	74.0	72.0	70.0	69.0	68.0	66.0
	250	95	45.0	86.0	81.0	76.0	74.0	70.0	69.0	66.0	64.0
	500	95	41.0	83.5	73.5	67.0	61.5	52.0	50.0		
	1000	95	41.0	76.0	67.0	63.0	60.0	59.0	57.0	52.0	50.0
	2000	95	38.0	86.0	78.5	74.4	70.0	69.0	65.0	63.0	59.0
	4000	95	31.0	80.5	74.0	67.5	59.5	62.0	57.0	55.0	52.0
	8000	95	31.0	83.0	75.5	69.0	60.5	64.0	59.0	55.0	53.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D6. SUMMARY OF NOISE DATA ON MEDIUM GRASS

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	45.0	83.3	78.7	72.7	65.7	58.5	54.5	51.5	50.0
	Linear	90	63.0	80.0	76.0	71.5	67.0	64.0	58.0		
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	57.0	80.5	74.5	71.0	68.0	66.0	63.7	62.0	60.0
	125	95	53.5	81.0	74.5	71.0	69.0	66.5	64.7	63.2	62.0
	250	95	45.0	84.0	77.5	73.2	70.0	67.7	66.2	63.5	67.0
Pink Noise	500	95	38.0	83.2	77.0	71.2	66.5	62.0	59.0	56.0	54.5
	1000	95	36.0	78.2	70.5	66.0	61.0	55.5	52.5	50.0	47.5
	2000	95	29.5	87.2	78.0	69.7	64.8	61.0	55.5	50.5	46.5
	4000	95	29.5	86.5	82.5	74.5	67.0	59.0	54.0	50.0	46.0
	8000	95	34.5	81.0	76.0	68.7	61.7	56.5	52.0	52.0	45.0

[a] The reference noise was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D7. SUMMARY OF NOISE DATA ON PLOWED FIELD

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	42.0	82.5	77.7	72.2	67.7	64.0	58.5	55.5	54.0
	Linear	90	63.5	79.2	74.7	71.5	68.0				
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	52.0	80.0	74.0	70.0	67.0	65.0	62.5		
	125	95	49.5	80.4	73.2	69.0	65.7	62.5	61.5		
	250	95	35.5	79.7	73.2	67.5	63.7	60.0	57.0		
Pink Noise	500	95	30.0	78.2	69.7	63.6	58.2	53.5	51.0	48.0	41.5
	1000	95	34.5	81.7	74.3	68.7	64.3	60.5	57.5	54.5	53.5
	2000	95	33.0	86.7	80.3	75.3	69.3	64.5	61.5	60.0	
	4000	95	25.5	82.3	77.3	72.0	67.3	63.0	59.0	55.5	52.5
	8000	95	35.5	82.7	76.0	69.0	63.0	58.0	55.2	52.0	50.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D8. SUMMARY OF NOISE DATA ON SNOW

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25 (7.6)	50 (15)	75 (23)	100 (30)	125 (38)	150 (46)	175 (53)	200 (61)
White	A-Weighted	95	48.5	82.2	76.0	71.7	67.5				
Noise	Linear	90	68.0	85.0	80.0	76.0	74.0				
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	65.0	80.0	74.0	70.5	68.0				
	125	95	60.0	79.0	73.0	67.0	63.0				
	250	95	48.5	76.0	66.5	59.5	57.0				
Pink	500	95	44.0	72.5	63.5	55.5	55.0	52.0			
Noise	1000	95	44.0	82.0	73.0	66.5	62.5	60.0	58.0	56.0	55.0
	2000	95	39.5	86.5	80.5	74.5	69.0	65.5	63.0	61.0	59.5
	4000	95	34.5	80.5	75.0	71.5	66.5	62.5	61.0	58.5	55.5
	8000	95	32.0	83.0	78.0	71.0	66.5	65.0	63.0	59.0	54.5

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

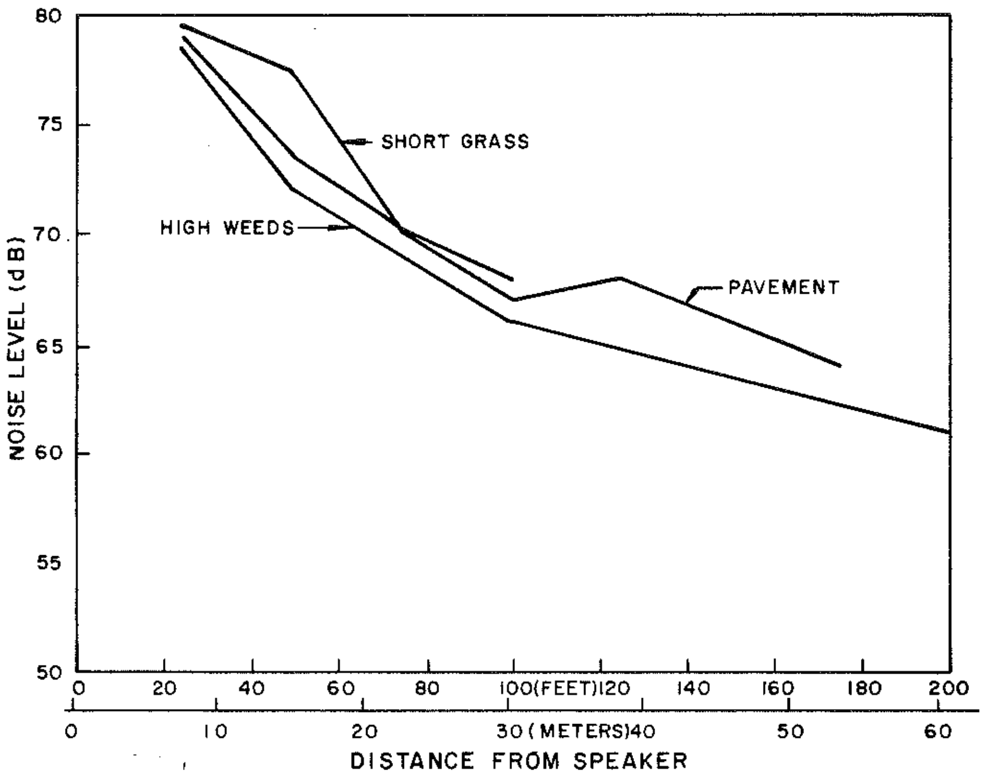

Figure D1. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (63 Hz Center Frequency) for Various Distances.

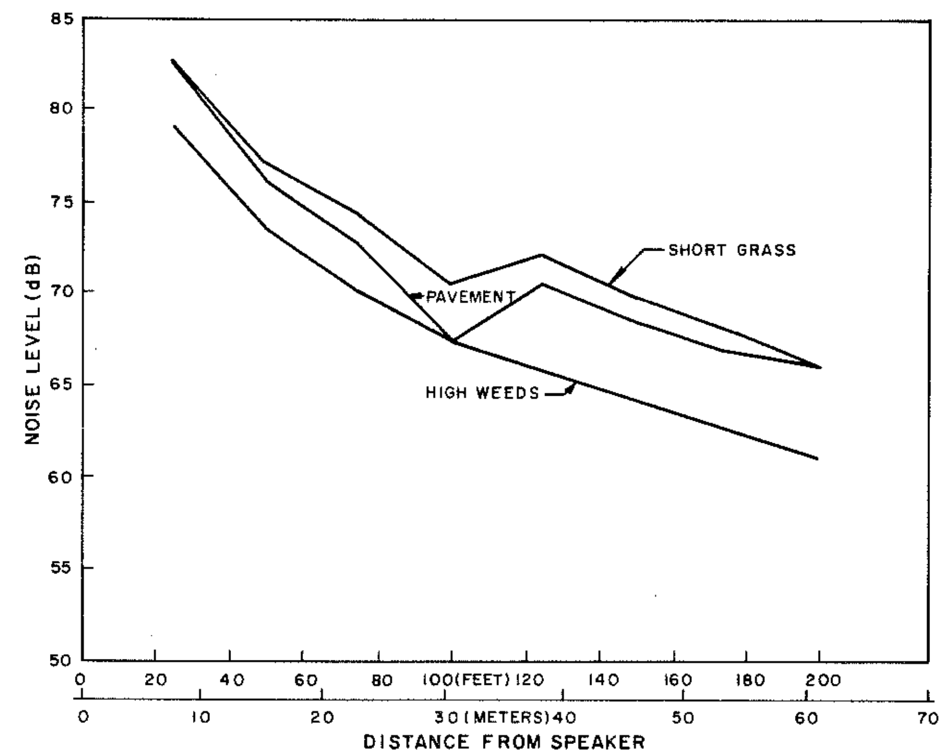

Figure D2. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (125 Hz Center Frequency) for Various Distances.

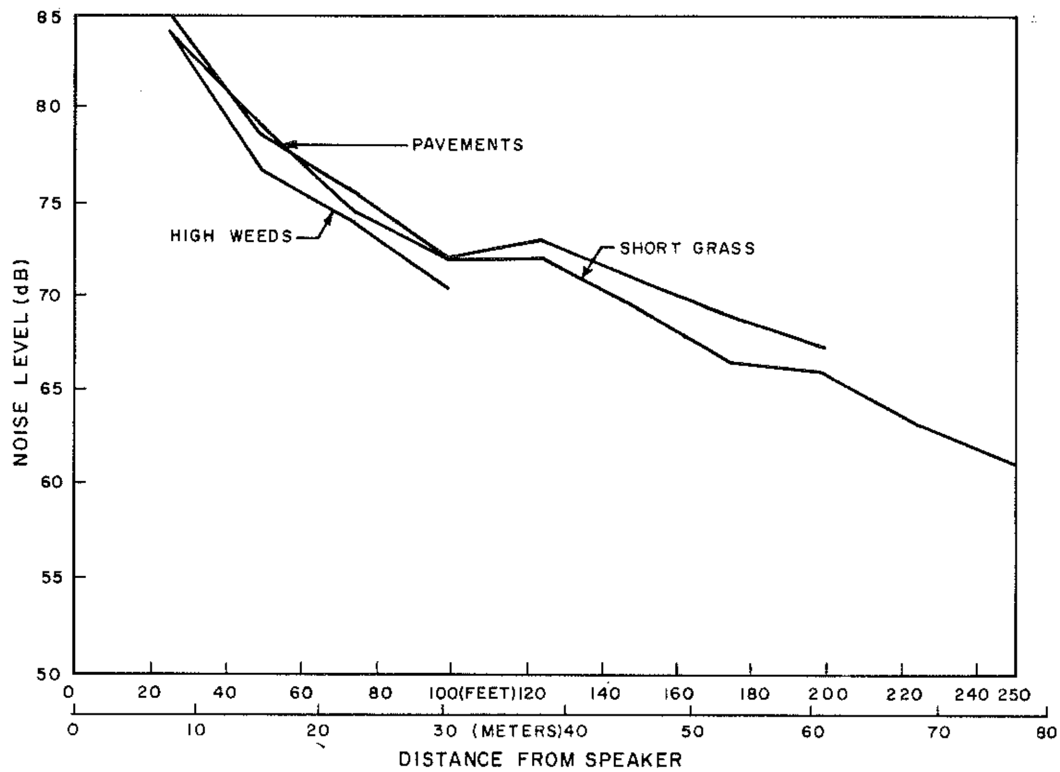

Figure D3. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (250 Hz Center Frequency) for Various Distances.

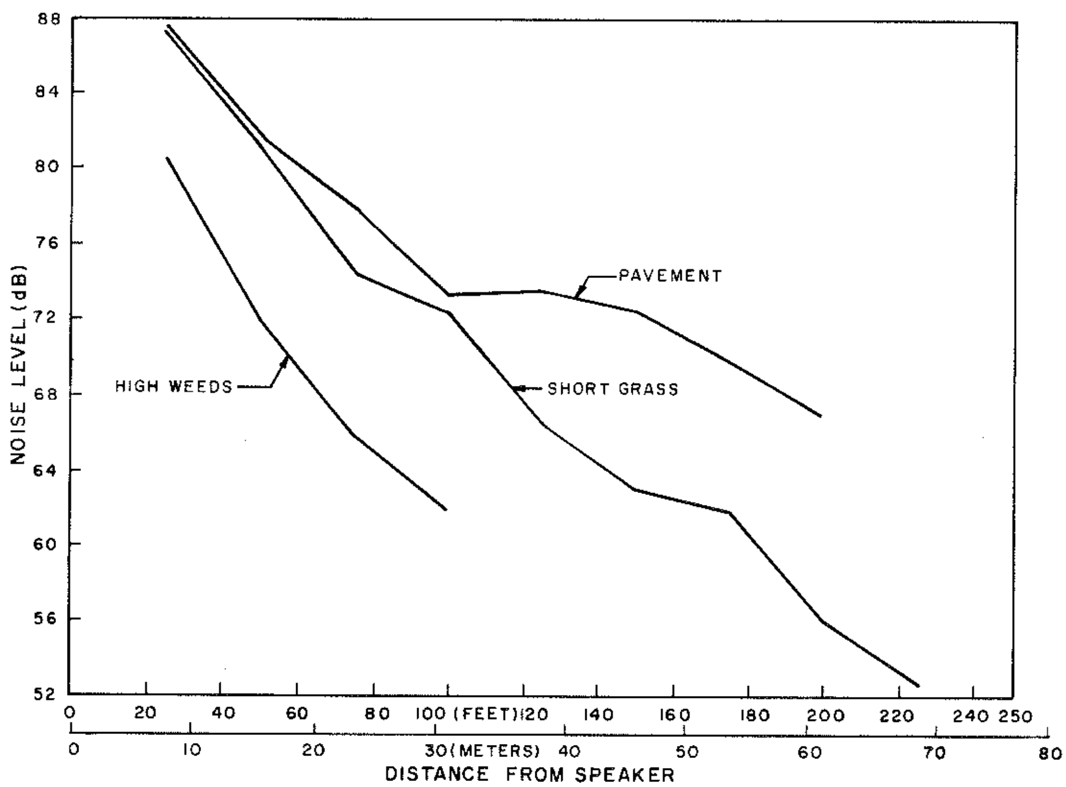

Figure D4. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (500 Hz Center Frequency) for Various Distances.

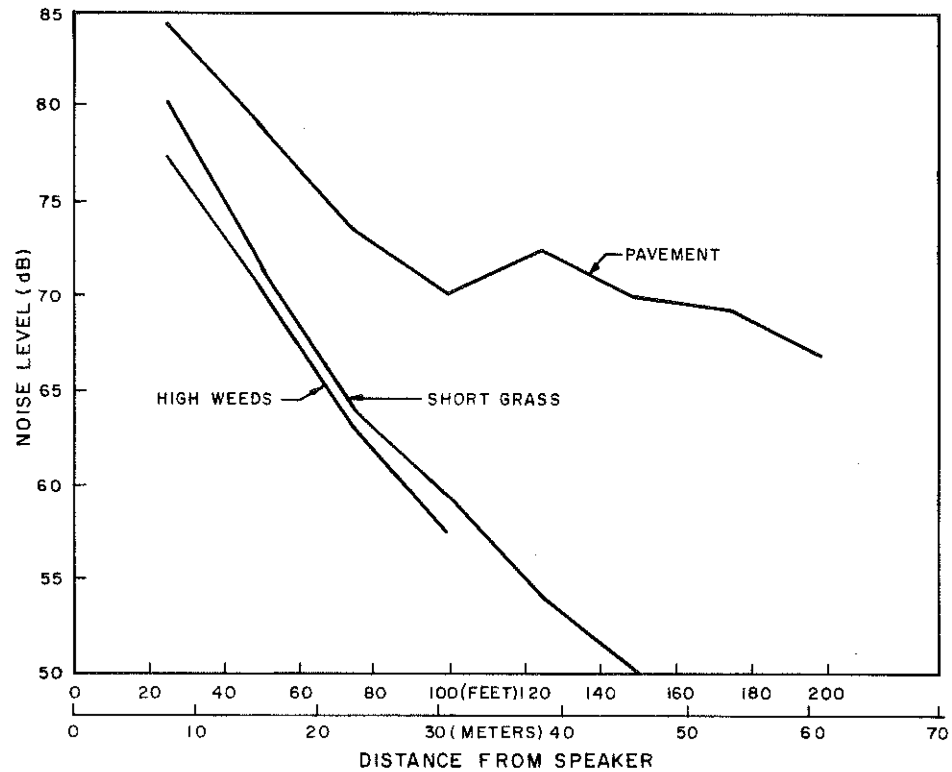

Figure D5. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (1,000 Hz Center Frequency) for Various Distances.

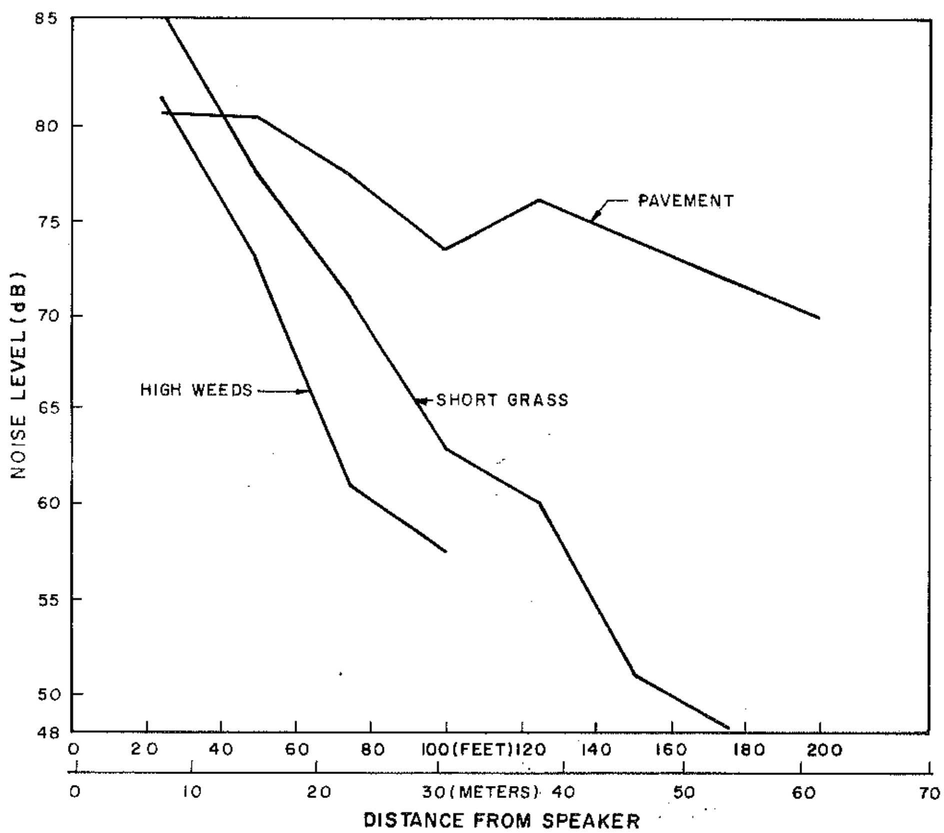

Figure D6. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (2,000 Hz Center Frequnecy) for Various Distances.

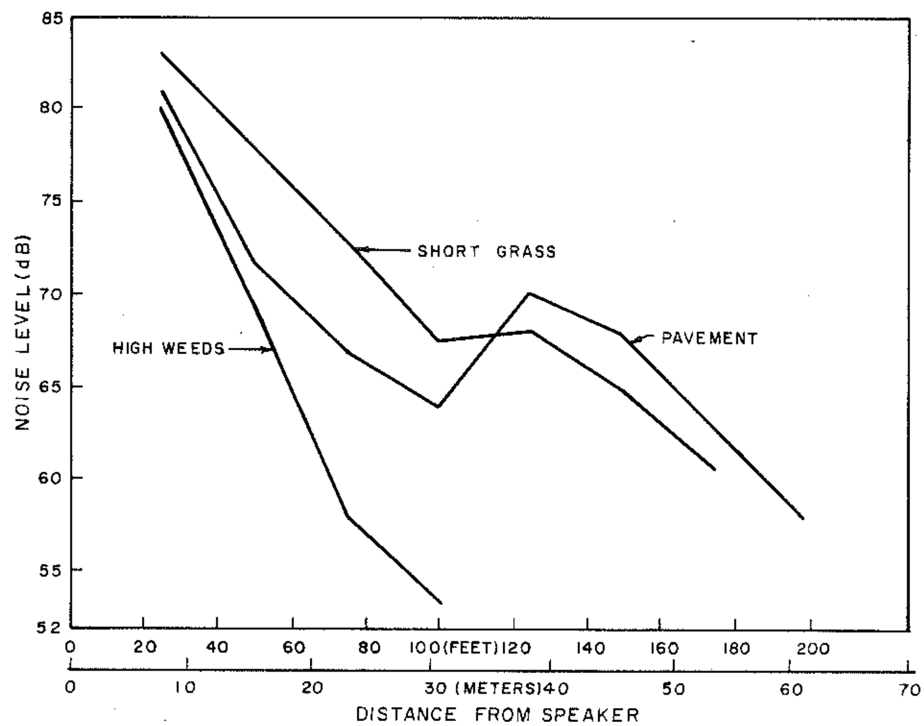

Figure D7. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (4,000 Hz Center Frequency) for Various Distances.

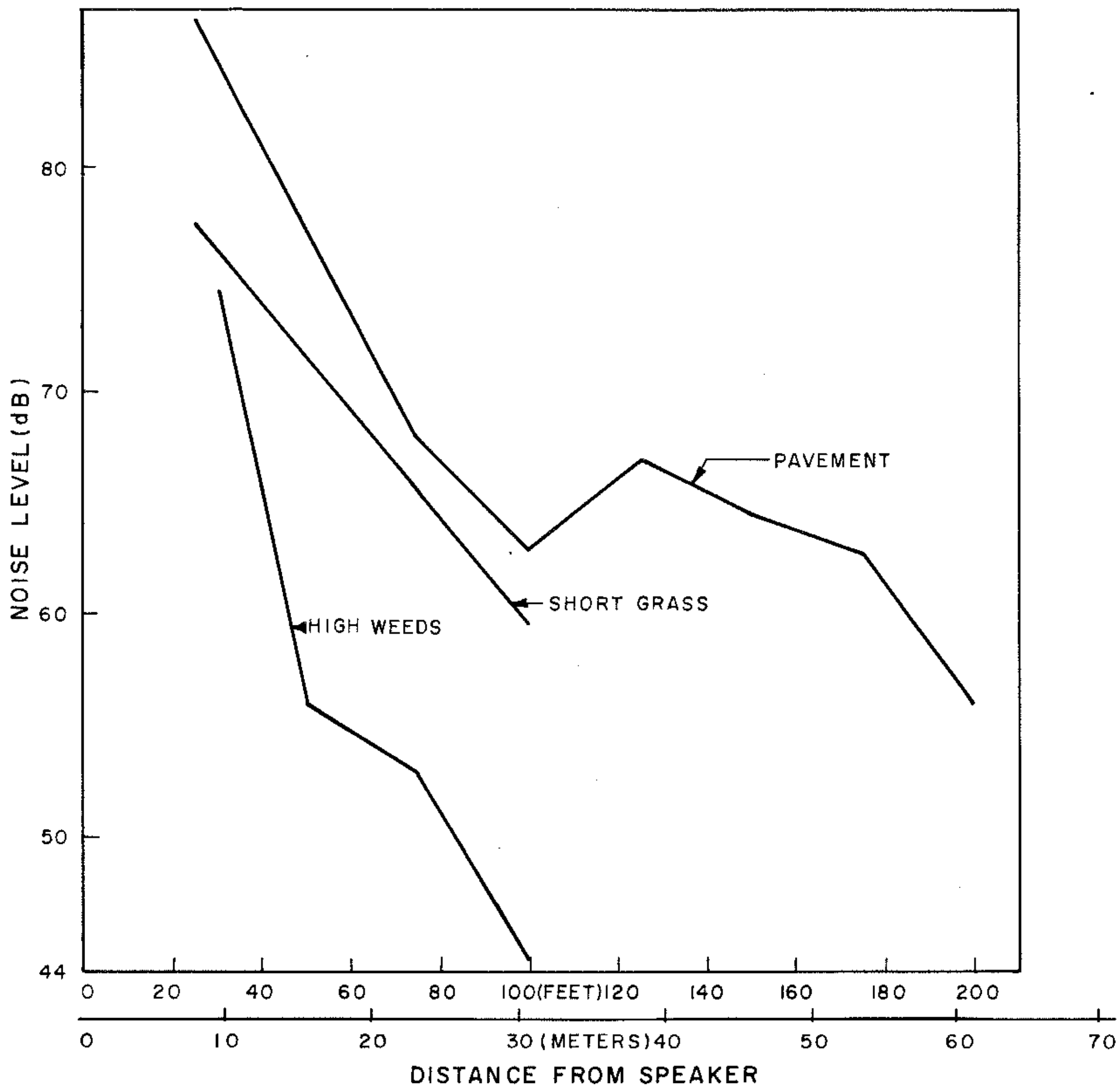

Figure D8. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (8000 Hz Center Frequency) for Various Distances.

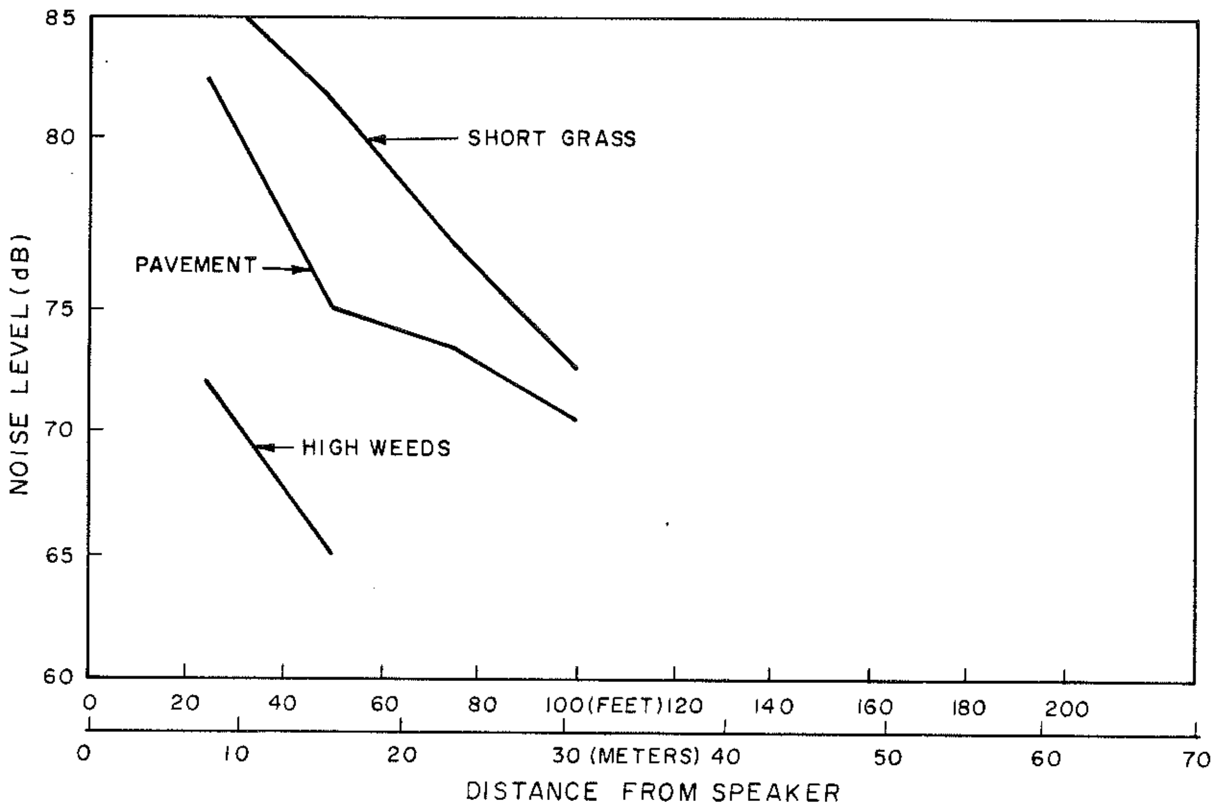

Figure D9. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (Unweighted (Linear) Noise) for Various Distances.

APPENDIX E

NOISE OVER SHORT GRASS COMPARED TO OTHER GROUND COVERS FOR VARIOUS FREQUENCIES

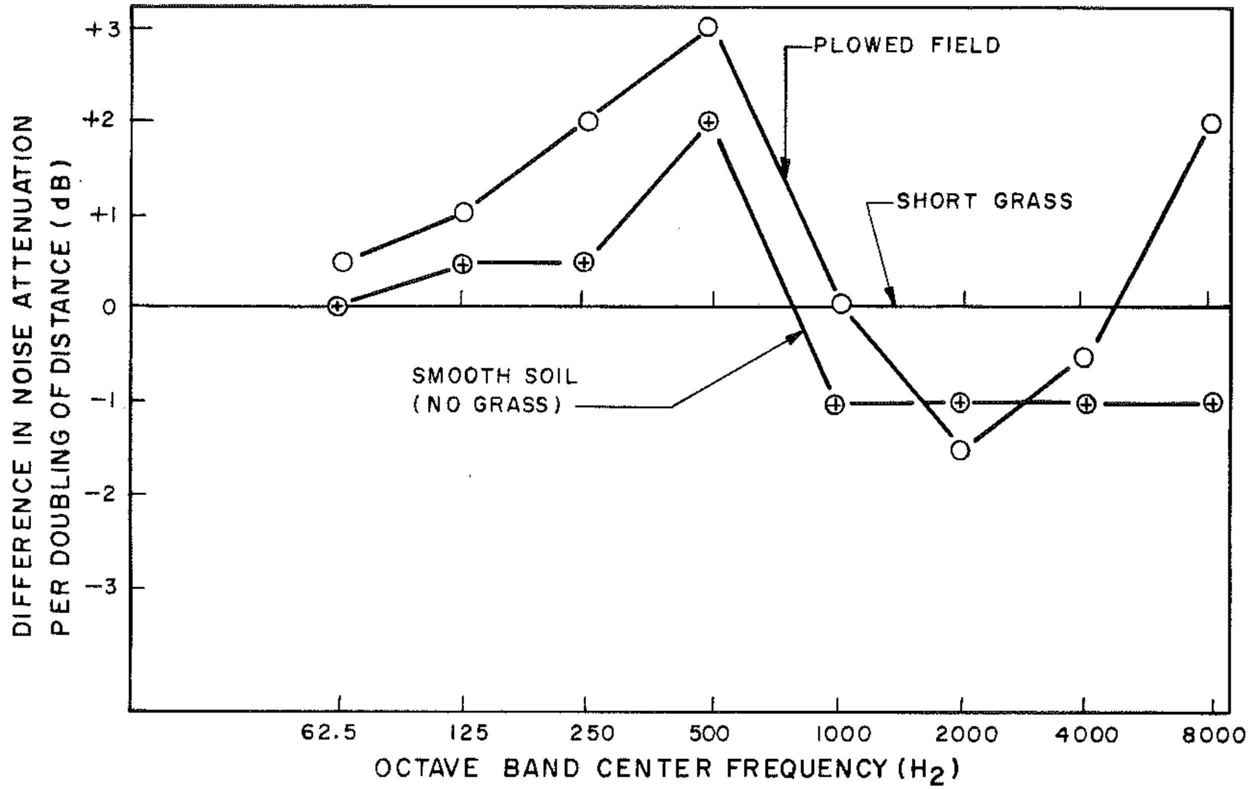

Figure E1. Noise Attenuation per Doubling of Distance over Short Grass Compared to Plowed Field and Smooth Ground for Various Frequencies.

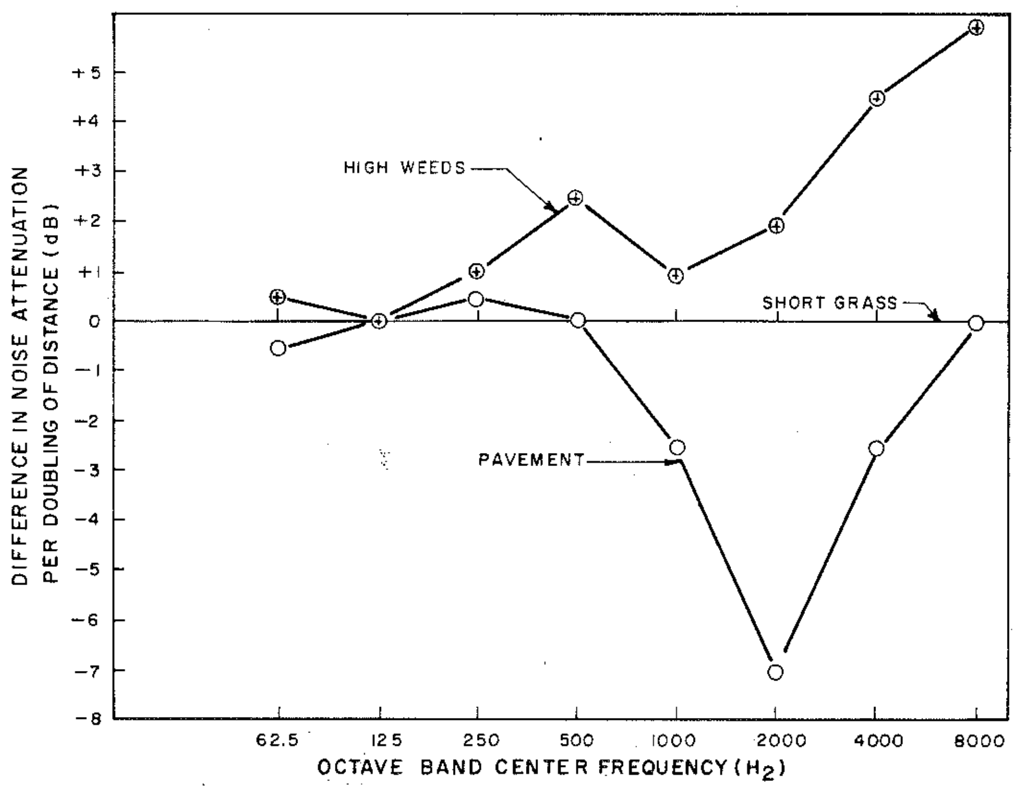

Figure E2. Noise Attenuation per Doubling of Distance over Short Grass Compared to Pavement and High Weeds for Various Frequencies.

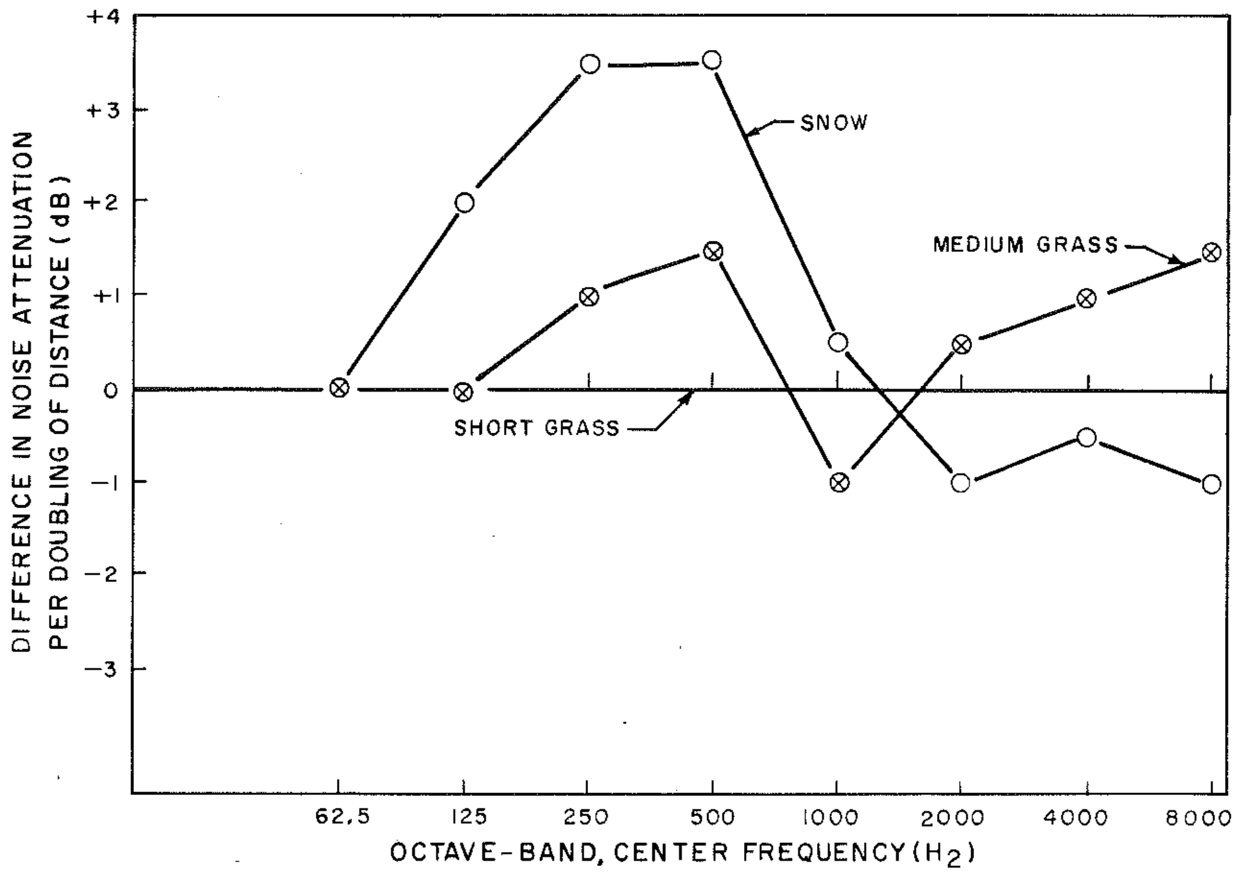

Figure E3. Noise Attenuation per Doubling of Distance over Short Grass Compared to Snow and Medium Grass for Various Frequencies.

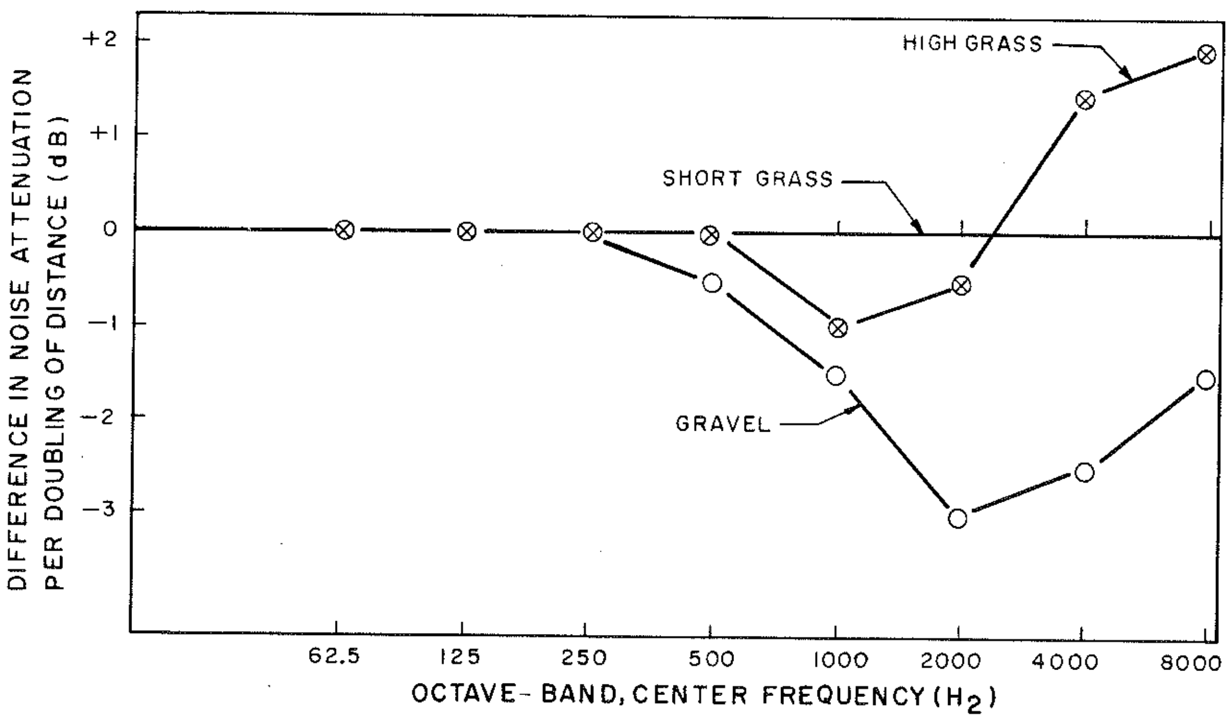

Figure E4. Noise Attenuation per Doubling of Distance over Short Grass Compared to High Grass and Gravel for Various Frequencies.

APPENDIX F

TRAFFIC STREAM NOISE DATA TAKEN AT
DIFFERENT RECEIVER HEIGHTS (SHORT GRASS)

TABLE F1. TRAFFIC STREAM NOISE DATA SUMMARY FOR VARIOUS RECEIVER HEIGHTS (SITE 1)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET)	(M)	HEIGHT (FEET)	(M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
2-24-76	6	100	(30)	5	(1.5)	65.9	62.2	58.5	63.4	72.8	53.8	2394	24	18	2436	2514
		100	(30)	10	(3.0)	67.7	64.2	60.8	65.2	73.3	53.8					
		200	(61)	10	(3.0)	63.6	60.1	56.9	60.8	65.4	53.8					
	7	100	(30)	5	(1.5)	65.9	62.5	59.0	63.8	75.9	53.6	2244	36	6	2286	2340
		100	(30)	15	(4.6)	65.9	66.1	62.3	67.2	75.9	54.9					
		200	(61)	15	(4.6)	64.1	60.9	57.7	61.5	65.1	53.3					
	8	100	(30)	5	(1.5)	65.4	62.3	59.0	63.0	69.5	55.4	2322	72	0	2394	2466
		100	(30)	20	(6.1)	70.3	67.3	63.8	67.9	73.3	61.3					
		200	(61)	20	(6.1)	64.6	62.2	59.5	62.6	65.6	57.4					
	9	200	(61)	10	(3.0)	63.1	60.3	57.2	60.9	68.2	51.0	2328	78	0	2406	2484
		200	(61)	15	(4.6)	63.7	61.6	59.2	61.9	66.8	54.7					
		200	(61)	20	(6.1)	63.8	61.1	58.5	61.7	71.0	51.0					
	10	100	(30)	10	(3.0)	67.4	64.0	60.3	64.8	72.3	55.9	1998	102	12	2112	2250
		100	(30)	15	(4.6)	68.7	64.9	60.5	65.9	73.1	54.6					
		100	(30)	20	(6.1)	70.0	66.3	62.1	67.3	74.4	54.9					
	11	100	(30)	10	(3.0)	66.2	63.4	60.0	64.0	70.5	56.7	2328	60	0	2388	2448
		100	(30)	15	(4.6)	68.5	65.2	61.3	66.0	73.6	55.6					
		100	(30)	20	(6.1)	71.8	65.3	60.0	67.9	76.9	51.3					
	12	50	(15)	10	(3.0)	71.3	68.0	63.1	69.1	80.5	57.2	2484	66	18	2568	2688
		50	(15)	15	(4.6)	72.6	69.2	64.4	70.4	82.1	56.4					
		50	(15)	20	(6.1)	72.8	69.5	64.6	70.7	82.8	57.4					
6-29-76	1	100	(30)	5	(1.5)	63.3	59.4	54.9	60.7	68.7	45.1	2172	66	6	2244	2328
		100	(30)	10	(3.0)	65.1	61.7	57.7	62.9	71.5	46.7					
	2	100	(30)	5	(1.5)	64.1	60.6	56.4	61.6	69.7	53.8	2100	42	12	2154	2232
		100	(30)	15	(4.6)	67.2	64.0	59.7	65.0	74.9	56.2					
	3	100	(30)	5	(1.5)	64.6	61.0	56.9	62.1	70.5	52.8	2316	48	6	2370	2436
		100	(30)	20	(6.1)	68.7	65.1	61.3	66.0	71.8	55.4					
		200	(61)	20	(6.1)	65.1	61.5	57.9	62.4	68.7	53.8					
	4	200	(61)	10	(3.0)	61.5	58.2	53.6	59.3	67.9	49.7	2400	24	12	2436	2496
		200	(61)	15	(4.6)	63.8	61.0	57.7	61.5	70.3	54.1					
		200	(61)	20	(6.1)	64.1	61.7	59.0	62.3	70.0	54.9					
	5	200	(61)	10	(3.0)	61.5	58.8	55.6	59.4	64.9	50.8	2526	48	0	2574	2622
		200	(61)	15	(4.6)	63.8	61.4	58.7	61.8	66.2	55.4					
		200	(61)	20	(6.1)	63.6	60.9	58.2	61.3	66.7	54.1					
7-19-77	1	25	(7.6)	5	(1.5)	75.8	70.4	63.8	72.7	84.0	53.3	1920	42	6	1968	2028
		25	(7.6)	10	(3.0)	76.4	70.6	63.6	73.1	83.6	52.3					
		25	(7.6)	20	(6.1)	75.1	69.9	63.8	72.0	82.8	54.4					
		25	(7.6)	30	(9.1)	76.2	71.0	66.7	72.8	83.1	57.9					
	2	25	(7.6)	5	(1.5)	74.7	68.7	59.0	71.6	83.3	49.5	2142	60	0	2202	2362
		25	(7.6)	10	(3.0)	74.9	69.0	60.8	71.6	83.1	49.5					
		25	(7.6)	20	(6.1)	73.8	68.8	61.5	70.8	81.8	51.0					
		25	(7.6)	30	(9.1)	75.1	69.9	63.8	71.8	81.5	53.6					
	3	25	(7.6)	5	(1.5)	74.7	69.3	61.2	71.9	84.4	50.9	2916	54	6	2976	3048
		25	(7.6)	10	(3.0)	75.1	69.6	61.3	72.0	83.3	51.0					
		25	(7.6)	20	(6.1)	74.4	69.3	62.3	71.5	83.1	53.8					
		25	(7.6)	30	(9.1)	75.1	70.6	65.9	72.3	83.8	57.4					
	4	50	(15)	5	(1.5)	69.4	64.7	58.6	66.9	80.6	50.6	2034	36	18	2088	2178
		50	(15)	10	(3.0)	70.8	66.2	60.0	68.4	81.5	51.0					
		50	(15)	20	(6.1)	71.8	67.7	62.3	69.4	80.0	54.6					
		50	(15)	30	(9.1)	71.8	69.7	66.2	71.1	82.8	58.5					
	5	50	(15)	5	(1.5)	68.1	64.3	60.1	65.5	74.2	52.6	1884	54	18	1956	2064
		50	(15)	10	(3.0)	70.5	66.5	62.3	67.7	75.1	53.6					
		50	(15)	20	(6.1)	71.3	67.6	63.6	68.6	75.6	56.4					
		50	(15)	30	(9.1)	71.5	69.6	67.2	70.0	77.7	59.7					
	6	50	(15)	5	(1.5)	68.5	65.0	60.6	66.5	79.4	54.7	2370	54	6	2430	2502
		50	(15)	10	(3.0)	71.0	67.1	62.6	68.4	79.2	55.6					
		50	(15)	20	(6.1)	71.3	68.0	64.1	69.0	80.3	59.5					
		50	(15)	30	(9.1)	71.8	70.0	66.9	70.7	81.5	63.8					
	7	100	(30)	5	(1.5)	65.8	62.3	58.7	63.3	72.1	52.4	3336	84	18	3438	3576
		100	(30)	10	(3.0)	67.9	64.7	61.3	65.7	74.4	53.3					
		100	(30)	20	(6.1)	67.7	64.5	61.3	65.4	76.2	52.6					
		100	(30)	30	(9.1)	70.3	68.0	65.4	68.5	76.4	57.9					
	8	100	(30)	5	(1.5)	65.3	61.7	57.6	62.7	71.9	52.9	2610	48	0	2658	2706
		100	(30)	10	(3.0)	67.4	63.9	59.7	64.9	72.8	53.3					
		100	(30)	20	(6.1)	67.2	63.9	60.0	64.7	71.0	53.1					
		100	(30)	30	(9.1)	70.0	67.5	64.6	68.0	75.6	58.7					
	9	100	(30)	5	(1.5)	65.1	62.0	58.7	62.7	69.0	55.6	2712	54	6	2772	2844
		100	(30)	10	(3.0)	66.7	63.1	59.2	63.9	69.2	55.6					
		100	(30)	20	(6.1)	68.5	65.4	61.3	----	----	56.7					
		100	(30)	30	(9.1)	69.7	67.4	64.6	67.7	71.5	62.1					
	10	100	(30)	5	(1.5)	66.4	62.1	56.5	64.2	79.1	50.9	1986	30	12	2028	2094
		100	(30)	10	(3.0)	67.7	63.3	57.9	65.4	79.5	52.1					
		100	(30)	20	(6.1)	68.7	64.5	59.2	66.6	81.3	52.8					
		100	(30)	30	(9.1)	70.0	66.7	62.3	68.2	82.8	56.4					

TABLE F1. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET)	(M)	HEIGHT (FEET)	(M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
	11	200	(61)	5	(1.5)	63.1	59.4	55.6	60.6	72.7	51.0	2094	60	18	2172	2286
		200	(61)	10	(3.0)	60.8	57.5	53.8	58.6	70.5	47.4					
		200	(61)	20	(6.1)	64.9	61.7	57.9	62.6	71.8	51.5					
		200	(61)	30	(9.1)	66.9	64.4	61.0	65.0	72.6	54.1					
	12	200	(61)	5	(1.5)	62.7	59.2	55.6	60.0	66.3	52.4	1908	54	12	1974	2064
		200	(61)	10	(3.0)	60.8	58.1	54.4	58.8	65.4	51.0					
		200	(61)	20	(6.1)	65.4	62.4	58.7	63.2	70.8	54.9					
		200	(61)	30	(9.1)	67.2	64.7	61.5	65.2	71.3	67.2					
	13	200	(61)	5	(1.5)	62.6	58.9	55.4	60.0	68.6	51.7	2064	54	18	2136	2244
		200	(61)	10	(3.0)	61.5	57.9	54.4	59.0	66.7	----					
		200	(61)	20	(6.1)	66.4	62.6	58.5	63.8	70.8	----					
		200	(61)	30	(9.1)	68.7	65.2	61.8	66.0	72.1	----					
7-28-78	1	400	(122)	10	(3.0)	56.4	52.7	49.5	54.6	67.7	45.9	1776	60	6	1842	1920
		400	(122)	20	(6.1)	58.7	55.5	53.6	57.5	74.1	49.5					
		400	(122)	30	(9.1)	61.0	57.7	54.1	59.8	73.8	52.1					
	2	400	(122)	10	(3.0)	53.6	50.8	48.2	52.0	67.7	46.7	1608	30	0	1638	1668
		400	(122)	20	(6.1)	58.7	55.6	52.6	59.8	82.3	50.3					
		400	(122)	30	(9.1)	60.8	58.0	54.9	59.6	74.4	52.6					
	3	400	(122)	10	(3.0)	55.6	52.0	48.7	52.9	61.5	46.2	1740	78	6	1824	1932
		400	(122)	30	(9.1)	62.3	58.2	53.6	59.4	67.2	48.5					
	4	400	(122)	5	(1.5)	54.0	50.9	47.1	51.7	59.1	45.2	1812	48	12	1872	1956
		400	(122)	20	(6.1)	57.4	54.5	51.0	55.3	62.6	46.7					
		400	(122)	30	(9.1)	59.2	56.0	52.8	56.8	63.3	48.2					
	5	200	(61)	5	(1.5)	60.4	56.7	53.2	57.7	64.7	46.5	2472	66	12	2550	2642
		200	(61)	10	(3.0)	61.0	58.2	54.9	58.9	66.2	48.5					
		200	(61)	20	(6.1)	62.6	58.9	54.9	59.9	66.9	47.4					
		200	(61)	30	(9.1)	64.4	60.7	56.4	61.7	68.5	51.5					
	6	200	(61)	5	(1.5)	58.3	56.2	53.8	56.6	61.7	50.1	2268	54	0	2322	2376
		200	(61)	10	(3.0)	60.5	58.1	56.2	58.6	65.4	52.8					
		200	(61)	20	(6.1)	60.3	58.0	55.6	58.4	64.6	48.5					
		200	(61)	30	(9.1)	61.5	59.2	56.2	59.7	66.4	49.5					
	7	100	(30)	5	(1.5)	65.0	61.3	58.1	62.5	71.7	52.6	2232	60	12	2304	2400
		100	(30)	10	(3.0)	67.2	63.3	59.7	64.5	73.3	53.6					
		100	(30)	20	(6.1)	67.2	63.6	60.0	64.9	75.1	56.2					
		100	(30)	30	(9.1)	68.2	64.5	61.0	65.7	74.6	55.9					
	8	100	(30)	5	(1.5)	63.8	60.4	56.8	61.4	69.2	52.6	2208	30	0	2238	2268
		100	(30)	10	(3.0)	64.6	61.1	57.9	62.0	71.0	54.6					
		100	(30)	20	(6.1)	66.4	63.1	59.5	64.0	72.3	56.4					
		100	(30)	30	(9.1)	67.4	63.7	59.2	65.2	76.2	52.8					
	9	50	(15)	5	(1.5)	65.0	60.0	54.2	62.1	72.7	48.7	2154	78	0	2232	2310
		50	(15)	10	(3.0)	67.9	64.6	60.5	65.6	72.8	52.1					
		50	(15)	20	(6.1)	70.0	65.6	60.3	67.8	83.1	51.0					
		50	(15)	30	(9.1)	70.8	66.2	61.0	68.4	82.3	53.6					
	10	50	(15)	5	(1.5)	68.2	63.2	57.4	65.4	78.5	48.5	1800	60	0	1860	1920
		50	(15)	10	(3.0)	67.7	64.2	60.0	65.2	73.3	52.8					
		50	(15)	20	(6.1)	72.1	66.1	60.0	68.4	79.2	53.8					
		50	(15)	30	(9.1)	71.3	67.0	61.3	68.7	80.8	55.4					
	11	25	(7.6)	5	(1.5)	72.7	67.7	61.2	70.3	83.7	53.8	1872	60	0	1932	2052
		25	(7.6)	10	(3.0)	73.3	67.8	62.6	70.1	85.1	54.1					
		25	(7.6)	20	(6.1)	72.3	67.9	62.3	70.1	82.1	52.8					
		25	(7.6)	30	(9.1)	72.6	68.2	62.6	70.3	83.1	53.6					
	12	25	(7.6)	5	(1.5)	72.1	66.7	60.4	69.1	79.7	49.5	1980	36	6	2022	2076
		25	(7.6)	10	(3.0)	73.1	68.9	64.1	70.6	86.7	55.4					
		25	(7.6)	20	(6.1)	72.3	67.5	62.3	69.5	81.3	52.8					
		25	(7.6)	30	(9.1)	72.1	67.4	62.6	69.1	79.5	53.6					

TABLE F2. TRAFFIC STREAM NOISE DATA SUMMARY FOR VARIOUS RECEIVER HEIGHTS (SITE 3)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET)	(M)	HEIGHT (FEET)	(M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
8-5-76	5	125	(38)	5	(1.5)	77.9	70.8	64.1	73.5	82.8	57.2	2010	114	246	2370	3222
		125	(38)	10	(3.0)	78.5	72.1	66.2	74.6	83.8	59.7					
		125	(38)	15	(4.6)	80.3	73.3	67.2	76.2	85.6	61.3					
	6	125	(38)	5	(1.5)	77.2	71.1	64.9	73.5	82.8	55.4	2370	78	276	2724	3630
		125	(38)	10	(3.0)	79.0	73.3	67.4	75.3	83.6	59.7					
		125	(38)	20	(6.1)	80.3	73.4	67.4	76.2	85.6	45.9					
	7	250	(76)	5	(1.5)	73.6	68.3	63.3	70.3	80.0	56.7	2052	144	258	2454	3372
		250	(76)	10	(3.0)	75.1	69.2	63.3	71.2	80.5	58.5					
	8	250	(76)	5	(1.5)	73.3	69.4	65.1	70.9	83.1	60.3	2142	108	288	2538	3510
		250	(76)	10	(3.0)	73.8	69.2	64.9	70.6	81.0	60.3					
		250	(76)	15	(4.6)	75.4	70.8	66.9	72.1	80.8	64.4					
	9	500	(152)	10	(3.0)	68.5	64.5	60.8	65.6	74.4	57.4	2028	66	240	2334	3120
		500	(152)	15	(4.6)	69.0	65.5	61.8	66.4	76.9	58.7					
	10	500	(152)	10	(3.0)	67.9	64.0	60.0	65.1	72.3	55.1	1962	90	198	2250	2934
		500	(152)	20	(6.1)	69.2	65.5	61.8	66.4	72.3	58.2					
7-14-77	1	80	(24)	5	(1.5)	79.6	72.5	65.6	75.9	87.3	60.4	1932	18	288	2238	3120
		80	(24)	10	(3.0)	81.0	74.4	68.2	77.6	90.5	61.8					
		80	(24)	20	(6.1)	80.5	74.2	68.7	77.2	89.7	61.3					
		80	(24)	30	(9.1)	79.0	73.8	69.2	75.5	83.3	62.8					
	2	80	(24)	5	(1.5)	79.9	73.0	66.2	76.2	86.2	56.8	2148	42	342	2532	4284
		80	(24)	10	(3.0)	82.1	75.2	68.7	78.4	89.7	60.8					
		80	(24)	20	(6.1)	81.8	75.2	69.5	77.9	88.5	63.1					
		80	(24)	30	(9.1)	80.0	74.7	70.0	76.1	82.3	64.1					
	3	140	(43)	5	(1.5)	73.6	66.6	60.8	70.0	81.3	54.6	2166	54	348	2568	3666
		140	(43)	10	(3.0)	78.5	72.1	66.4	74.7	85.4	58.7					
		140	(43)	20	(6.1)	78.5	72.5	67.4	74.8	84.9	62.6					
		140	(43)	30	(9.1)	77.4	70.8	66.7	73.3	84.6	63.1					
	4	140	(43)	5	(1.5)	73.3	67.0	61.0	69.6	78.6	52.3	2334	48	414	2796	4086
		140	(43)	10	(3.0)	78.2	71.9	66.2	74.1	82.8	56.4					
		140	(43)	20	(6.1)	77.7	71.8	66.4	73.7	81.5	59.0					
		140	(43)	30	(9.1)	77.2	70.4	65.9	72.5	81.3	60.5					
	5	200	(61)	5	(1.5)	68.2	61.5	55.1	64.2	75.8	49.5	1992	54	306	2352	3324
		200	(61)	10	(3.0)	74.4	68.1	62.1	70.5	78.5	53.1					
		200	(61)	20	(6.1)	76.2	70.7	65.1	72.6	81.0	57.7					
		200	(61)	30	(9.1)	74.6	68.6	63.8	70.5	78.5	58.5					
	6	200	(61)	5	(1.5)	67.7	61.8	56.3	64.0	76.0	52.4	1962	120	300	2382	3402
		200	(61)	10	(3.0)	73.8	68.2	62.6	70.6	82.1	56.7					
		200	(61)	20	(6.1)	76.7	70.9	65.4	73.0	82.6	62.3					
		200	(61)	30	(9.1)	74.1	68.7	64.4	70.7	81.5	62.1					
	7	300	(91)	5	(1.5)	64.0	57.6	51.8	59.9	67.7	46.8	2070	138	366	2574	3810
		300	(91)	10	(3.0)	67.7	60.8	54.4	63.6	73.3	48.7					
		300	(91)	20	(6.1)	71.5	65.4	59.2	68.0	77.4	52.1					
		300	(91)	30	(9.1)	71.3	66.7	61.8	68.5	78.2	54.9					
	8	300	(91)	5	(1.5)	63.8	59.1	54.2	61.2	75.1	49.0	1914	108	342	2364	3498
		300	(91)	10	(3.0)	66.7	61.0	55.6	63.8	78.7	49.0					
		300	(91)	20	(6.1)	71.3	65.4	59.5	67.8	78.5	52.6					
		300	(91)	30	(9.1)	71.8	67.3	63.1	68.9	79.7	55.4					
	9	400	(122)	5	(1.5)	57.9	52.7	47.9	54.6	63.5	44.7	1770	66	258	2094	2934
		400	(122)	10	(3.0)	62.6	56.7	51.5	58.7	68.5	44.1					
		400	(122)	20	(6.1)	68.5	61.8	55.6	64.3	72.1	50.5					
		400	(122)	30	(9.1)	69.0	64.1	59.0	65.6	73.8	55.6					
	10	400	(122)	5	(1.5)	57.4	53.7	49.1	54.8	61.9	46.9	2106	66	258	2430	3270
		400	(122)	10	(3.0)	62.3	58.4	54.1	59.6	69.5	46.9					
		400	(122)	20	(6.1)	66.4	62.4	58.2	63.5	71.8	54.9					
		400	(122)	30	(9.1)	68.2	65.1	61.3	65.8	71.0	58.5					
	11	500	(152)	5	(1.5)	56.4	52.2	48.1	53.4	60.5	45.3	2154	114	276	2544	3486
		500	(152)	10	(3.0)	61.0	56.4	52.3	57.6	66.4	47.7					
		500	(152)	20	(6.1)	65.6	60.4	55.9	61.8	68.7	51.5					
		500	(152)	30	(9.1)	67.2	61.7	58.5	63.0	71.0	55.6					
	12	500	(152)	5	(1.5)	54.1	50.0	45.9	51.1	58.2	43.1	2232	60	246	2538	3336
		500	(152)	10	(3.0)	57.9	53.5	49.5	55.0	62.8	46.7					
		500	(152)	20	(6.1)	62.3	57.0	52.6	58.6	67.2	49.2					
		500	(152)	30	(9.1)	62.8	59.6	55.6	61.0	70.0	51.8					
	13	600	(183)	5	(1.5)	55.0	51.0	47.1	52.0	57.7	44.4	2238	36	372	2646	3798
		600	(183)	10	(3.0)	59.0	54.7	50.5	55.9	63.1	46.4					
		600	(183)	20	(6.1)	61.8	57.9	53.8	58.8	64.1	49.8					
		600	(183)	30	(9.1)	61.5	59.3	56.4	59.7	65.4	53.6					
	14	600	(183)	5	(1.5)	53.1	49.0	44.5	50.1	57.4	39.2	2040	96	318	2454	3504
		600	(183)	10	(3.0)	56.7	52.6	47.4	54.2	66.4	44.1					
		600	(183)	20	(6.1)	60.5	55.8	50.3	58.0	73.6	46.9					
		600	(183)	30	(9.1)	60.3	56.7	52.3	57.5	62.3	49.7					

APPENDIX G

EFFECT OF DISTANCE ON NOISE LEVELS

TABLE G1. NOISE LEVELS FOR VARIOUS DISTANCES FROM THE ROADWAY (SITE 4)

DISTANCE FT	(M)	NUMBER DATA POINTS	AVERAGE L_{10}	AVERAGE L_{50}	AVERAGE L_{90}	AVERAGE L_{eq}
50	(15)	34	77.0	71.6	66.4	74.2
100	(31)	34	73.3	68.2	63.6	70.3
200	(61)	34	67.8	63.3	59.3	64.9

TABLE G2. NOISE LEVELS FOR VARIOUS DISTANCES FROM THE ROADWAY (SITE 5)

DISTANCE FT	(M)	NUMBER DATA POINTS	AVERAGE L_{10}	AVERAGE L_{50}	AVERAGE L_{90}	AVERAGE L_{eq}
25	(8)	7	72.7	61.2	51.4	68.6
50	(15)	11	68.2	58.9	49.7	64.5
100	(31)	16	63.8	56.1	48.3	60.5
200	(61)	8	60.7	54.7	48.4	57.5
400	(122)	4	54.4	49.3	44.4	52.4

TABLE G3. NOISE LEVELS FOR VARIOUS DISTANCES FROM THE ROADWAY (SITE 6)

DISTANCE FT	(M)	NUMBER DATA POINTS	AVERAGE L_{10}	AVERAGE L_{50}	AVERAGE L_{90}	AVERAGE L_{eq}
50	(15)	11	72.2	66.5	60.2	69.6
100	(31)	11	67.8	61.9	56.5	64.6
200	(61)	11	62.2	57.8	53.7	60.1

TABLE G4. NOISE DROPOFF PER DOUBLING OF DISTANCES (SITE 4)

DISTANCE		DROPOFF PER DOUBLING DISTANCE	
FT	M	L_{10}	L_{eq}
50 to 100	15 to 31	3.7	3.9
100 to 200	31 to 61	5.5	5.4
Average		4.6	4.6

TABLE G5. NOISE DROPOFF PER DOUBLING OF DISTANCES (SITE 5)

DISTANCE		DROPOFF PER DOUBLING DISTANCE	
FT	M	L_{10}	L_{eq}
25 to 50	8 to 15	4.5	4.1
50 to 100	15 to 31	4.4	4.0
100 to 200	31 to 61	3.1	3.0
200 to 400	61 to 122	6.3	5.1
Average		4.6	4.1

TABLE G6. NOISE DROPOFF PER DOUBLING OF DISTANCES (SITE 6)

DISTANCE		DROPOFF PER DOUBLING DISTANCE	
FT	M	L_{10}	L_{eq}
50 to 100	15 to 31	4.4	5.0
100 to 200	31 to 61	5.6	4.5
Average		5.0	4.8

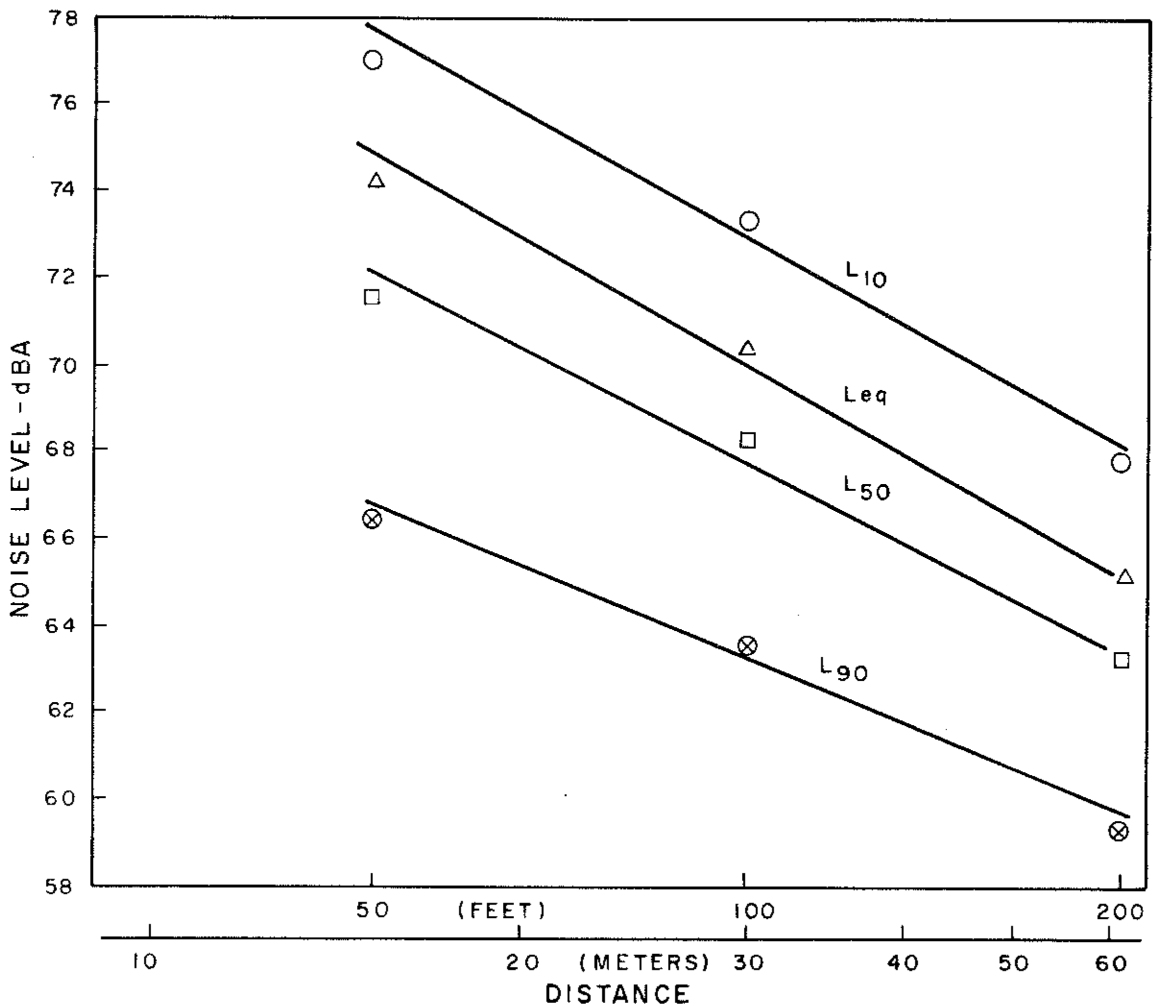

Figure G1. Effect of Distance on Noise Level (Site 4).

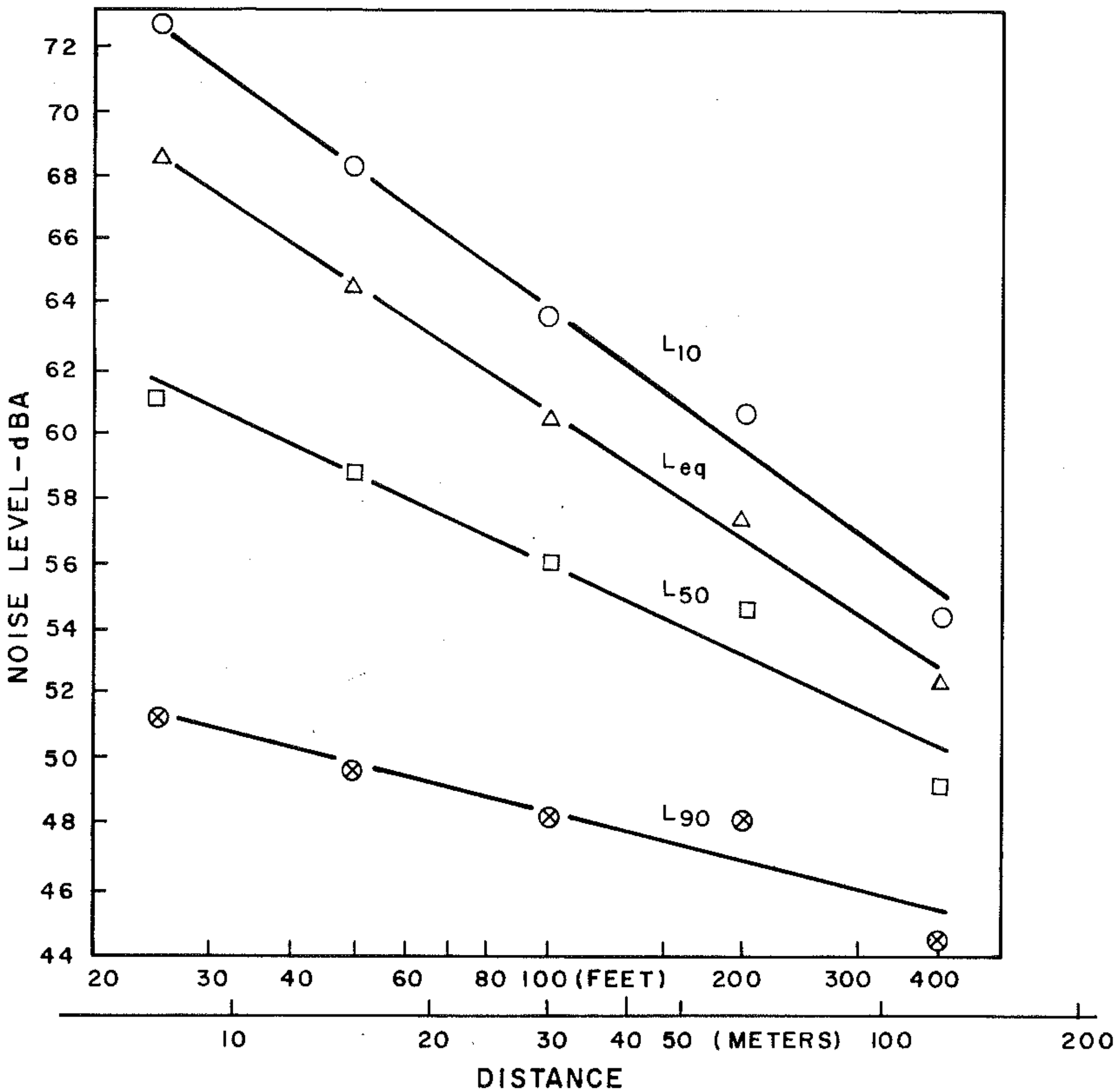

Figure G2. Effect of Distance on Noise Level (Site 5).

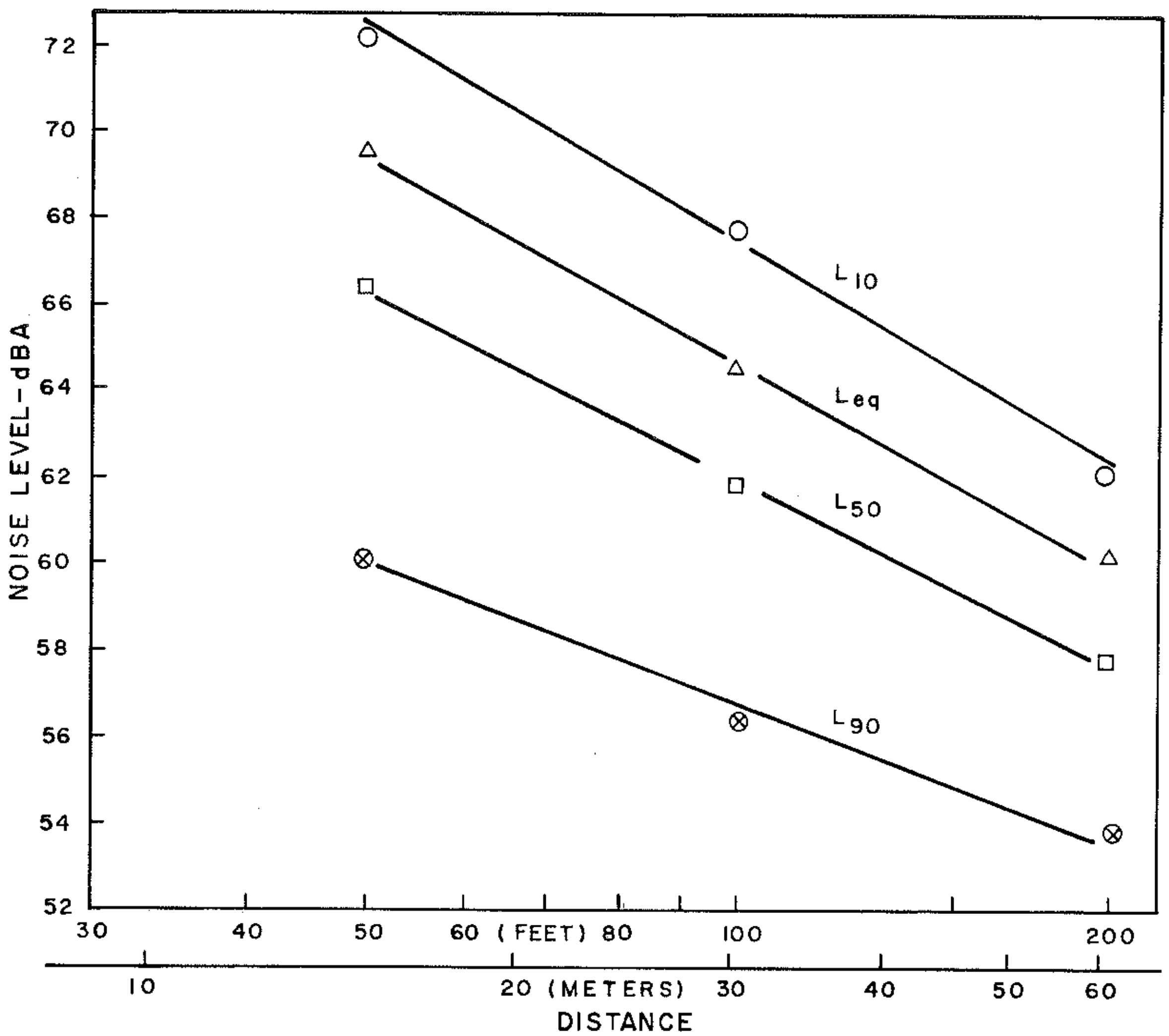

Figure G3. Effect of Distance on Noise Level (Site 6).

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF TRANSPORTATION
Division of Research
533 South Limestone
Lexington, KY 40508

FRANK R. METTS
SECRETARY

JOHN Y. BROWN, Jr.
GOVERNOR

October 8, 1980

H-2-78

MEMO TO: Henry Bennett
Acting, State Highway Engineer
Acting, Chairman, Research Committee

SUBJECT: Report 540; "Propagation of Traffic Noise;"
KYHPR-75-78; HPR-PL-1(15), Part II

Each vehicle in a traffic stream emits noise. The intensity of each diminishes in proportion to the distance squared. A listener hears the combination of diminished intensities. Doubling the distance diminishes the sound pressure to 1/4 and the loudness by 6 dBA. Reflection, damping, and mixing cause the decrease to vary somewhat from the expected, simple-theory value of 6 dBA. The variations can be significant. From a ground-level emitter to a ground-level receiver, the attenuation or loss may exceed 6 dBA. From an elevated emitter, the sound may travel in a straight line and be reinforced at the receiver by sound reflected from the ground. An increase or decrease of 10 dBA doubles or halves the loudness of the noise. The objective in defining and refining these variations is the protection of the roadside areas from noisome noises.

This work began in 1975 and has been completed. Some data acquired soon thereafter was utilized by FHWA (Tim Barry) in improving the prediction model. The new or improved model was then tested by us and recommended to the Division of Environmental Analysis (Report 534; January 1980).

Considerable instrumentation was acquired in a previous study (Report 379; November 1974). This was supplemented by other equipment to do simultaneous measurements and automatic analyses. Some of the equipment will become surplus. An inventory and disposition plan is being prepared.

Respectfully submitted,

Jas. H. Havens
Director of Research

gh
Attachment
cc's: Research Committee

Technical Report Documentation Page

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16. Abstract

The effects of various traffic, ground cover, and geometric conditions on traffic noise propagation were evaluated in this study. There were two general methods of data collection. The first method consisted of using as many as four sound-level meters and graphic-level recorders to take simultaneous recordings of the traffic stream; the second method involved a constant noise source using a random noise generator.

The L_{10} noise level reduction per doubling of distance was found to increase substantially when the traffic volume was less than 1,000 vehicles per hour. Wind speed and direction were found to have a large effect on noise propagation. Ground cover was also found to have a definite effect. Data were taken on short grass, tall weeds, tall grass, average grass, pavement, gravel, smooth dirt, snow, and plowed field. The drop-off per doubling of distance was found to decrease from about 4.5 dBA for receiver heights of 10 feet (3 m) or below to 3.0 dBA for heights above 10 feet (3 m). At heights above 10 feet (3 m), the type of ground cover did not have a significant influence on the propagation loss. Noise attenuation per doubling of distance remained constant back to about 400 feet (122 m) where the drop-offs were influenced by the ambient noise level. Individual noise readings indicated that noise propagation was influenced by vehicle type and speed. Noise drop-off was larger for smaller percentage levels, but the differences decreased as volumes increased. Source height was also found to have an effect on noise propagation.

17. Key Words traffic noise propagation traffic volume octave band receiver height source height ground cover	18. Distribution Statement

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Research Report
540

PROPAGATION OF TRAFFIC NOISE

KYHPR-75-78; HPR-PL-1(15), Part II B

by

Kenneth R. Agent
Research Engineer Chief

and

Charles V. Zegeer
Formerly Research Engineer Principal

Division of Research
Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

March 1980

INTRODUCTION

The propagation of traffic noise is a concept hard to quantify in the prediction of highway noise levels. To some degree, noise propagation depends on traffic conditions, type of ground cover, and the geometry of the highway and nearby terrain. The effect of these variables on noise levels, combined with the difficulty of predicting noise levels on low-volume roads, make accurate noise prediction difficult. As a general rule, sound from a point source, such as a single vehicle, spreads out uniformly (spherical spreading) and the sound level drops off at the rate of 6 dB for each doubling of distance. This is referred to in acoustics as the "inverse square law". This drop-off rate does not apply to highway situations because an observer seldom hears just a single vehicle. In the limiting case, a continuous line of vehicles becomes a line source and the rate of sound level drop-off with distance approaches "cylindrical spreading," which produces a 3-dB drop-off rate for each doubling of distance. The effects of various traffic, ground cover, and geometric conditions on traffic noise propagation were evaluated in this study.

BACKGROUND

Considerable research has been completed in the past in an attempt to quantify the effect of various factors on noise propagation. Some of the results have not provided clear answers and some have been contradictory. The following is a summary of previous research dealing with noise propagation.

TRAFFIC VOLUME

The rate of noise propagation is theoretically a function of traffic volume. For a point source such as one vehicle, the sound level decreases by 6 dB for each doubling of distance away from the roadway. For a line source the drop-off of noise level is 3 dB per doubling of distance *(1)*. Data reported in one source tended to confirm this information *(2)*. For use in highway noise prediction models; a noise decline of 4.5 dB per doubling of distance is used for all volume conditions *(3, 4)*. This is referred to as a modified line source. One reference states that, for an average four-lane highway, the assumption of a line source will be true when the total traffic volume exceeds perhaps 1,000 vehicles per hour *(5)*. However, for traffic volumes less than this, the line-source assumption may not be completely correct.

The effect of traffic volume on the propagation loss factor was not found to be significant for volumes over 2,000 vehicles per hour (vph) based on data shown in NCHRP Report 173 *(6)*. The loss factor was thought possibly to be affected for volumes below 2,000 vph; however, ambient noise influence on the low-volume measurements prevented valid conclusions *(6)*. Additional research was needed to adequately define the effect of low-volume conditions on noise propagation.

GROUND COVER

The effect of the ground cover between the noise source and observer has been found to significantly affect noise propagation. In a Connecticut study completed in 1971, the transmission of random noise was measured through dense corn, a dense hemlock plantation, an open pine stand, dense hardwood brush, and cultivated soil. Bare ground was found to attenuate noise between 200-1,000 hertz (Hz). Tilling the soil reduced the frequency of peak attenuation from 700 to 350 Hz. All types of dense forests were about equally as effective in attenuating high-frequency noise *(7)*.

In another study, the difference in noise propagation from a loudspeaker was compared for grass and pavement surfaces. For distances of 3 to 30 feet (0.9 to 9.1 m), the noise levels were 2 to 3 dBA louder over pavement than grass covers. The meter and speaker were both centered at 4 feet (1.2 m) above the ground *(8)*.

A model for the attenuation of traffic noise, developed in England in 1974, considered various types of ground cover for distances of 26 to 1,300 feet (8 to 400 m). The difference in propagation increased with increasing distance from the roadway. At about 330 feet (101 m), the combined attenuation by distance and ground cover was least for hard ground (22 dBA) compared to the open site (26 dBA), farmland (30 dBA), and dense woodland (37 dBA) *(9)*.

The present design guide provides for excess noise attenuation due to vegetation. This factor applies when the vegetation is dense enough to break the line of sight between the roadway and observer and is at least 15 feet (4.6 m) high and 100 feet (30 m) deep. The maximum noise reduction allowable from vegetation alone is 10 dB based on 5 dB for every 100 feet (30 m) of dense trees *(3, 4, 5)*.

Also, the ground condition between the receiver and roadway is considered. The ground is defined as either absorbent or reflective *(5)*. Reflective ground means that the ground is flat and hard with very few or no obstructions. The design guide uses an attenuation of 3 dB per doubling of distance when the surface of the terrain is highly reflective, as with asphalt or concrete pavements *(6)*.

MEASUREMENT HEIGHT

Results from several studies have shown that sound levels increase with increasing measurement height due to ground attenuation. In a Canadian study, adjustment factors were developed for various heights and distances on short grass ground covers. For example, at 100 feet (30 m) from the road, adjustments for various heights (reference: 0 dBA at 4 feet (1.2 m)) were plus 5 dBA at 10 feet (3.0 m), plus 7 dBA at 20 feet (6.1 m), and plus 6 dBA at 40 feet (12 m). Corrections for 200 and 300 feet (61 and 91 m) from the road were also given *(10)*.

In a study by Scholes et al., in England in 1974, the L_{10} values at a site 75 feet (23 m) from a road were plotted for heights of 5 feet (1.5 m), 10 feet (3.0 m), 20 feet (6.1 m), and 30 feet (9.1 m). For conditions of no wind, L_{10} values for these heights were 74.5, 76, 79, and 80 dBA, respectively. Thus, heights above 5 feet (1.5 m) would cause noise increases of about 1.5 dBA at 10 feet (3.0 m), 4.5 dBA at 20 feet (6.1 m), and 5.5 dBA at 30 feet (9. 1 m) *(11)*.

The current design guide uses an attenuation factor depending on observer height *(4)*. For observers near the gound, an attenuation of 4.5 dB is used for each doubling of distance. However, for higher receivers (above 10 feet (3.0 m)), a reduction of 3 dB per doubling of distance is used.

A stated conclusion in NCHRP Report 173 was that the propagation loss factor was not significantly dependent on measurement height for heights up to 15 feet (4.6 m) above ground. However, propagation loss would be expected to fall as the height increased above 15 feet (5 m) over a lush ground cover *(6)*.

DISTANCE FROM ROADWAY

Another variable which may affect noise propagation is the distance of the observer from the roadway. The propagation loss factor (noise drop-off per doubling of distance) has been found to be a constant for distances of 50 to 1,600 feet (15 to 488 m). This applied to high traffic volumes (over a few thousand vph), but it was not necessarily applicable to low-volume sites *(6)*.

VEHICLE SPEEDS AND CHARACTERISTICS

Very little information is available concerning the effect of vehicle types and speeds on noise propagation. For automobiles, as speed increases, tire-roadway noise increased rapidly and becomes the controlling factor. Noise from medium and heavy trucks is controlled by engine and exhaust noise and is louder than car noise. As the speed of most vehicles increases, higher frequencies begin to dominate.

Most grassy ground covers reduce higher frequencies better than low frequencies. Since frequency generally increases as speed increases, more attenuation may be expected at higher speeds for cars in particular. Because of the many factors affecting truck noise, the effect of speed on noise propagation is not clear. The source height of noise from large trucks is assumed to be 8 feet (2.4 m). The noise source heights of different vehicles may also have an effect on noise propagation *(12)*.

PERCENTAGE LEVEL

The percentage level is a way of expressing noise levels over a period of time. Examples of percentage levels commonly used are L_{01}, L_{10}, L_{50}, and L_{90}. L_{10} is the noise level exceeded 10 percent of the time. The L_{eq}, or equivalent level, is an expression of the total noise energy over a time period. Values of L_{10} and L_{eq} are more commonly used in highway noise standards and in comparisons of highway noise levels *(12)*.

A relationship has been found between percentage levels and noise propagation *(6)*. At traffic volumes below 5,000 vph and at distances within 1,600 feet (488 m) of the roadway, the propagation loss factor varied significantly with percentage level. In such cases, more propagation loss was found in the smaller percentage levels (L_{01} and L_{10}) than higher percentage levels (L_{90}). This seems reasonable since L_{90} levels are usually quite low at low-volume sites (near ambient levels) and have little room for further decrease in propagation loss. At volumes above 5,000 vph, a common propagation loss factor could be applied for all percentage levels.

WIND AND TEMPERATURE

The direction and speed of wind affects the propagation of sound, although the effect is not always well known. In a calm environment, the sound-wave fronts are undistorted and sound propagates radially. In wind, the sound upward from the source refracts up and away from the ground, creating a shadow zone. This would have little effect for close distances to the source; but beyond the edge of the shadow zone, there may be a considerable reduction in noise. The downwind sound is refracted down towards the ground, so sound would be carried farther than for calm conditions *(13)*.

Irregular or gusty winds of 15 to 30 mph (6.7 to 13.4 m/s) may cause fluctuations in sound levels by an average of about 4 to 6 dBA per 300 feet (91 m). Short-term fluctuations may be much greater than average losses. However, changes in noise levels based on high wind speeds cannot be counted on for noise control for any extended period of time under normal circumstances *(2, 14)*.

In one study, reductions up to 20 dB were found upwind compared to calm conditions. Excess attenuation upwind exceeded downwind propagation by 25 dB (at 12 feet (3.7 m) heights) to 30 dB (at 5-foot (1.5-m) heights) *(15)*.

Air temperature can also have an effect on sound propagation. Under normal daytime situations, temperature decreases with height. This may result in temperature-created shadow zones upward and symmetrical from the noise source. During temperature inversions, the sound is refracted down towards the ground in all directions. Sometimes, irregularities in the temperature inversion profile can cause a focusing of sound, and the perceived noise level can be higher at some locations than others closer to the source *(13)*.

PROCEDURE

TYPES OF DATA

Data were collected to determine the effects of the following variables on traffic noise propagation:

(1) traffic volume,
(2) wind,
(3) ground cover,
(4) receiver height,
(5) distance,
(6) traffic speed,
(7) source height,
(8) percentage level, and
(9) type of vehicle.

DATA COLLECTION

There were two general methods of data collection. The first consisted of using as many as four sound-level meters and graphic-level recorders to take simultaneous recordings of the traffic stream. These data were taken at different distances and heights from the roadway. The distances were measured from the centerline of the near traffic lane. Ten-minute recordings were obtained using the A-weighting scale. Noise levels at intervals slightly greater than one second were determined in the laboratory utilizing a digital datareduction system where noise output was punched onto computer cards as described in a previous report *(16)* and analyzed. Figure 1 illustrates the various methods of data collection and analysis used at sites adjacent to the roadway. The setup to collect simultaneous data at four different heights is shown in Figure 2. A description of the sites at which measurements were taken is given in Table 1. Noise levels of individual vehicles were also obtained using the sound-level meter. The second method involved a constant noise source using a random noise generator. The output noise was input into a sound-level meter equipped with an octave band analyzer, amplified, and broadcast through a speaker. The resulting noise level was analyzed at different distances and heights from the speaker using a sound-level meter equipped with an octave band analyzer (Figure 3). Octave band analysis was set for center frequencies from 63 through 8,000 hertz. Pink noise (constant energy per octave bandwidth) was used for the octave band analysis while white noise (flat spectrum with constant energy per hertz bandwidth) was used for unweighted (linear) and A-weighted noise analysis. A photograph of the equipment used for this data collection is in Figure 4.

For the traffic stream locations, the data were generally analyzed in terms of the L_{10} or L_{eq} noise level. A computer program using the trapezoidal rule and Simpson's rule was used to determine L_{eq}. Following is a list of the terms used in the summaries of the data:

L_{10}	=	noise level exceeded 10 percent of the time,
L_{50}	=	noise level exceeded 50 percent of the time,
L_{90}	=	noise level exceeded 90 percent of the time,
L_{eq}	=	noise equivalent level,
L_{max}	=	maximum noise level,
L_{min}	=	minimum noise level,
AUTO	=	automobiles and light trucks,
MT	=	medium trucks, and
HT	=	heavy trucks.

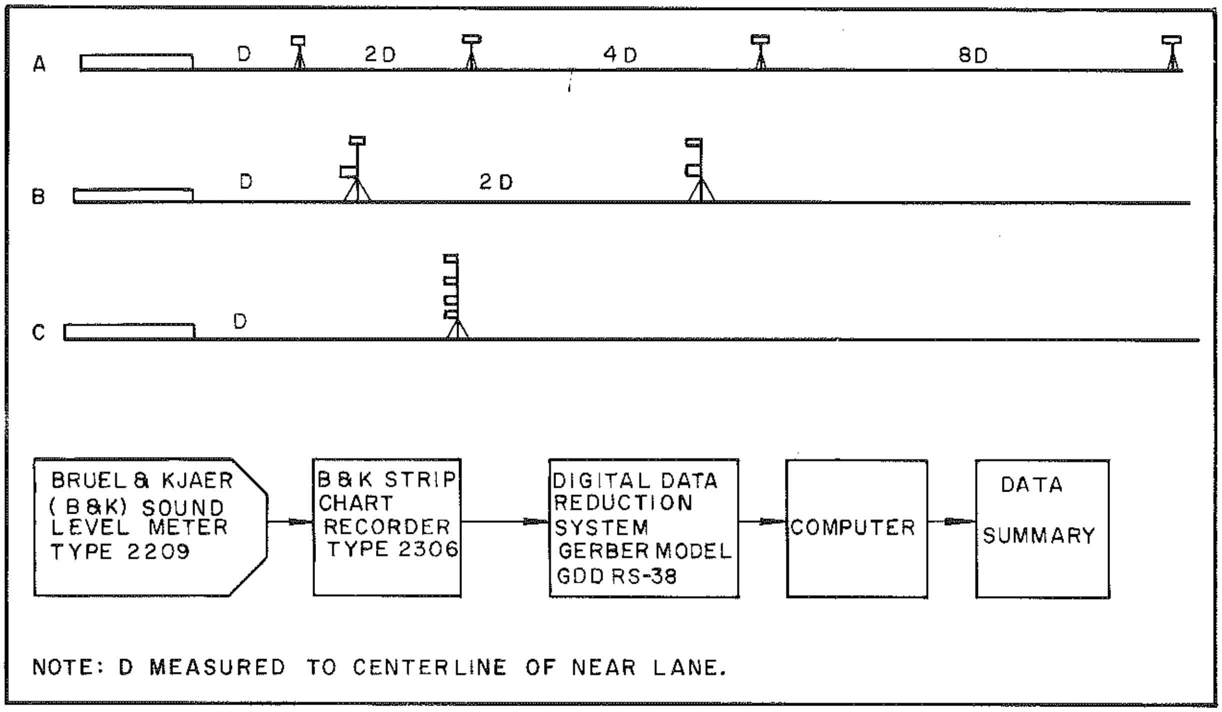


Figure 1. Data Collection and Analysis Used at Sites Adjacent to Roadway.

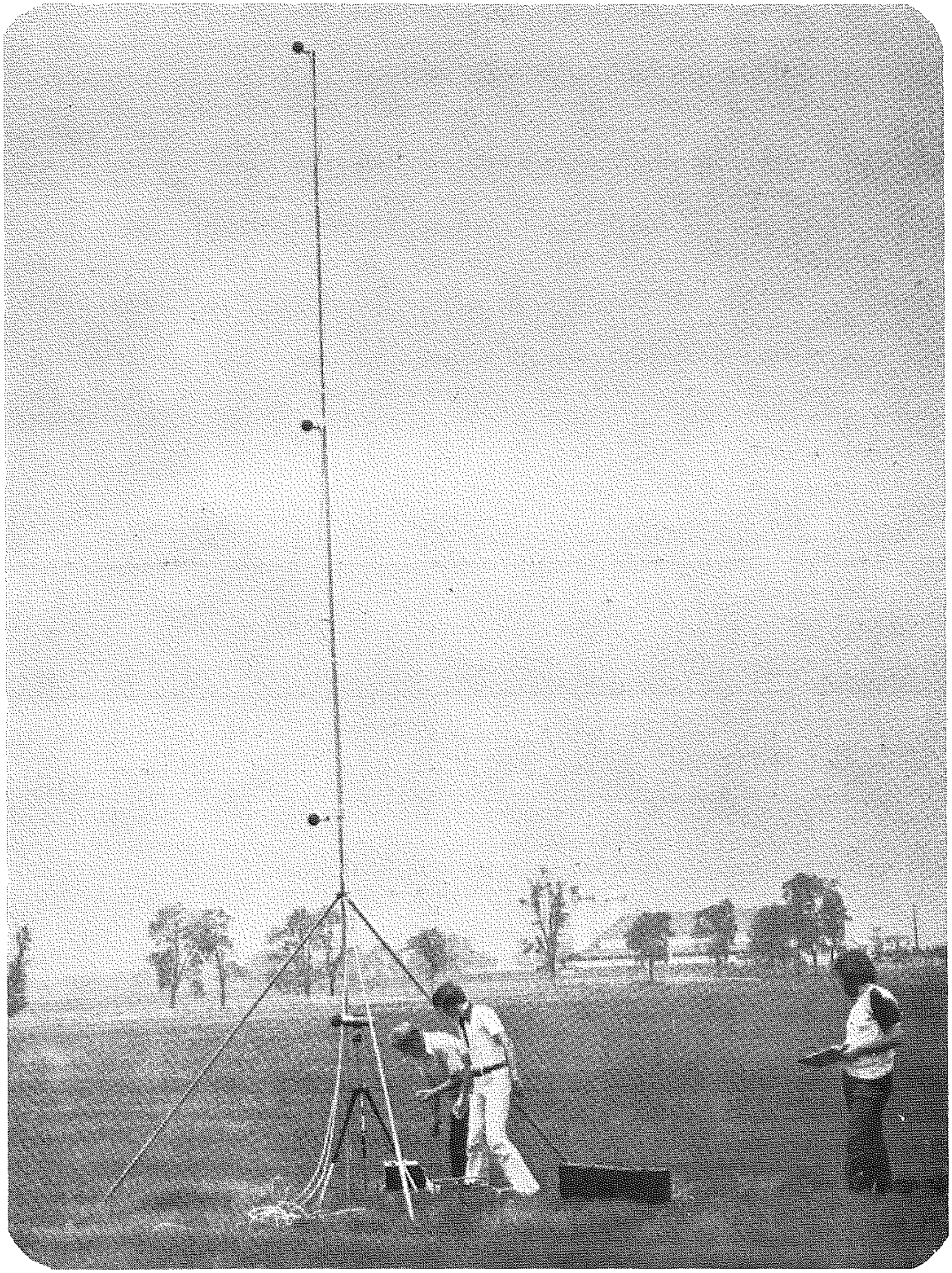
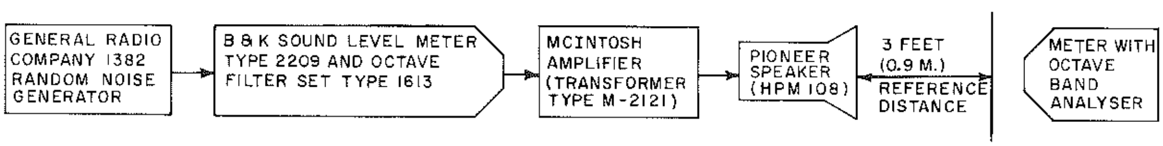


Figure 2. Photograph of Setup Used to Collect Data Simultaneously at Four Measurement Heights.

TABLE 1. TRAFFIC STREAM MEASUREMENT SITES

SITE NUMBER	ROUTE	LOCATION (CITY)	HIGHWAY NAME	TYPE OF LOCATION	SPEED LIMIT (MPH)	SPEED LIMIT (M/S)	AVERAGE SPEED (MPH)	AVERAGE SPEED (M/S)	TYPICAL HOURLY VOLUME	NUMBER OF NOISE RECORDINGS: 10-MINUTE MEASUREMENTS	NUMBER OF NOISE RECORDINGS: TOTAL PERIODS
1	US 27	Lexington	South Limestone Street	Urban	40	(18)	37	(17)	2150	244	78
2	US 68	Lexington	Harrodsburg Road	Rural	55	(25)	54	(24)	570	102	36
3	I 75	Lexington	Interstate 75	Rural	55	(25)	62	(28)	1800	203	75
4	I 264	Louisville	Watterson Expressway	Urban	55	(25)	48	(21)	3880	102	34
5	US 60	Lexington	Winchester Road	Rural	55	(25)	53	(24)	420	58	20
6	US 31W	Louisville	Dixie Highway	Urban	40	(18)	36	(16)	2500	51	17
7	US 60	Versailles	Versailles Road	Rural	50	(22)	56	(25)	820	80	22
8	US 68	Lexington	Harrodsburg Road	Urban	45	(20)	37	(17)	660	36	12
9	US 60	Lexington	Winchester Road	Urban	45	(20)	34	(15)	2130	15	5
Totals										891	299



NOTE:

1. RANDOM NOISE GENERATOR PROVIDES BOTH PINK AND WHITE NOISE.
2. OCTAVE BOND ANALYSIS FOR CENTER FREQUENCIES OF 63 THROUGH 8,000 ALSO LINEAR AND A-WEIGHTED.
3. USED PINK NOISE FOR OCTAVE BAND ANALYSIS.
4. USED WHITE NOISE FOR LINEAR AND A-WEIGHTED.
5. NOISE LEVEL AT REFERENCE DISTANCE WAS 95 dB FOR ALL DATA EXCEPT LINEAR NOISE (90dB).

OCTAVE FREQUENCY RANGE(H_2)	GEOMETRIC MEAN FREQUENCY OF BAND (H_2)
22—44	31
44—88	63
88—175	125
175—350	250
350—700	500
700—1400	1000
1400—2800	2000
2800-5600	4000
5600-11200	8000

Figure 3. Data Collection Procedure Using Random Noise Generator.

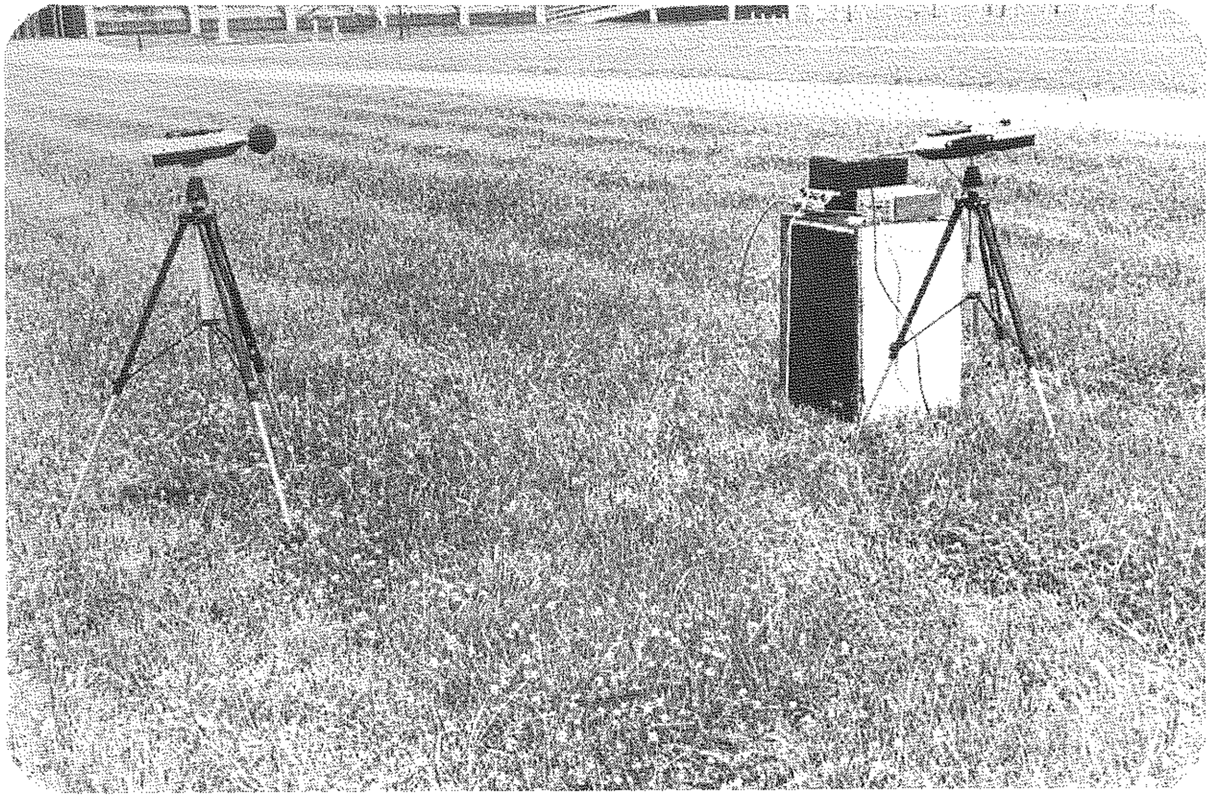


Figure 4. Photograph of Equipment Used with Random Noise Generator.

RESULTS

TRAFFIC VOLUME

One of the primary objectives of the study was to determine the effect of traffic volume on traffic noise propagation. Theory states that noise propagation will vary from 3 to 6 dB for a line or point source, respectively. The current design guide used a 4.5 dBA drop-off for all traffic volumes. This is termed a modified line source. A past study concluded that traffic volume did not influence noise propagation when the volume was over 2,000 vph *(6)*. However, it was stated that noise propagation might be significantly influenced by volumes lower than 2,000 vph. Since a large percentage of Kentucky highways have volumes less than 2,000 vph, a large amount of data was taken in an attempt to resolve this question.

The method of data collection involved taking simultaneous recordings of the traffic stream at different distances. All the data were taken at a 5-foot (1.5-m) height over short grass. Sites were chosen at locations with zero grade, with the observer level with the roadway, and with no shielding to reduce the number of variables which would alter the noise drop-off. Sites were chosen so that a large range in traffic volumes could be obtained. The wind speed and direction were obtained and data were not used in the analysis if the wind vector either toward or away from the roadway was over 10 knots. A summary of the data is given in APPENDIX A.

Results shown in Table 2 give the average noise reduction per doubling of distance for various traffic volumes. Two sets of data are given. One set of data represents all the data while the other excludes some data. Data were excluded from the modified set if the reduction per doubling of distance was greater than 6.5 dBA or less than 2.5 dBA. This allowed a one-half decibel variance from the theoretical limits which could have resulted from data collection and analysis errors. Considering the L_{10} noise level data, approximately four percent of the data showed a reduction less than 2.5 dBA; about 12 percent was greater than 6.5 dBA.

TABLE 2. REDUCTION IN TRAFFIC NOISE LEVEL PER DOUBLING OF DISTANCE FOR VARIOUS TRAFFIC VOLUMES

TRAFFIC VOLUME (VEHICLES PER HOUR)	NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE: ALL DATA			EXCLUDING SOME DATA[a]		
	L_{10}	L_{eq}	L_{50}	L_{10}	L_{eq}	L_{50}
Less than 1000	5.7	5.2	3.4	5.2	5.0	3.8
1000 - 1999	4.9	4.6	3.9	4.2	4.2	4.1
2000 - 2999	4.0	3.8	3.5	4.2	4.0	3.7
3000 - 4000	4.6	4.7	4.0	4.6	4.7	4.1
Over 4000	4.2	4.3	4.2	4.2	4.3	4.2

[a] Exclude data if the reduction per doubling of distance was greater than 6.5 dBA or less than 2.5 dBA.

The reduction in the L_{10} noise level per doubling of distance increased substantially when the volume was less than 1,000 vph. The reduction in the L_{eq} noise level also increased for volumes less than 1,000 vph; however, the increase was not quite as dramatic as for the L_{10} level. For both the L_{10} and L_{eq} noise levels, the average reduction for the various traffic volumes was very close to the 4.5-dBA drop-off per doubling of distance currently used in traffic noise prediction for all traffic volumes. The data summarized in Table 2 show this assumption to be very good, except for traffic volumes less than 1,000 vph where this drop-off increases to over 5 dBA. It should be noted that this is an average value for volumes less than 1,000 vph. In some cases, the drop-off was less than 5 dBA. However, considering all data, it is recommended that the reduction per doubling of distance used to predict L_{10} noise levels be increased to 5.0 dBA for volumes less than 1,000 vph.

The equivalent distance, which is basically the distance to the centerline of the roadway, is used rather than the distance to the near lane in the prediction procedure *(4)*. An analysis similar to that shown in Table 2 was done using the equivalent distance to determine if any significant difference occurred. As in Table 2, there was an increase in the noise reduction per doubling of distance for low-volume conditions, particularly using the L_{10} values. An analysis excluding data where the reduction per doubling of distance was greater than 6.5 dBA or less than 2.5 dBA found the L_{10} reduction varied from 4.5 dBA for volumes of 2,001 to 3,000 vph to 4.8 dBA for volumes between 1,000 and 2,000 to 5.1 for volumes less than 1,000 vph. For L_{eq}, the reduction per doubling of distance varied from 4.5 dBA for volumes of 2,001 to 3,000 vph to 4.7 dBA for volumes between 1,000 and 2,000 to 4.9 dBA for volumes less than 1,000 vph.

Current highway design criteria is based on L_{10}. For comparison purposes, the noise drop-off was also obtained for L_{eq} and L_{50}. Theoretically, when the L_{eq} noise level is considered, traffic volume should not have the influence reflected in the L_{10} value. However, the L_{eq} drop-off also increased for volumes less than 1,000 vph but not as much as that found for L_{10}. A different situation was found when the L_{50} was considered. The L_{50} experienced a lower drop-off compared to both L_{10} and L_{eq}. Also, the L_{50} drop-off was not significantly affected by traffic volume. The L_{50} reduction actually decreased slightly for lower traffic volumes.

In addition to using the actual volume count, a separate analysis was made using what was termed the "equivalent volume." This was a weighted volume based on the number of automobiles and medium and heavy trucks in the traffic stream. The formula for equivalent volume was as follows:

$$EV = A + 2M + 4H$$

where
EV = equivalent volume (per hour),
A = number of automobiles and light trucks,
M = number of medium trucks, and
H = number of heavy trucks.

Light trucks refer to two-axle, four-wheel vehicles. Medium trucks generally refer to gasoline-powered, two-axle, six-wheel vehicles. Heavy trucks refer generally to diesel-powered, three-or-more-axle truck combinations. There is a large difference in the noise levels emitted by these types of vehicles. Multiplying factors were applied to medium and heavy trucks to determine if this would alter the previous findings concerning the relationship between noise-level reduction per doubling of distance and traffic volume. However, when the data were summarized using equivalent volume very similar results were found.

WIND

Large fluctuations in noise drop-off were sometimes found at a site even when the traffic volumes were similar. These variations were partially explained by the effect of wind. The wind speed and direction for each measurement are given in APPENDIX B. These data were used to determine the component blowing either directly toward or away from the roadway. These components were then grouped according to speed. Data taken when the traffic volume was less than 1,000 vph were not used in these calculations, since the low traffic volume influenced the data. The measurement height was 5 feet (1.5 m) and the ground cover was short grass. Results are shown in Table 3.

TABLE 3. REDUCTION OF TRAFFIC NOISE LEVEL PER DOUBLING OF DISTANCE FOR VARIOUS WIND VECTORS

DIRECTION	WIND VELOCITY (KNOTS)[a]	TRAFFIC NOISE REDUCTION PER PER DOUBLING OF DISTANCE L_{10}[b]	L_{eq}[c]
Away from roadway	Greater than 10	8.6	8.3
	5 - 10	5.0	4.8
	1 - 4.9	5.0	4.9
Toward roadway	0 - 4.9	4.2	4.1
	5 - 10	3.8	3.6
	Greater than 10	2.7	2.7

a Wind vector blowing either directly away from or toward roadway. Calculated usingwind speed and direction given in Table B-1.

b The equation for the relationship between the L_{10} reduction per doubling of distance and wind vector was $y = 4.78 - .21 x$ where x is the wind vector and y is the L_{10} noise dropoff. The r^2 was 0.93. A wind vector away from the roadway was negative; toward the roadway positive; parrallel to the roadway was zero.

c The equation for the relationship between the L_{eq} reduction per doubling of distance and wind victor was $y = 4.63 - .20 x$ where x is the wind vector and y is the L_{eq} noise dropoff. The r^2 was 0.93.

When the component speed was over 10 knots (11.5 mph (5 m/s)), the noise drop-off was influenced significantly. When the wind was blowing away from the roadway, the noise was spread by the wind, and the noise drop-off was small. Conversely, when the wind was blowing toward the roadway, the spreading of the noise was inhibited and the drop-off was increased. The results showed that reliable data cannot be taken when the speed of the wind component is greater than 10 knots (11.5 mph (5 m/s)). Also, even at speeds less than 10 knots (11.5 mph (5 m/s)), the wind speed and direction should be considered.

GROUND COVER

The effect of ground cover on noise propagation was investigated using both types of data sources -- noise generated by the traffic stream and a random noise generator. The traffic-stream data were collected at a low-volume location (Harrodsburg Road (US 68) near Lexington) and a high-volume location (Dixie Highway in Louisville). Summaries of the data used in this analysis plus other traffic-stream noise data taken on a ground cover other than short grass are given in APPENDIX C. The random noise generator was used at numerous sites such as parking lots, grass fields, and agricultural areas isolated from highways. Reference noise levels (at a distance of 3 feet (0.9 m)) from the random noise generator was 95 dB for all measurements except linear noise where a 90 dB reference was used.

A summary was made of the traffic stream data as shown in Table 4. The drop-off in L_{10} and L_{eq} are given per doubling of distance for various ground covers. On short grass, the L_{10} dropped off 5.0 dBA compared to 4.7 dBA for L_{eq} at the high-volume site. The L_{10} reduction per doubling of distance dropped off 5.8 dBA over tall grass (5.4 dBA for L_{eq}) compared to a drop-off of only 2.9 dBA over pavement (2.8 dBA for L_{eq}). For the low-volume site, the L_{10} noise level dropped off 5.9 dBA over short grass and a plowed field compared to 3.1 dBA over pavement. The effect of a reflective surface (pavement) on noise attenuation is clearly demonstrated.

TABLE 4. NOISE LEVEL DROP-OFF PER DOUBLING OF DISTANCE FOR VARIOUS GROUND COVERS AND TRAFFIC VOLUMES (TRAFFIC STREAM DATA)

		NOISE DROP-OFF PER DOUBLING OF DISTANCE (dBA)	
	GROUND COVER	L_{10}	L_{eq}
High volume	Short grass	5.0	4.7
Location	Tall grass	5.8	5.4
(Site 6)	Pavement	2.9	2.8
Low volume	Short grass	5.9	5.2
Location	Pavement	3.1	3.1
(Sites 2 and 8)	Plowed field	5.9	5.1

The random noise generator was utilized for determining the difference in noise attenuation (A-weighted noise levels) between short grass and other ground covers as plotted in Figure 5. A plowed field produced the same attenuation as short grass. Attenuations per doubling of distance for medium and high grass, snow, and smooth dirt ground covers were within 1 dBA compared to short grass. Pavement, followed by gravel, provided the least attenuation. High weeds provided much more attenuation than any other ground cover. A comparison of the attenuation provided by pavement compared to high weeds showed that ground cover can have a significant effect on noise propagation. However, comparison of various heights of grass showed that typical right-of-way ground covers do not show a large range in attenuation.

A series of plots were made to show noise levels over pavement, short grass, and high weeds for distances of 25 to 200 feet (7.6 to 61 m) using the random noise generator data. The relationship for A-weighted noise (Figure 6) shows that noise over pavement decreased from about 85 dBA at 25 feet (7.6 m) to about 63 dBA at 200 feet (61 m). Over short grass, noise levels decreased from about 84 dBA at 25 feet (7.6 m) to 50 dBA at 175 feet (53 m). Noise levels dropped off much more over high weeds. A decrease from 80 dBA at 25 feet (7.6 m) to about 56 dBA at 100 feet (30 m) was found. A plot of noise levels for other ground covers versus distances showed no great differences (Figure 7).

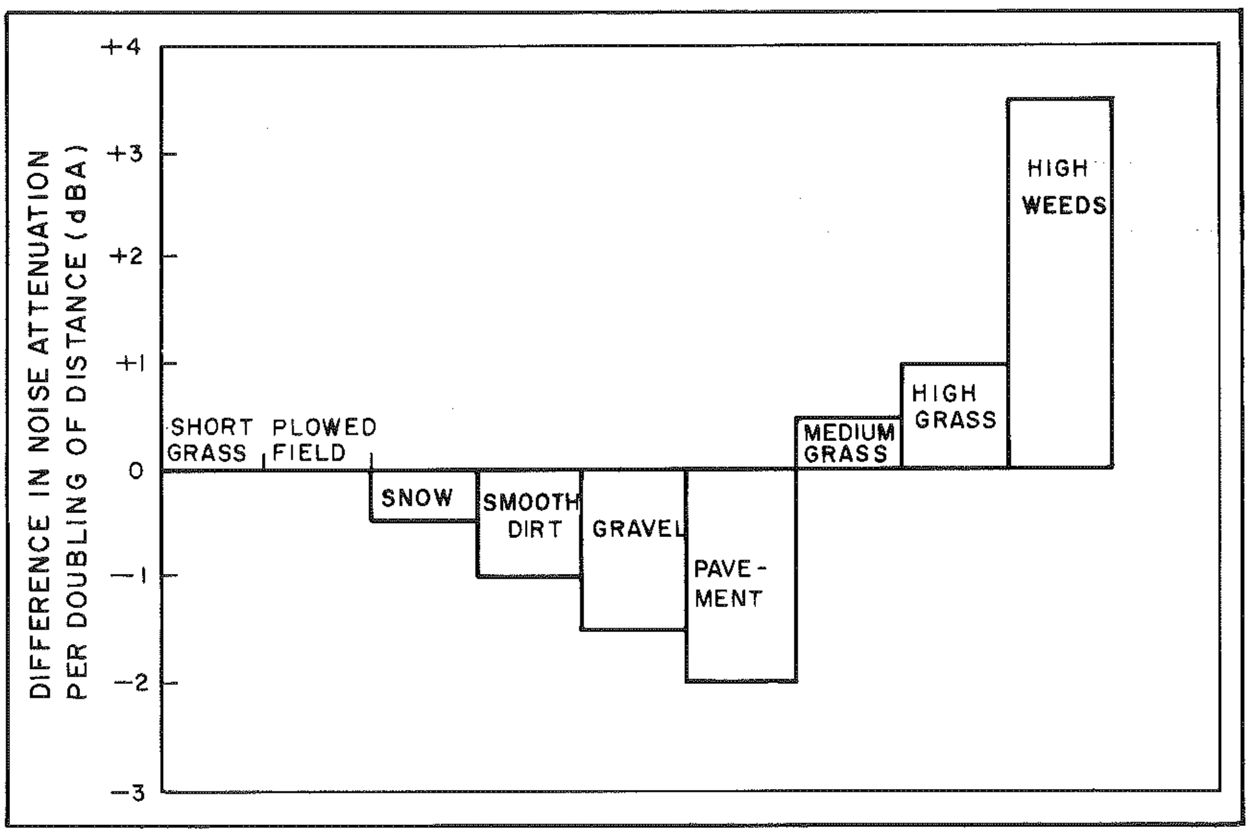
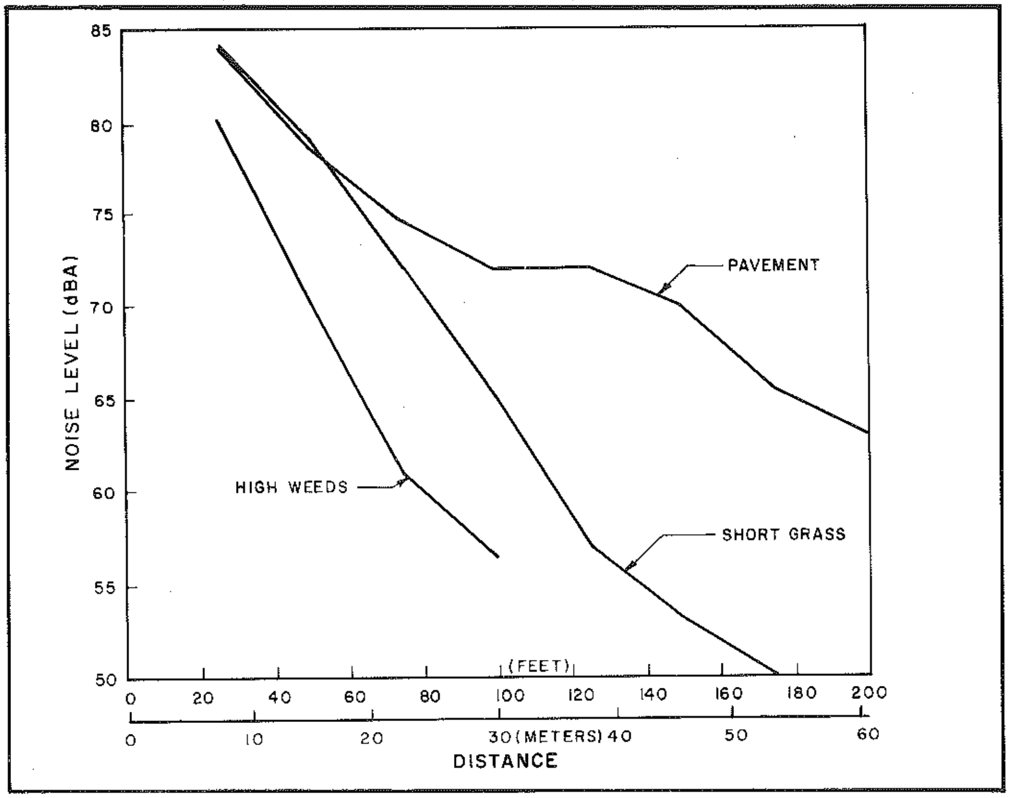


Figure 5. Noise Attenuation per Doubling of Distance for Various Ground Covers Compared to Short Grass (A-weighted Noise Level).

Figure 6. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (A-weighted) for Various Distances from the Random Noise Generator.



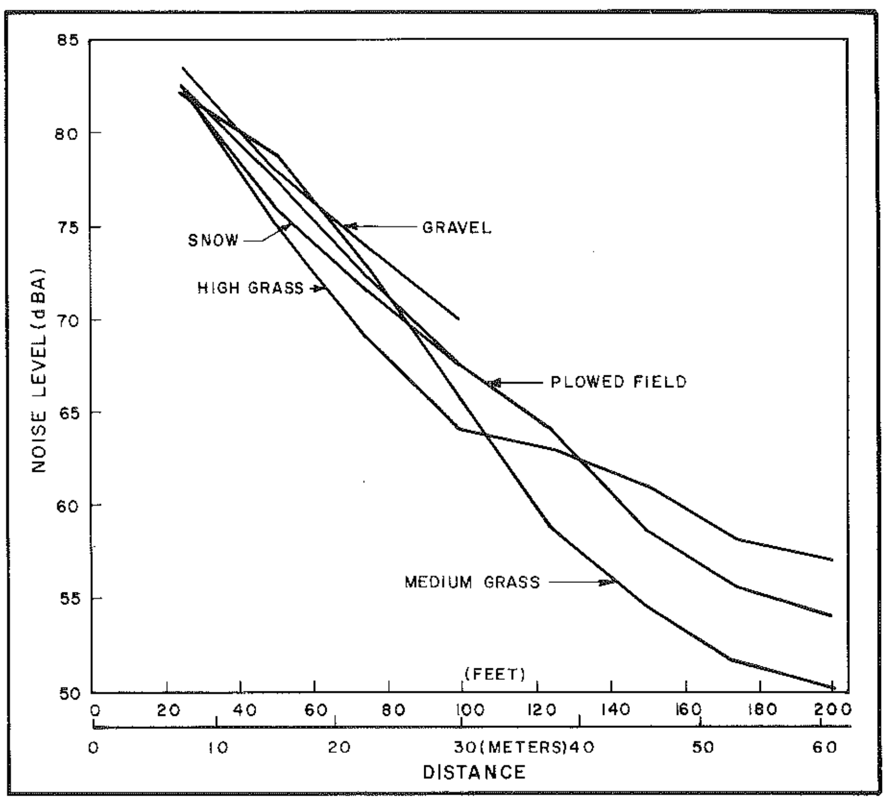


Figure 7. Effect of Other Ground Covers on Noise Levels (A-weighted) for Various Distances from the Random Noise Generator.

Similar plots of noise level (dB) versus distances were made for short grass, pavement, and high weeds for octave-band, center frequencies of 63, 125, 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz and linear (unweighted) noise (see APPENDIX D). Noise attenuations over the three ground covers were less for low frequencies (centered on 63, 125, and 250 Hz octave bands) than for high frequencies; low-frequency noise was affected very little by ground cover. Ground covers had a greater effect on noise levels for the 500 and 2,000 Hz center frequencies. At 1,000 Hz, noise levels on high weeds and short grass were almost identical but were considerably lower than noise levels over bituminous pavements. At 4,000 Hz, noise levels were higher on short grass than pavement up to a distance of 100 feet (30 m). At 8,000 Hz, a difference of nearly 20 dB was found between bituminous pavements (63 dB) and high weeds (44 dB) at a distance of 100 feet (31 m).

For unweighted (linear) noise, drop-offs could be detected only to about 100 feet (30 m); this was due to the high ambient (background) levels. Tables show average noise levels for all frequencies (in A-weighted and unweighted) for each distance; the data are given in APPENDIX D.

The noise drop-off per doubling of distance for the other ground covers are shown in Table 5. Using short grass as the reference cover, the difference in noise attenuation per doubling of distance was plotted for octave-band center frequencies of 62.5 to 8,000 Hz (APPENDIX E). The difference in propagation for the ground covers varied in different octave-band center frequencies. For example, a plowed field or smooth soil provided higher attenuation than short grass at 500 Hz but less at 2,000 Hz. The higher attenuation over high weeds compared to short grass varied from 1 dB at 250 hertz to 6 dB at 8,000 Hz. The attenuation over pavement was 7 dB less than over short grass at 2,000 Hz. Medium grass had lower noise drop-offs of about 1.5 dB at 500 and 8,000 Hz compared to short grass. The noise drop-off on snow was greater than on short grass at 125 through 1,000 Hz but was lower at the higher frequencies. The lower attenuation on gravel and pavement was due primarily to a low attenuation of the higher frequencies. Attenuation over high grass was higher than over short grass at 4,000 and 8,000 Hz.

TABLE 5. NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE FOR VARIOUS GROUND COVERS[a]

	NOISE REDUCTION PER DOUBLING OF DISTANCE (dB)								
		OCTAVE - BAND CENTER FREQUENCY (HZ)							
GROUND COVER	A-WEIGHTED NOISE	63	125	250	500	1,000	2,000	4,000	8,000
Pavement	6.0	5.5	6.0	6.5	6.5	6.5	3.0	6.5	9.0
Gravel	6.5	6.0	6.0	6.0	6.0	7.5	7.0	6.5	8.5
Smooth ground (No grass)	7.0	6.0	6.5	6.5	8.5	8.0	9.0	8.0	8.0
Snow	7.5	6.0	8.0	9.5	10.0	9.5	9.0	8.5	8.0
Plowed field	8.0	6.5	7.0	8.0	9.5	9.0	8.5	8.5	11.0
Short grass[b]	8.0	6.0	6.0	6.0	6.5	9.0	10.0	9.0	9.0
Medium grass[c]	8.5	6.0	6.0	7.0	8.0	8.0	10.5	10.0	10.5
High grass[d]	9.0	6.0	6.0	6.0	6.5	8.0	9.5	10.5	11.0
High weeds[e]	11.5	6.5	6.0	7.0	9.5	10.0	12.0	13.5	15.0

[a] Reference noise level of 95 dB at distance of 3 feet (0.9 m) from speaker for each test. Microphone height of 4 feet (1.2 m). Distances of 25 (7.6 m), 50 (15 m), 75 (2.3 m), and 100 feet (30 m) from reference point were used. White random noise used for A-weighted. Pink random noise used for various frequencies.

[b] About 1 inch (2.5 cm) high.

[c] About 3 (7.6) to 5 (13) inches (cm) high.

[d] About 9 (23) to 12 (30) inches (cm) high.

[e] About 3 (0.8) to 4 (1.0) feet (m) high.

RECEIVER HEIGHT

Traffic stream noise data were measured along with the random noise generator to determine the relationship between noise propagation and measurement (receiver) height. The major objective was to determine the height above the ground where the effect of ground cover becomes negligible. Measurements were made at receiver heights of 5 to 30 feet (1.5 to 9.1 m) above the ground. Distance from the roadway (measured from the centerline of the near lane) ranged from 25 to 600 feet (7.6 to 183 m). The data are given in APPENDIX F. The data collected at an urban location are given in Tables 6 and 7. Both the L_{10} and L_{eq} noise levels showed a reduction in drop-off per doubling of distance for the 20-foot (1.5-m) and 10-foot (3.0-m) heights. This relationship was also found for a high-speed interstate location which had a high volume of heavy trucks (see Table 8). The data support the present procedure of using a different noise reduction per doubling of distance depending on receiver height. Also, the current level of 10 feet (3.0 m) appears to be the point at which the drop-off changes.

Results obtained with the random noise generator confirmed findings obtained from measurement of the traffic stream. The reduction per doubling of distance for short grass and pavement were compared at different heights. Data were taken with the noise source at ground level to represent car noise (Table 9) and at an 8-foot (2.4-m) height to represent truck noise (Table 10). With the noise source at ground level, the difference in propagation over grass compared to pavement almost dissipated at a 9-foot (2.7 m) measurement height and completely dissipated at the 15-foot (4.6-m) height. This agreed with data from the traffic stream which showed that a change in the propagation loss occurs above a measurement height of 10 feet (3.0 m). At this height above the ground, the ground cover no longer has a significant influence on noise propagation.

TABLE 6. L_{10} NOISE LEVEL FOR VARIOUS RECEIVER HEIGHTS AND DISTANCES FROM ROADWAY (URBAN ROADS) (SITE 1)

DISTANCE FROM ROADWAY (FEET (M))	AVERAGE L_{10} NOISE LEVEL — HEIGHT ABOVE GROUND (FEET (M)) 5 (1.5)	10 (3.0)	20 (6.1)	30 (9.1)
25 (7.6)	74.0	74.6	73.6	74.2
50 (15.2)	67.8	69.9	71.6	71.4
100 (30.5)	65.1	66.8	68.7	69.3
200 (61.0)	61.4	61.6	64.1	65.7
400 (122.0)	54.0	55.2	58.3	60.8
Average reduction per doubling of distance	5.0	4.8	3.8	3.4

TABLE 7. L_{eq} NOISE LEVEL FOR VARIOUS RECEIVER HEIGHTS AND DISTANCES FROM ROADWAY (URBAN LOCATION) (SITE 1)

DISTANCE FROM ROADWAY (FEET (M))	AVERAGE L_{eq} NOISE LEVEL			
	HEIGHT ABOVE GROUND (FEET (M))			
	5 (1.5)	10 (3.0)	20 (6.1)	30 (9.1)
25 (7.6)	71.1	71.5	70.8	71.3
50 (15.2)	65.3	67.4	69.0	69.8
100 (30.5)	62.6	64.3	66.1	67.2
200 (61.0)	59.0	59.4	61.8	63.5
400 (122.0)	51.7	53.2	57.5	58.9
Average reduction per doubling of distance	4.8	4.6	3.3	3.1

TABLE 8. REDUCTION IN NOISE LEVEL (L_{10}) FOR VARIOUS RECEIVER HEIGHTS AND DISTANCES FROM THE ROADWAY (INTERSTATE ROADS) (SITE 3)

MEASUREMENT HEIGHT (FEET (M))	DECREASE IN NOISE LEVEL (L_{10}) BETWEEN GIVEN DISTANCES	
	80 FEET (24.4 M) TO 300 FEET (91.4 M)	80 FEET (24.4 M) TO 600 FEET (183 M)
5 (1.5)	15.9	25.7
10 (3.0)	15.3	23.7
20 (6.1)	9.7	20.0
30 (9.1)	7.9	18.6

TABLE 9. NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE FOR GRASS COMPARED TO PAVEMENT (NOISE SOURCE AT GROUND LEVEL)[a]

MEASUREMENT HEIGHT	NOISE REDUCTION PER DOUBLING OF DISTANCE (dB)													
	A-WEIGHTED NOISE		OCTAVE-BAND CENTER FREQUENCY (HZ)											
			125		250		500		1,000		2,000		4,000	
(FEET) (M)	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT
5 (1.5)	8.5	5.5	5.5	5.5	6.5	6.5	7	5	7.5	4	5	3.5	5.5	5.5
9 (2.7)	6	5	5.5	5.5	5.5	6	7.5	4.5	2	2.5	4.5	4	6.5	6
15 (4.6)	4.5	4.5	5	5	5	4	4	1.5	6.5	2.5	2	5	5	4.5
20 (6.1)	3.5	3.5	4.5	5	3.5	3.5	2.5	0	5.5	3	3.5	4	3	3.5

[a] Reference noise level taken at distance of 3 feet (0.9 m) from speaker for each test. Reference levels varied slightly for different frequencies. Distances of 25 (7.6 m), 50 (15 m), 75 (23 m), and 100 feet (30 m) from the reference point were used. White random noise was used for A-weighted measurements, and pink random noise was used for the various frequencies.

TABLE 10. NOISE LEVEL REDUCTION PER DOUBLING OF DISTANCE FOR GRASS COMPARED TO PAVEMENT (NOISE SOURCE AT 8-FOOT (2.4 M) HEIGHT)

MEASUREMENT HEIGHT	NOISE REDUCTION PER DOUBLING OF DISTANCE (dB)													
	A-WEIGHT NOISE		OCTAVE-BAND CENTER FREQUENCY (HZ)											
			125		250		500		1,000		2,000		4,000	
(FEET) (M)	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT	GRASS	PAVEMENT
5 (1.5)	5.5	5.5	2.5	2.5	6	3.5	7.5	6	4.5	5	4.5	4.5	5.5	5.5
9 (2.7)	5.5	5.5	4	4	8	7	5.5	6.5	5.5	4.5	6	5.5	6	6
15 (4.6)	5.5	5.5	7.5	6	6.5	7	5.5	5	5	4.5	5	4.5	7	6.5
20 (6.1)	5	4.5	7	6	4	4.5	5.5	4.5	5	3.5	3	2.5	5.5	6

[a] Reference noise level taken at distance of 3 feet (0.9 m) from speaker for each test. Reference levels varied slightly for different frequencies. Distances of 25 (7.6), 50 (15), 75 (23), and 100 feet (30 m) from the reference point were used. White random noise was used for A-weighted measurements, and pink random noise was used for the various frequencies.

Data on noise reduction in various octave bands are also given in Table 9. The major differences in noise reduction between grass and pavement surfaces occurs in the octave bands centered on 500 and 1,000 Hz. The results (Table 10) show no difference in noise reduction per doubling of distance at any measurement height when the noise source was put at a height of 8 feet (2.4 m). This was found for A-weighted noise and all octave bands.

Also considered was the change in noise level at any given measurement distance as a function of measurement height. Except at locations close to the roadway or noise source, noise increases as measurement height increases. Simultaneous recording of the traffic stream showed that noise levels kept increasing to the highest point of measurement (30 feet (9.1 m)).

A plot of the L_{10} noise levels as a function of receiver height and distance from the roadway for the urban location is given in Figure 8. At 50 feet (15.2 m) from the roadway, the increase in noise level with increased height above the ground ceased at the 20-foot (6.1-m) height. At 25 feet (7.6 m) from the roadway, the noise level was the same at all measurement heights. At 100 feet (30.5 m) from the roadway, the noise level increased very little above the 20-foot (6.10-m) height. However, as the distance from the roadway increased, the noise level increased more with height. Also, the height at which the increase ceased kept increasing as the distance from the roadway increased. At 200 feet (61 m), the noise level appeared to be leveling at the 30-foot (9.1-m) height. Also, at 400 feet (122 m), the increase in noise level from the 20-foot (6.1-m) to 30-foot (9 1-m) height was less than from the 10-foot (3.0-m) to 20-feet (6.1-m) height.

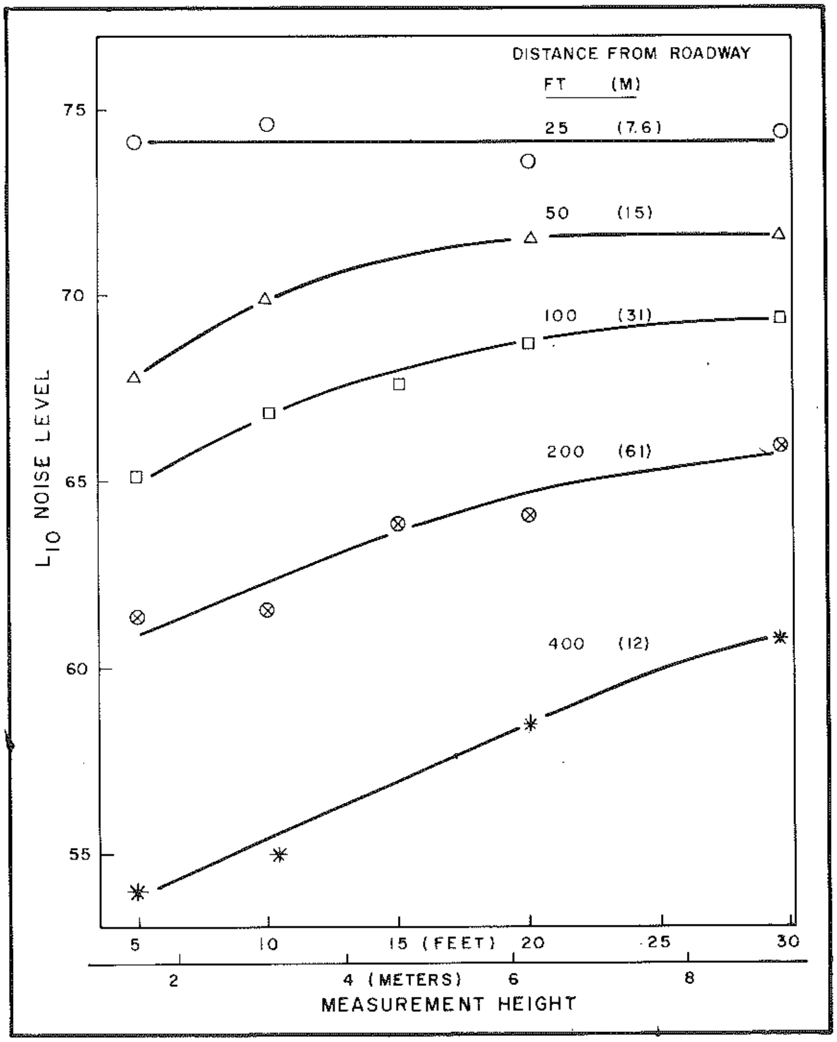


Figure 8. L_{10} Noise Level as a Function of Receiver Height and Distance from Roadway (Site 1).

DISTANCE

Measurements were made to determine how noise drops off as distance increases for a microphone height of 5 feet (1.5 m). Distances ranged from 25 to 400 feet (7.6 to 122 m) for most measurements, and three or four distances were monitored simultaneously to determine noise drop-off per doubling of distance.

On a low-speed urban road (Nicholasville Road in Lexington), data for L_{10}, L_{50}, L_{90}, and L_{eq} were obtained as cited in Table 11. Measurements were made at 25, 50, 100, 200, and 400 feet (7.6, 15, 30, 61, and 122 m) over short grass. The data were used to calculate the drop-off in noise per doubling of distances for L_{10} and L_{eq} (Table 12). The average drop-off per doubling of distance was 3.3 dBA for L_{10} and 3.1 dBA for L_{eq}. Noise drop-offs remained relatively constant per doubling of distance, but dropped slightly between 200 and 400 feet (61 and 122 m). This was probably caused by the low noise levels at 400 feet (122 m) (approached ambient (background) noise).

Plots of L_{10}, L_{eq}, L_{50}, and L_{90} were made for various distances as shown in Figure 9. A linear relationship was found using a log scale of distance. All L_{eq} levels were about halfway between L_{50} and L_{10} values at each distance.

TABLE 11. NOISE LEVELS AT VARIOUS DISTANCES (SITE 1)

DISTANCE FT (M)	NUMBER DATA POINTS	AVERAGE NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}
25 (7.6)	2	70.9	65.6	58.2	67.7
50 (15)	28	67.2	62.6	57.7	64.7
100 (31)	25	63.6	59.8	55.8	61.5
200 (61)	27	59.9	56.4	53.1	57.5
400 (122)	11	57.8	54.3	51.0	55.5

TABLE 12. NOISE LEVEL DROP-OFF PER DOUBLING OF DISTANCE (SITE 1)

DISTANCE FT	M	DROP-OFF PER DOUBLING DISTANCE L_{10}	L_{eq}
25 to 50	8 to 15	3.7	3.0
50 to 100	15 to 31	3.6	3.2
100 to 200	31 to 61	3.7	4.0
200 to 400	61 to 122	2.1	2.0
Average		3.3	3.1

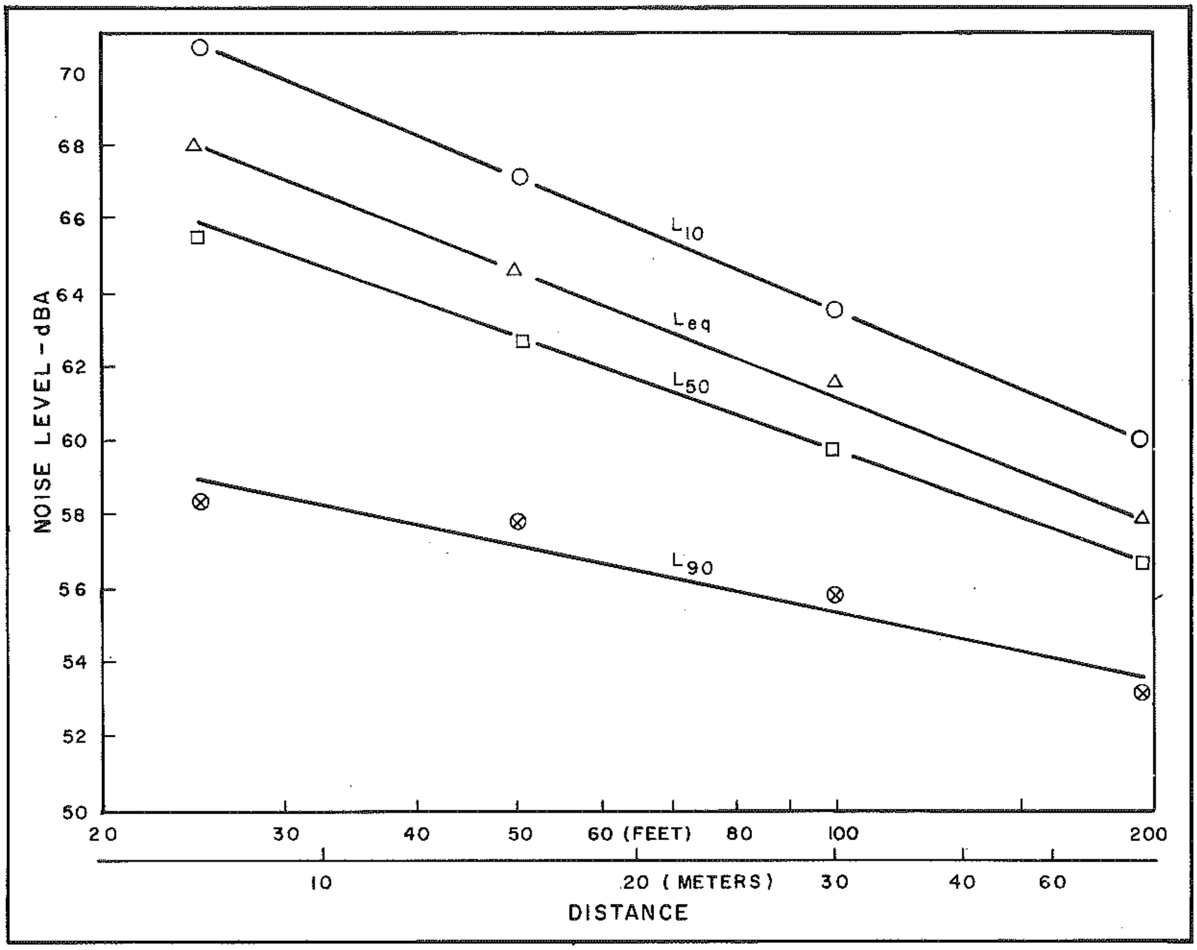


Figure 9. Effect of Distance on Noise Level (Site 1).

Similar data were collected and summarized on a high-speed rural road (US 68 in Fayette County). Distances of 25, 50, 100, and 200 feet (7.6, 15, 30, and 61 m) were used over short grass. Values of L_{10} ranged from 71.9 dBA at 25 feet (7.6 m) to 54.8 dBA at 200 feet (61 m) (Table 13). Drop-offs per doubling of distance averaged 5.7 dBA (L_{10}) and 5.5 dBA (L_{eq}) (Table 14). These average drop-offs were higher than at the urban site, probably because of lower volumes and higher speeds. Plots of L_{10}, L_{eq}, L_{50}, and L_{90} are shown in Figure 10 for various distances. Similar summaries and plots for other locations are given in APPENDIX G.

The equivalent distance was also used to verify these results. When the equivalent distance was used, the noise drop-off increased at distances close to the roadway (less than 50 feet (15 m) from the centerline of the near lane). Using the equivalent distance also increased the noise drop-offs at each distance.

The dual effect of distance and measurement height on noise propagation was then analyzed. Noise data were collected on Nicholasville Road at heights of 5, 10, 20, and 30 feet (1.5, 3.0, 6.1, and 9.1 m) and distances of 25 to 400 feet (7.6 to 122 m). A plot of these data for the L_{10} level is shown in Figure 11. At a distance of 25 feet (7.6 m), noise levels were about the same regardless of height. As distance increased, noise levels were definitely higher at greater measurement heights. At 400 feet (122 m), noise levels at the 30-foot (9-m) height were about 62 dBA compared to 60 dBA at 20 feet (6.1 m), 56 dBA at 10 feet (3.0 m), and 55 dBA at 5 feet (1.5 m). Values of r^2 ranged between 0.96 to 0.99 for all relationships. Similar findings are shown in a plot of L_{eq} values in Figure 12.

The very high correlation found between noise level and distance from the roadway indicated the validity of the assumption that traffic noise attenuation is constant per doubling of distance. Results show that this assumption, which was questioned in a past report *(6)*, is also valid at low-volume locations.

TABLE 13. NOISE LEVELS AT VARIOUS DISTANCES (SITE 2)					
		AVERAGE NOISE LEVEL			
DISTANCE FT (M)	NUMBER DATA POINTS	L_{10}	L_{50}	L_{90}	L_{eq}
25 (7.6)	8	71.9	59.2	47.2	68.7
50 (15)	35	66.7	55.8	47.4	63.3
100 (31)	28	60.4	52.4	45.3	57.6
200 (61)	30	54.8	49.9	45.4	52.3

TABLE 14. NOISE LEVEL DROP-OFFS PER DOUBLING OF DISTANCE (SITE 2)			
DISTANCE		DROP-OFF PER DOUBLING DISTANCE	
FT	M	L_{10}	L_{eq}
25 to 50	8 to 15	5.2	5.4
50 to 100	15 to 31	6.3	5.7
100 to 200	31 to 61	5.6	5.3
Average		5.7	5.5

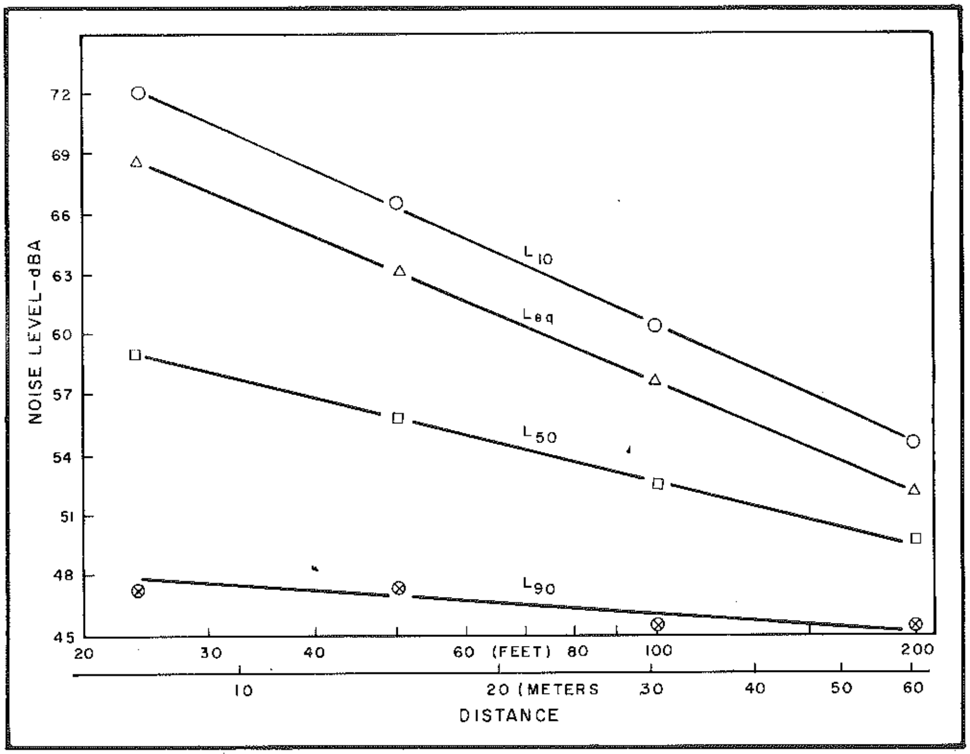


Figure 10. Effect of Distance on Noise Level (Site 2).

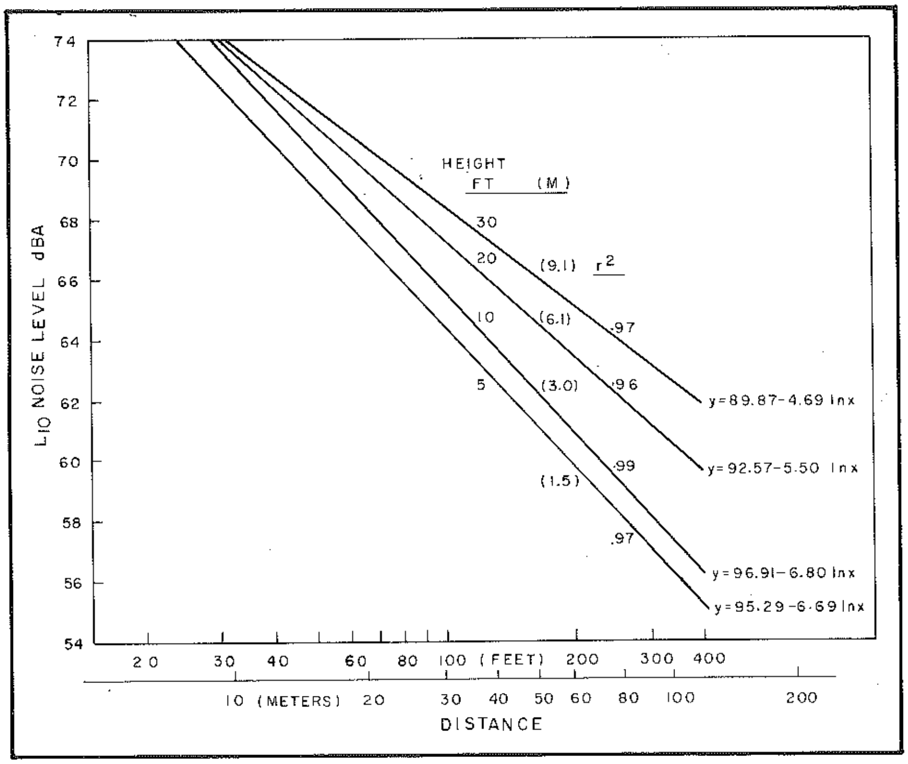


Figure 11. L_{10} Noise Levels for Various Distances and Receiver Heights.

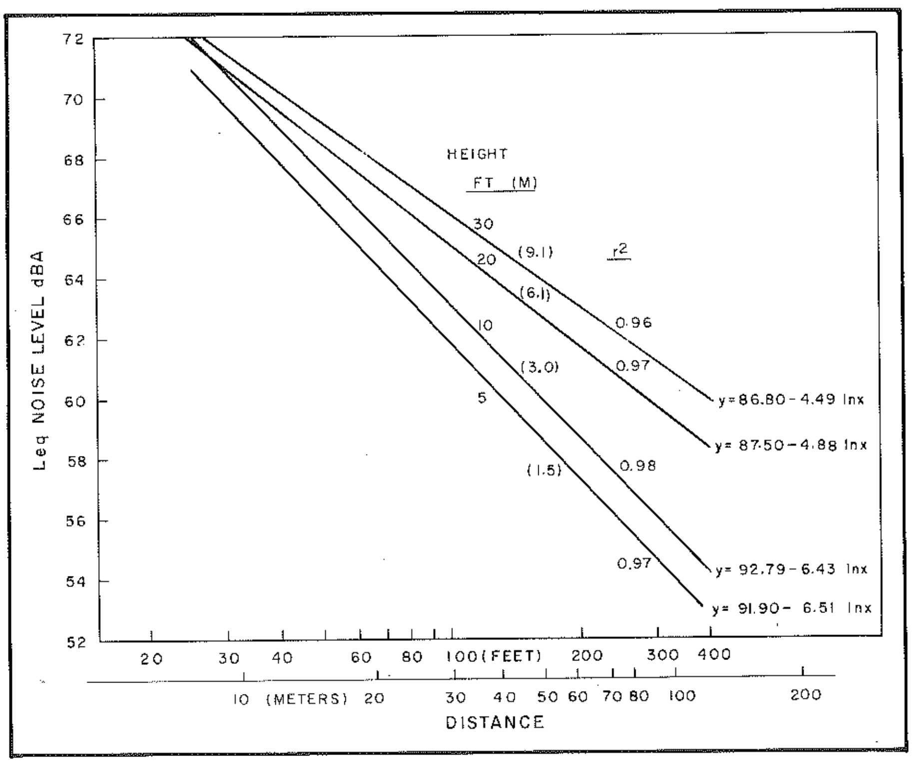


Figure 12. L_{eq} Noise Levels for Various Distances and Receiver Heights.

SPEED

To determine if vehicle speed is related to noise propagation, measurements were taken using a test car. Simultaneous measurements were made as the car was driven by at a constant speed. Data were taken at 25 feet (7.6 m) and 50 feet (15.2 m) from the centerline of the driving lane. Noise from other vehicles caused problems when distances greater than 50 feet (15.2 m) were used. The speeds used were 30, 40, and 50 miles per hour (13.4, 17.9, and 22.4 m/s). Also, data were collected on various ground covers including pavement and short and tall grasses.

The variation in noise propagation as a function of ground cover is illustrated in Table 15. The average reduction for all speeds for a doubling of distance varied from 5.2 dBA for pavement to 8.2 dBA for tall grass. The noise propagation varied with the speed of the test car for short and tall grass ground covers; the noise drop-off increased as vehicle speed increased. The drop-off remained relatively constant over pavement. As speeds increase, tire-pavement noise increases rapidly and becomes the controlling factor in automobile noise. The tire-pavement noise which predominates at higher speeds has a higher frequency than engine noise. Thus, the noise at higher speeds is made up of higher frequencies which were found to have a high drop-off with distance compared to low frequencies.

SOURCE HEIGHT

The random noise generator was used to determine the effect of source height on noise propagation. The speaker was set at ground level and then at 8 feet (2.4 m). The ground level source represented automobile noise. The 8-foot (2.4-m) height represented the noise height for trucks. Microphone heights of 2.5 to 25 feet (0.8 to 7.6 m) were obtained by connecting the microphone to a surveying level rod and adjusting the measurement heights. Distances of 25 to 300 feet (7.6 to 91 m) from the speaker were used.

The first series of measurements were taken with a zero height above grass and pavement. The results for grass are given in Table 16 and for pavement in Table 17.

For a microphone height of 2.5 feet (0.8 m), noise levels over grass were reduced by 11 dBA per doubling of distance compared to only 6 dBA over pavement. As height increased to 10 feet (3 m), the drop-off per doubling of distance over grass decreased sharply to about 5 dBA and then was very similar to pavement from 10 to 25 feet (3 to 9 m). The drop-offs for grass and pavement both approached about 3.0 to 3.5 dBA. The curves in Figure 13 show that the noise drop-off per doubling of distance decreased for both ground covers as measurement height increased. This drop-off is greater for grass than pavement at measurement heights up to 10 feet (3.0 m). Drop-offs per doubling of distance ranged from about 11 dBA to 3 dBA, depending on measurement height.

The other source height used was 8 feet (2.4 m), obtained by mounting the speaker on a platform in the bed of a pickup truck. Data were collected over grass and pavement at heights of 2.5 to 25 feet (0.8 to 7.6 m). Results of these data are given in Tables 18 and 19.

TABLE 15. NOISE PROPAGATION FOR VARIOUS VEHICLE SPEEDS (TEST CAR) AND GROUND COVERS

	NOISE REDUCTION FROM 25 (7.6) TO 50 FEET (15 m)		
SPEED (MPH) (M/S)	SHORT GRASS	PAVEMENT	TALL GRASS
30 (13.4)	4.9	5.3	7.5
40 (17.9)	6.8	4.7	8.1
50 (22.4)	7.5	5.7	9.0
Average (all speeds)	6.4	5.2	8.2

TABLE 16. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (GRASS GROUND COVER AND NOISE SOURCE AT GROUND LEVEL)[a]

DISTANCE FEET (m)[b]	NOISE LEVEL (dBA) HEIGHT, FEET (m) 2.5 (.8)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	88.5	88	88.5	83	81	79
50 (15)	83	84	82	80.5	79.5	77.5
75 (23)	77	79	79	79	77	75.5
100 (30)	69	76	76	76	75	74
125 (38)	63	71	74	74	74	73
150 (46)	56	63	72	72	72.5	73
175 (53)	c	61	70	71	71	71
200 (61)	c	59	67	68.5	69	69
225 (69)	c	c	62	67.5	67.5	68
250 (76)	c	c	60	64	64.5	64.5

a Reference noise level was 95 dBA at 3 feet (.9 m) from speaker at 5-foot (1.5-m) height.
b Distance from reference point which was 3 feet (.9 m) from speaker.
c Noise level was too close to the ambient.

TABLE 17. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (PAVEMENT GROUND COVER AND NOISE SOURCE AT GROUND LEVEL)[a]

DISTANCE FEET (M)[b]	NOISE LEVEL (dBA) HEIGHT, FEET (m) 2.5 (.8m)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	89.5	88.5	87	84	82	79.5
50 (15)	84.5	83	82.5	81	80.5	79
75 (23)	82	81.5	80.5	79	78	76.5
100 (30)	80	78.5	77.5	76.5	75.5	74.5
125 (38)	77	77.5	76.5	74	74	74
150 (46)	75	76.5	76	72	72	72.5
175 (53)	71	74.5	74	71.5	71	71.5
200 (61)	67.5	72	72	71	70	69.5
225 (69)	64	71	71	70.5	69.5	68.5
250 (76)	63	66	68	69	68.5	68
275 (84)	60	65	67	67	68	67.5
300 (91)	58	61	63.5	64	67	67

a Reference noise level was 95dBA at 3 feet (.9 m) from speaker at 5 foot (1.5-m) height.
b Distance from reference point which was 3 feet (.9 m) from speaker.

Figure 13. Noise Level Reduction per Doubling of Distance for Grass Compared to Pavement (Noise Source at Ground Level) (A-weighted Noise).

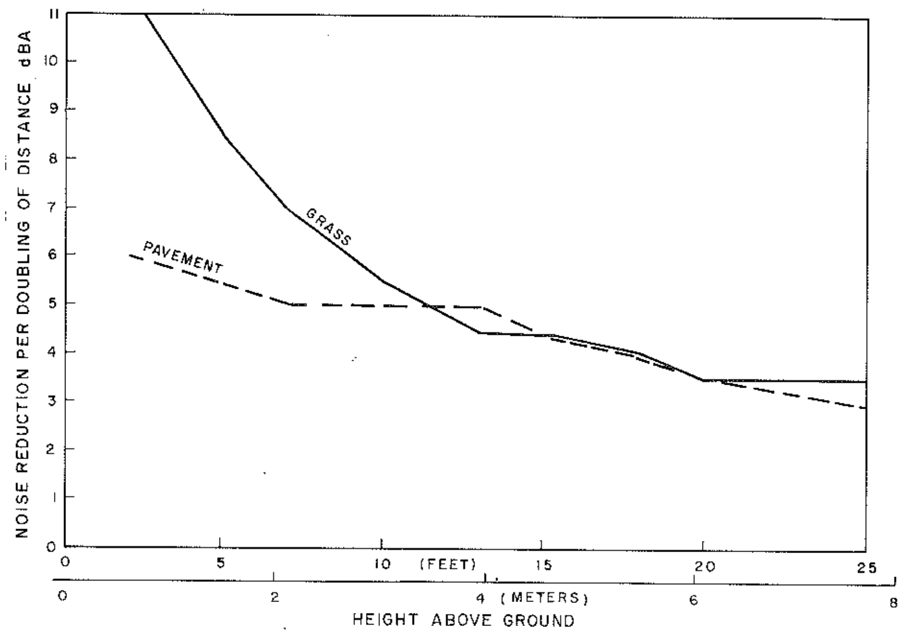


TABLE 18. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (GRASS GROUND COVER AND NOISE SOURCE AT 8-FOOT (2.4-M) HEIGHT)[a]

	NOISE LEVEL (dBA)					
	HEIGHT, FEET (m)					
DISTANCE FEET (M)[b]	2.5 (.8)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	87	88	87	86.5	85	82
50 (15)	83.5	83.5	82	81.5	80	80
75 (23)	80.5	80	79	77	77	77
100 (30)	77	77.5	76	75	75	75
125 (38)	76	74.5	74.5	74	73	73
150 (46)	75	73	72.5	72	71.5	70.5
175 (53)	74	73	71.5	71	70.5	69.5
200 (61)	72.5	72.5	71	70	69.5	68.5
225 (69)	71.5	72	69	69	68.5	67.5
250 (76)	67.5	70.5	68	68	67.5	66.5
275 (84)	64	68	66	66	65.5	66
300 (91)	59	66	66	65	64.5	65

[a] Reference noise level was 93 dBA at 3 feet (.9 m) from speaker at 5-foot (1.5-m) height.

[b] Distance from reference point which was 3 feet (.9 m) from speaker.

TABLE 19. NOISE LEVEL AT VARIOUS DISTANCES AND HEIGHTS FROM A CONSTANT NOISE SOURCE (PAVEMENT GROUND COVER AND NOISE SOURCE AT 8-FOOT (2.4-M) HEIGHT)[a]

	NOISE LEVEL (dBA)					
	HEIGHT, FEET (m)					
DISTANCE FEET (M)[b]	2.5 (.8)	5 (1.5)	10 (3.0)	15 (4.6)	20 (6.1)	25 (7.6)
25 (7.6)	86.5	88.5	88	86.5	85	82.5
50 (15)	84	84	82.5	82	81.5	80.5
75 (23)	82	81	79.5	79	79	78.5
100 (30)	79	79	77.5	76.5	76	76
125 (38)	76	76	75	75	74	73.5
150 (46)	74	74	73.5	73.5	73.5	72.5
175 (53)	73.5	73	72	72.5	72	71.5
200 (61)	73	71	71	71	70.5	70
225 (69)	69	69	68.5	69	67.5	67.5
250 (76)	69	69	68.5	69	67.5	67.5
275 (84)	66	68	67.5	68	67	66.5
300 (91)	65	67.5	66	66	65.5	65

[a] Reference noise level was 93 dBA at 3 feet (.9 m) from speaker at 5-foot (1.5-m) height.
[b] Distance from reference point which was 3 feet (.9 m) from speaker.

For the 8-foot (2.4-m) source height, the noise reduction per doubling of distance was plotted for grass and pavement surfaces for various measurement heights (Figure 14). For both ground covers, the noise reduction per doubling of distance remained at 5.5 dBA for measurement heights up to 15 feet (4.6 m). Above 15 feet (4.6 m), reductions dropped to 3.5 dBA over pavement and 4.0 dBA over grass. Thus, ground cover has little if any effect on noise propagation for 8-foot (2.4-m) source heights. Also, the drop-off per doubling of distance is nearly constant at around 5.5 dBA for an 8-foot (2.4-m) source height at measurement heights up to 15 feet (4.6 m).

In summary, ground cover had very little influence on noise propagation when the source height was 8 feet (2.4 m). When the noise source was at ground level, ground cover influenced noise propagation up to a receiver height of about 10 feet (3 m).

PERCENTAGE LEVEL

Noise reduction per doubling of distance was found for L_{10}, L_{50}, L_{90}, and L_{eq} at these locations. The locations included a low-volume location (hourly volume below 1,000) on Harrodsburg Road, a medium-volume location (hourly volume around 2,000) on Nicholasville Road, and a high-volume location on I 264 in Louisville (hourly volumes above 3,000) (Table 20).

The average drop-off per doubling of distance for all sites was 4.5 dBA for L_{10} and 4.4 dBA for L_{eq}. At the low-volume location, drop-offs were 5.7 and 5.5 dBA for L_{10} and L_{eq}. At the high-volume site, drop-offs of 4.6 dBA were observed for both L_{10} and L_{eq}. At the medium-volume site, lower drop-offs in L_{10} (3.3 dBA) and L_{eq} (3.1 dBA) were found. These could have resulted from the lower speeds and low truck volumes.

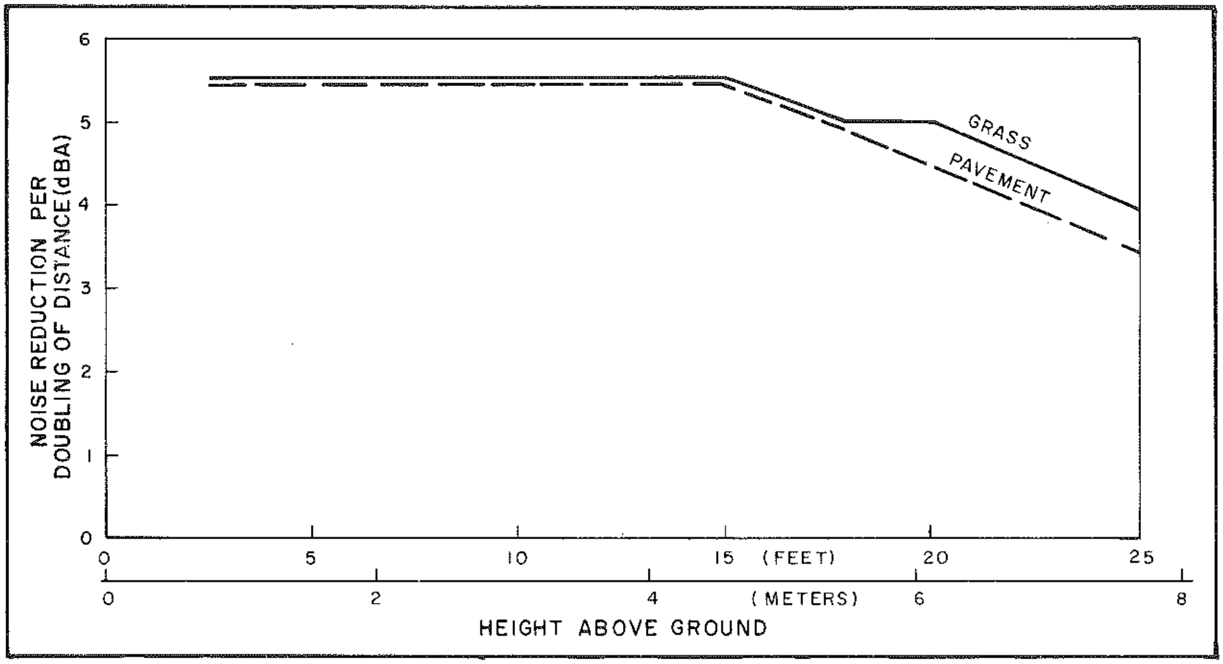


Figure 14. Noise Level Reduction per Doubling of Distance for Grass Compared to Pavement (Noise Source at 8-Foot (2.4-m) Height) (A-weighted Noise).

TABLE 20. TRAFFIC NOISE REDUCTION PER DOUBLING OF DISTANCE FOR VARIOUS VOLUMES OF TRAFFIC AND NOISE DESCRIPTIONS

NOISE DESCRIPTOR	TRAFFIC NOISE REDUCTION PER DOUBLING OF DISTANCE			
	LOW VOLUME LOCATION (<1000 VPH)[a]	MEDIUM VOLUME LOCATION (≈2000 VPH)[b]	HIGH VOLUME LOCATION (>3000 VPH)[c]	AVERAGE
L_{10}	5.7	3.3	4.6	4.5
L_{50}	3.1	2.8	4.1	3.3
L_{90}	0.9	1.8	3.5	2.1
L_{eq}	5.5	3.1	4.6	4.4

[a] US 68 (Harrodsburg Road) in Fayette County
[b] Nicholasville Road in Lexington
[c] Watterson Expressway (I-264) in Louisville

The drop-offs in L_{50} averaged 3.3 dBA for all sites. The L_{90} drop-offs averaged only 2.1 dBA, since these levels often approach ambient levels, especially at low volume sites. The L_{90} drop-offs were lowest (0.9 dBA) at the low-volume site and highest (3.5 dBA) at the high-volume location. Drop-offs in L_{50} at the sites varied between 2.8 and 4.1 dBA.

A distribution of noise levels (dBA) was plotted by percentage level for all six locations in Figure 15. The graph shows that, at 100 feet (30 m), noise levels were highest on I 75 and lowest on Harrodsburg Road. Values of L_{max}, L_{10}, L_{50}, L_{90}, and L_{min} were plotted for each location to show this noise distribution.

Plots were also made to show the distribution of noise levels for various heights at distances of 50 feet (15 m) (Figure 16), 100 feet (30 m) (Figure 17), 200 feet (61 m) (Figure 18), and 400 feet (122 m) (Figure 19). These distributions were based on data collected on Nicholasville Road at measurement heights of 5, 10, 20, and 30 feet (1.5, 3.0, 6.1, and 9.1 m). Again, L_{max}, L_{10}, L_{50}, L_{90}, and L_{min} noise levels were used to determine these distributions. At 100 feet (30 m), the curves are evenly spaced. The 5- and 10-foot (1.5 and 3.0-m) receiver-height curves are closely spaced for 200 and 400 feet (61 and 122 m). At 50 feet (15 m), the 5-foot (1.5-m) curve is considerably lower than the others, and all curves have large ranges between minimum and maximum values.

The data showed that the noise drop-off varies with the percentage level used to describe the noise. In general, as the percentage level becomes smaller, the noise drop-off increased. However, the difference in drop-off between the various percentage levels decreased as the traffic volume increased. At volumes over 4,000 vph, the difference in the noise drop-off disappeared.

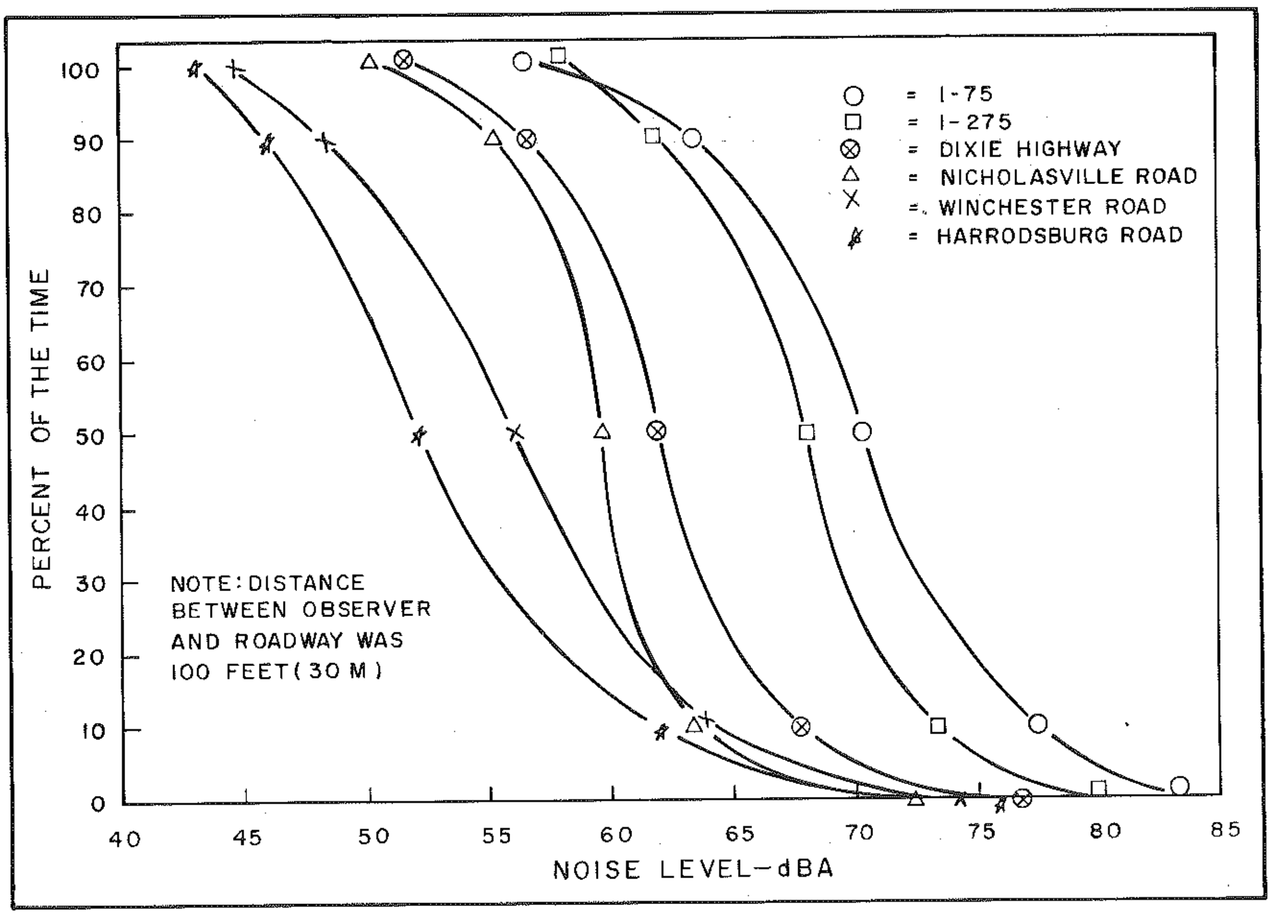


Figure 15. Distribution of Noise Levels at Six Test Locations.

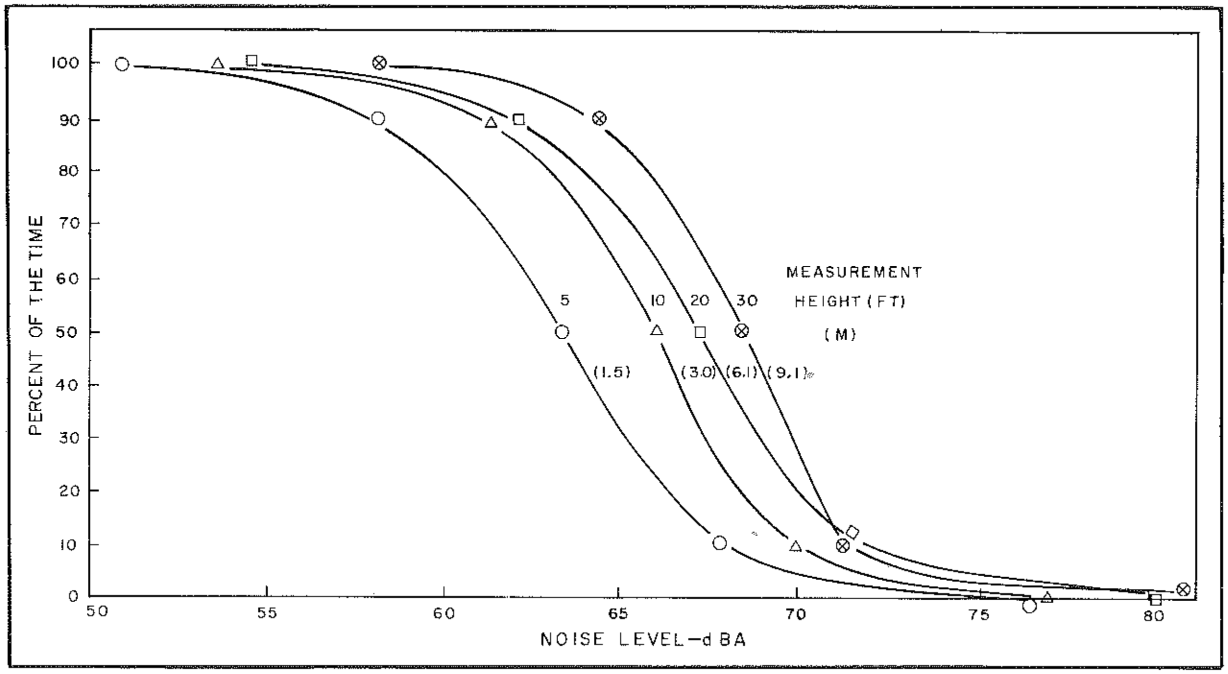


Figure 16. Distribution of Noise Levels for Various Receiver Heights at a Distance of 50 Feet (15.2 m) (Site 1).

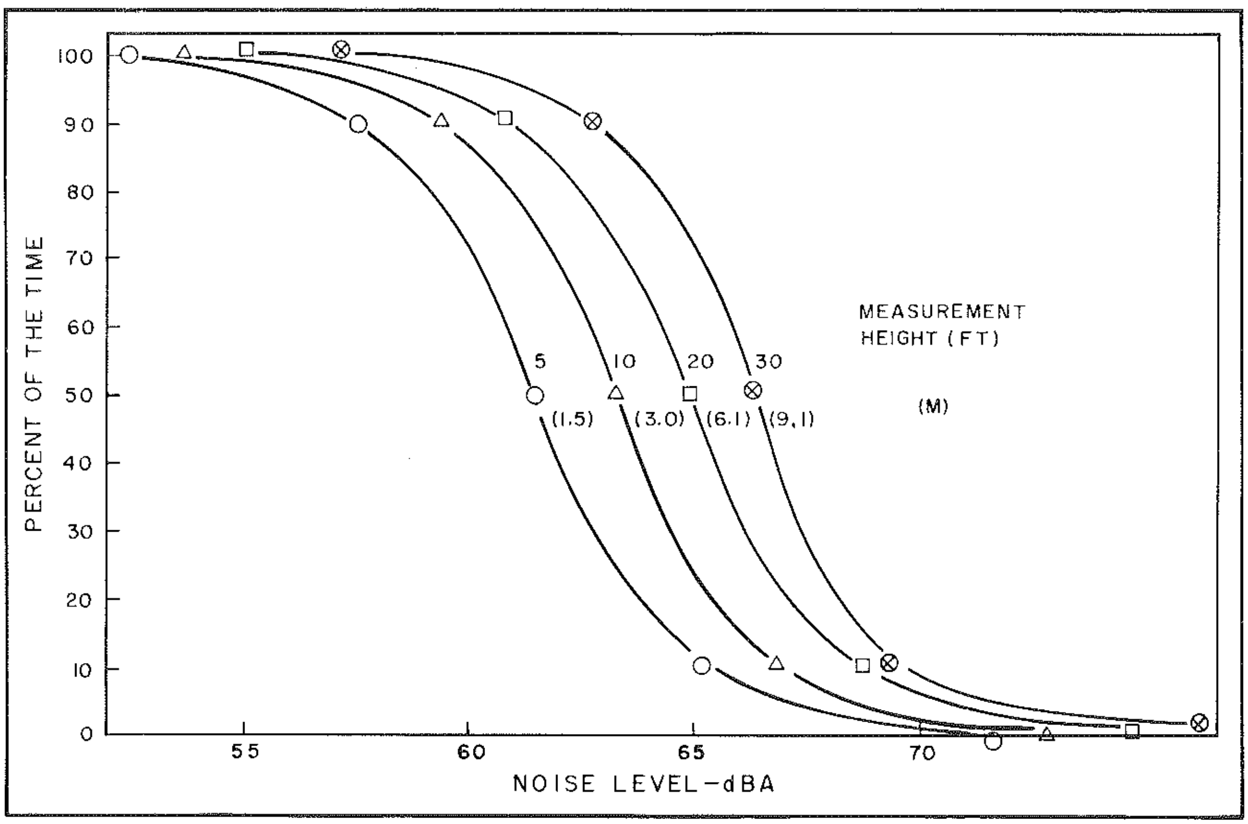


Figure 17. Distribution of Noise Levels for Various Reciever Heights at a Distance of 100 Feet (30.5 m) (Site 1).

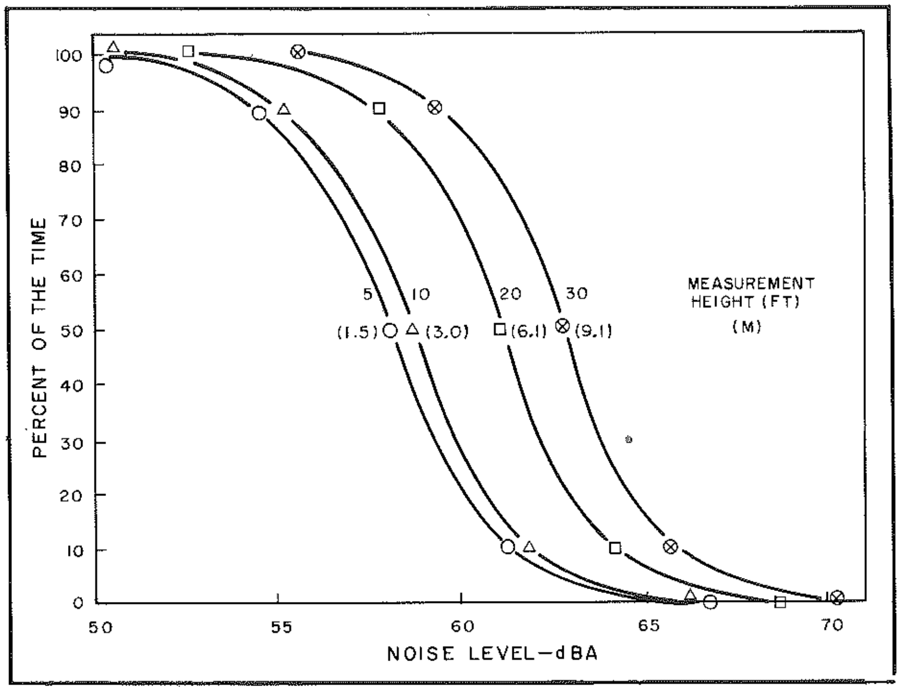


Figure 18. Distribution of Noise Levels for Various Receiver Heights at a Distance of 200 Feet (61.0 m) (Site 1).

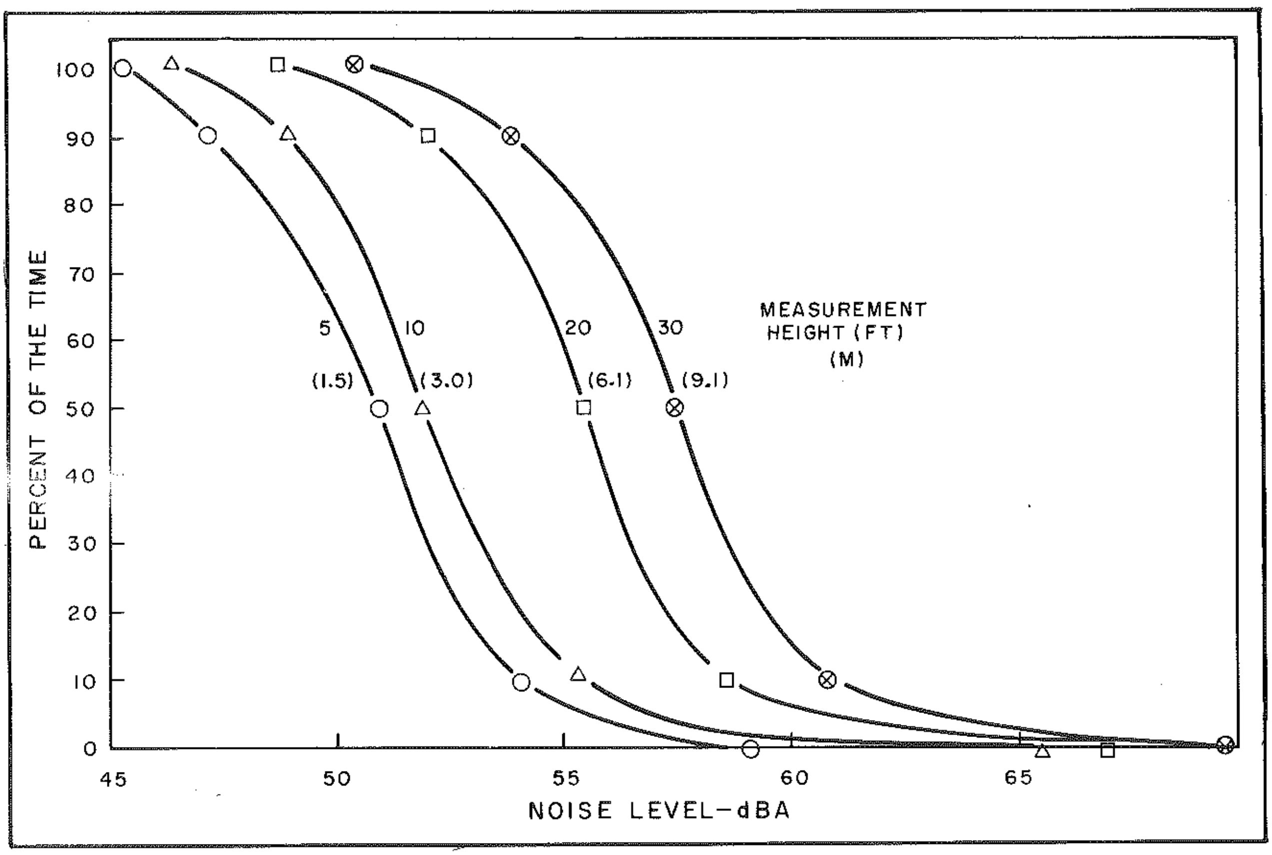


Figure 19. Distribution of Noise Levels for Various Receiver Heights at a Distance of 400 Feet (121.9 m) (Site 1).

TYPE OF VEHICLE

Measurements were made of individual automobile and truck noise levels with a sound-level meter employing the A-weighting network. Measurements were taken at 50 feet (15 m) and 100 feet (30 m) from the center of the traffic lane and approximately 4 feet (1.2 m) above ground. The vehicle type and noise level were recorded manually as a vehicle passed. Measurements were taken only when the noise emitted by a single vehicle could be clearly isolated or distinguished from the noise of the traffic stream.

Results from this analysis are given in Table 21. The data were taken at several locations which were classified as urban, interstate, and rural non-interstate roads. These road categories were based primarily on traffic speeds. Average automobile speeds ranged from 40 mph (18 m/s) on the urban roads to 54 mph (24 m/s) at the rural non-interstate roads, and 62 mph (28 m/s) on the interstate roads. Three different vehicle types were used to represent the various types of vehicles on the highway. These categories corresponded to those types listed in the new noise prediction design guide *(4)*. Noise data obtained from single-unit, two-axle, six-tire trucks were used to represent the medium truck category. Noise readings were obtained for over 8,000 vehicles which included approximately 6,000 automobiles, 1,000 medium trucks, and 1,000 heavy trucks.

Results indicated that the noise drop-off with distance for automobiles was slightly higher for the high-speed locations. This agrees with the findings shown in Table 15.

The noise drop-off with distance for heavy trucks was also higher at the high-speed locations. The average speeds for the heavy-truck category ranged from 35 mph (16 m/s) on the urban roads to 51 mph (23 m/s) on the rural non-interstate roads and 61 mph (27 m/s) on the interstate roads. The reason for the increase in noise drop-off may be attributable to a change in the frequency distribution of the noise to a higher proportion of high-frequency noise at higher speeds. This change occurs for automobiles *(2)*. The higher frequencies have a higher drop-off with distance. At higher speeds, tire noise may constitute a large proportion of the noise; this would lower the overall source height which also would lead to a larger drop-off. When all locations were considered, the noise reduction was close to 6.0 dBA per doubling of distance for both automobiles and heavy trucks.

At urban locations where the speed is low, automobiles had a larger drop-off with distance compared to heavy trucks; however, on the high-speed, interstate roads, heavy trucks had a larger drop-off than automobiles. The medium truck category had the largest overall drop-off. Inconsistancy in the data made generalized conclusions difficult.

TABLE 21. PROPAGATION OF NOISE FROM VARIOUS TYPES OF VEHICLES AND DISTANCES FROM THE ROADWAY

	NOISE REDUCTION FROM 50 FEET (15 M) TO 100 FEET (30 M)[a]		
	VEHICLE TYPE		
TYPE OF ROAD	AUTOMOBILE	MEDIUM TRUCK[b]	HEAVY TRUCK[c]
Urban	5.8	6.8	4.6
Rural, Non-Interstate	6.5	5.5	6.4
Interstate	6.3	8.3	7.6
All	6.0	6.9	6.2

[a] The distances were measured from the centerline of the traffic lane.
[b] Single-unit, two-axle, six-tire truck.
[c] Combination, five-axle truck.

SUMMARY AND CONCLUSIONS

TRAFFIC VOLUME

1. The L_{10} noise level reduction per doubling of distance increased substantially when traffic volume was less than 1,000 vph. For the peak volumes experienced in Kentucky, the noise reduction did not decrease significantly below 4.5 dBA per doubling of distance.

2. The L_{eq} noise level reduction increased for traffic volumes less than 1,000 vph; however, the increase was not quite as dramatic as the L_{10} level.

3. When L_{50} levels were considered, the drop-off in noise was not significantly affected by traffic volume.

4. Truck volumes did not alter findings concerning the relationship between noise level reduction per doubling of distance and traffic volumes.

WIND

1. Large fluctuations in noise drop-off at a given site for similar traffic volumes were found to be partially explained by the effect of wind. Very good relationships were found between noise drop-off and wind vector (component of the wind blowing either directly toward or away from the roadway).

2. Reliable data could not be obtained when the wind vector speed was greater than 10 knots (11.5 mph (5 m/s)).

GROUND COVER

1. Based on traffic stream data, drop-offs in L_{10} noise per doubling of distance were 5.0 dBA over short grass, 2.9 dBA over pavement, and 5.8 dBA over tall grass for high-volume roads. Slightly larger drop-offs were found on low-volume roads.

2. Data obtained using a random noise generator showed that ground cover can have a significant effect on noise attenuation. Using short grass as a reference surface, higher noise attenuation per doubling of distance was found for high weeds (3.5 dBA). Attenuation over high grass, medium grass, smooth dirt, snow, and plowed field was within 1.0 dBA of short grass. Attenuation per doubling of distance was lower on gravel (1.5 dBA) and pavement (2.0 dBA) compared to short grass.

3. Low frequency noise (octave-bands centered at 63, 125, and 250 hz) was affected very little by ground cover. Compared to short grass, high grass and weeds have higher attenuations at high frequencies (above 1,000 Hz); plowed field and smooth ground had attenuation of 2 to 3 dB higher at 500 Hz; pavement had a decrease in attenuation of about 7 dB at 2,000 Hz; and snow had 3.5 dB higher attenuation at 250 and 500 Hz.

4. A comparison of the attenuation provided by pavement and high weeds showed that ground cover can have a significant effect on noise propagation. However, various heights of grass showed that typical right-of-way ground covers did not significantly affect noise attenuation.

RECEIVER HEIGHT

1. Data from both traffic stream and random noise generator showed that changes in noise attenuation occurred at heights above 10 feet (3.0 m); the drop-off per doubling of distance decreased from about 4.5 dBA for receiver heights of 10 feet (3.0 m) or below to slightly over 3.0 dBA for heights above 10 feet (3.0 m).

2. For receivers heights above 10 feet (3.0 m), ground cover had no significant influence on attenuation.

3. The major differences in propagation loss between grass and pavement occurred in the octave bands with center frequencies of 500 and 1,000 Hz.

4. No difference in noise reduction per doubling of distance was found at any measurement height when the noise source was at a height of 8 feet (2.4 m).

5. Except at locations close to the roadway (closer than about 50 feet (15 m)), noise increased as height of the receiver increased.

6. Up to 400 feet (122 m) from the roadway, the noise level increased with height of the receiver. Also, the height at which the increase in noise level ceased increased with distance from the roadway.

DISTANCE

1. Up to about 400 feet (122 m), noise drop-offs (dBA) remained constant per doubling of distance. When the equivalent distance was used, the noise drop-off increased at distances close to the roadway (less than 50 feet (15 m) from the centerline of the near lane).

2. Logarithmic best-fit curves for L_{10} and L_{eq} were determined for heights of 5 to 30 feet (1.5 to 9.1 m) and distances of 25 to 400 feet (8 to 22 m) (one site). Values of r^2 ranged from 0.96 to 0.99.

3. The very high correlation between noise level and distance from the roadway validated the assumption that traffic noise attenuation is constant per doubling of distance.

SPEED

Using a test car driven at various speeds, noise drop-off with distance increased over grass as vehicle speed increased. No changes with speed were noted over pavement surfaces.

SOURCE HEIGHT

1. For a ground level noise source over grass, noise drop-off per doubling of distance varied from 11 at a 2.5-feet (0.8-m) receiver height to 3.5 dBA at a 25-foot (7.6-m) height. Over pavement, the drop-off per doubling of distance varied from 6 dBA at 2.5 feet (0.8 m) to 3 dBA at 25 feet (7.6 m).

2. For an 8-foot (2.4-m) source height, the drop-off per doubling of distance was found to be constant at 5.5 dBA over grass and pavement for receiver heights up to about 15 feet (4.6 m). Above 15 feet (4.6 m), the drop-offs decreased to about 4 dBA at 25 feet (2.6 m).

3. Ground cover had very little influence on noise propagation when the source height was 8 feet (2.4 m). When the noise source was at ground level, ground cover influenced noise propagation up to measurement heights of about 10 feet (3.0 m).

PERCENTAGE LEVEL

1. At three locations with varying traffic volumes and speeds, the average drop-off in noise level per doubling of distance was 4.5 dBA for L_{10}, 4.4 for L_{eq}, 3.3 for L_{50}, and 2.1 dBA for L_{90}.

2. In general, as the percentage level became smaller, the noise drop-off per doubling of distance increased. The difference in drop-off between the various percentage levels decreased as the traffic volume increased. At volumes over 4,000 vph, this difference disappeared.

TYPE OF VEHICLE

Individual noise readings indicated that noise propagation was influenced by vehicle type and speed. This was related to the differences in frequency distribution and source height of different vehicles and the changes that occur at different speeds. Noise attenuation generally increased with increased vehicle speed. On urban roads, automobile noise showed a larger drop-off with distance compared to heavy trucks; however, on high-speed interstate roads, heavy trucks had a larger drop-off than automobiles. Inconsistencies in the data made general conclusions difficult.

RECOMMENDATIONS

1. The reduction per doubling of distance used to predict L_{10} noise levels should be increased to 5.0 dBA for volumes less than 1,000 vph.

2. For receiver heights of 10 feet (3.0 m) or below, a noise drop-off of 3.0 dBA per doubling of distance should be used for reflective ground covers (pavement); a 4.5-dBA reduction should be used for normally absorptive ground covers; and a 6.0-dBA reduction should be used for extremely absorptive ground covers (high weeds).

3. For receiver heights above 10 feet (3.0 m), a 3.0-dBA drop-off per doubling of distance should be used regardless of the type of ground cover.

4. The noise propagation factor should be constant per doubling of distance.

5. Traffic noise data should not be taken when the component of the wind either blowing toward or away from the roadway exceeds 10 knots (11.5 mph (5/m)).

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APPENDIX A

SUMMARY OF
TRAFFIC STREAM NOISE
(8 SITES AT 5-FOOT (1.5-m) HEIGHT ON SHORT GRASS

TABLE A1. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 1) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
2-24-76	1	50(15)	70.5	65.8	59.2	67.6	75.9	54.1	2184	36	6	2226	2280
		100(30)	65.6	62.9	56.7	63.4	72.1	52.6					
		400(122)	57.4	54.7	51.8	55.4	62.6	49.2					
	2	50(15)	71.0	66.9	62.6	68.0	75.6	54.4	1824	30	12	1866	1932
		100(30)	66.4	63.1	59.2	64.1	73.1	52.8					
		400(122)	61.0	56.2	52.8	57.4	56.6	50.3					
	3	50(15)	70.5	66.3	61.0	67.6	75.9	50.8	2484	42	0	2526	2568
		100(30)	65.1	62.1	58.2	63.0	70.3	49.7					
		400(122)	59.0	55.5	52.6	56.2	64.1	49.0					
	4	50(15)	70.5	67.2	63.3	68.2	76.4	56.9	2328	42	12	2382	2460
		100(30)	66.2	63.1	59.7	63.9	71.8	54.9					
		400(122)	58.7	55.6	52.8	56.5	65.1	50.8					
	5	50(15)	70.0	66.1	61.0	67.5	75.9	54.6	2382	24	12	2418	2478
		100(30)	66.2	62.6	58.2	63.6	73.6	53.8					
		400(122)	56.4	54.0	51.3	54.8	63.3	48.5					
6-29-76	6	50(15)	68.2	65.1	61.3	66.1	76.2	55.6	2766	24	0	2790	2814
		100(30)	64.1	60.5	57.2	61.5	71.3	52.3					
		400(122)	58.5	54.1	50.8	56.0	70.3	42.3					
	7	50(15)	68.2	64.9	61.5	65.9	74.6	53.3	2904	6	0	2910	2916
		100(30)	63.1	60.2	57.4	60.8	67.7	51.5					
		400(122)	56.9	53.2	49.0	54.4	63.6	46.4					
	8	50(15)	67.9	64.2	60.5	65.5	76.7	49.5	2862	12	6	2880	2910
		100(30)	63.1	59.8	56.7	60.8	70.5	47.7					
		400(122)	56.9	53.7	50.8	54.5	62.6	47.4					
	9	50(15)	67.7	63.6	59.0	67.5	88.7	48.5	2676	24	0	2700	2724
		100(30)	62.6	59.3	55.1	64.6	85.6	47.2					
		400(122)	57.4	53.4	49.7	56.9	73.3	44.9					
11-3-77	1	50(15)	65.4	59.4	54.6	62.4	76.4	50.0	1794	60	12	1866	1962
		200(61)	58.7	55.2	51.8	56.4	66.2	49.7					
	2	50(15)	64.1	58.7	53.6	61.0	76.4	48.7	1818	42	0	1860	1902
		200(61)	57.2	54.3	51.5	55.0	65.4	48.5					
	3	50(15)	64.6	58.4	52.1	60.7	70.8	48.2	1662	18	6	1686	1722
		200(61)	56.9	53.6	50.5	54.3	62.3	46.7					
	4	50(15)	63.8	58.2	52.8	60.4	72.8	47.4	1806	30	6	1842	1890
		200(61)	56.7	53.4	50.5	54.0	59.2	47.9					
11-9-77	1	200(61)	67.6	58.2	54.0	60.0	73.1	51.5	2046	6	0	2052	2058
	2	200(61)	61.3	57.0	53.1	58.3	68.5	49.7	1806	48	0	1854	1902
	3	200(61)	59.5	56.4	53.3	57.2	66.9	49.2	1692	0	0	1692	1692
	4	200(61)	59.7	57.2	54.9	57.6	63.3	51.0	1650	0	0	1650	1650
4-10-78	1	50(15)	69.7	65.3	61.5	66.3	71.5	55.6	1464	30	18	1512	1596
		100(30)	64.1	60.5	56.4	61.7	73.6	51.3					
		200(61)	62.3	58.9	55.1	60.1	68.5	43.3					
	2	50(15)	67.7	63.7	59.5	64.8	71.0	55.6	1524	48	30	1602	1740
		100(30)	63.6	60.1	56.4	61.0	70.0	51.0					
		200(61)	61.3	58.4	55.4	59.0	65.9	50.8					
	3	75(23)	65.4	61.6	57.4	62.8	74.1	50.8	1992	60	24	2076	2208
		150(46)											
		300(91)	60.8	58.1	55.6	58.6	63.3	48.7					
	4	75(23)	64.4	60.8	56.9	62.0	72.6	51.5	1956	24	12	1992	2052
		150(46)											
		300(91)	58.5	56.5	54.4	56.8	61.0	50.0					
6-13-78	1	50(15)	63.6	59.2	53.1	60.9	69.7	47.7	1560	18		1578	1596
		100(30)	60.3	55.7	50.8	57.6	69.7	47.7					
		200(61)	57.9	54.4	50.8	56.0	69.7	47.7					

TABLE A1. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
10-11-76	1	50(15)	68.2	63.8	58.5	65.7	77.9	53.8	1656	60	12	1728	1824
		100(30)	64.1	60.1	55.9	61.7	74.4	52.1					
		200(61)	59.5	56.4	53.6	57.2	67.4	50.3					
	2	50(15)	67.9	63.8	59.2	65.2	75.6	53.1	1932	42	6	1980	2040
		100(30)	63.6	60.3	56.9	61.2	70.0	52.6					
		200(61)	60.0	56.7	53.8	57.5	65.9	49.7					
	3	50(15)	67.9	63.3	57.2	66.2	80.0	52.8	1431	26	0	1457	1483
		100(30)	64.1	59.9	55.4	63.2	81.3	52.8					
		200(61)	61.3	56.9	53.3	58.6	69.0	47.4					
	4	50(15)	67.7	63.5	58.2	68.4	88.7	52.6	2034	60	0	2094	2154
		100(30)	61.8	59.3	56.4	59.7	62.8	52.8					
		200(61)	59.2	56.7	53.3	58.3	71.5	48.2					
	5	50(15)	66.7	63.1	59.0	69.0	93.6	53.1	1884	36	6	1926	1960
		100(30)	61.8	59.6	56.7	64.5	87.7	53.1					
		200(61)	58.7	56.1	53.8	57.5	75.6	50.0					
4-13-77	1	25(7.6)	70.3	64.8	57.7	67.0	78.7	49.0	1806	66	6	1878	1912
		50(15)	67.7	62.6	56.4	64.6	79.0	50.3					
		100(30)	65.6	61.0	56.4	62.6	72.8	50.8					
		200(61)	61.7	56.9	52.8	58.3	69.0	48.7					
	2	25(7.6)	71.5	66.3	58.7	68.4	76.4	51.5	1722	42	0	1764	1806
		50(15)	67.2	62.5	56.2	64.2	72.1	49.5					
		100(30)	65.6	61.4	56.2	62.7	69.5	48.2					
		200(61)	61.5	57.6	54.0	58.5	64.2	49.5					
	3	35(11)	67.7	64.0	58.7	66.7	82.1	44.6	2088	36	6	2130	2184
		80(24)	65.9	61.9	56.9	64.7	79.7	46.4					
		160(49)	63.3	59.5	54.9	62.3	76.4	47.9					
		320(98)	59.6	56.0	52.8	58.8	72.3	48.4					
	4	35(11)	67.2	63.1	56.9	64.6	75.6	49.5	2148	60	0	2208	2268
		80(24)	64.6	61.1	55.6	62.5	76.9	48.7					
		160(49)	63.1	59.0	54.6	60.2	69.0	48.7					
		320(98)	58.7	55.7	52.1	56.5	65.9	47.8					
	5	60(18)	66.4	63.4	60.3	64.1	69.5	53.1	2016	96	12	2124	2256
		120(37)	65.4	61.9	57.7	62.9	71.5	53.1					
		240(78)	60.0	57.1	54.4	57.7	65.6	51.0					
	6	60(18)	66.4	63.7	60.8	64.2	70.0	54.9	2334	42	12	2382	2466
		200(61)	64.4	61.2	58.2	62.0	73.8	54.1					
		240(73)	60.0	57.7	55.1	58.2	69.7	52.3					
		480(146)	56.7	54.6	52.6	55.0	63.5	49.7					
	7	60(18)	65.1	61.7	58.2	62.8	75.9	44.6	2112	48	6	2166	2232
		200(61)	62.8	59.6	56.2	60.4	68.5	50.3					
		300(91)	59.5	56.5	53.3	57.1	67.4	50.5					
		400(122)	58.7	55.9	53.1	56.4	64.2	50.8					
10-18-77	1	50(15)	64.9	59.7	54.4	61.6	76.9	51.0	1920	84	0	2004	2088
		100(30)	62.3	57.8	54.1	59.2	68.2	50.0					
		200(61)	60.0	56.3	53.1	57.4	68.2	49.0					
	2	50(15)	64.6	59.1	53.6	61.1	74.4	50.5	1518	42	6	1566	1626
		100(30)	61.5	57.1	53.1	58.8	70.8	50.3					
		200(61)	60.5	57.1	53.8	58.4	69.7	50.3					
	3	50(15)	64.6	60.4	56.2	62.0	78.7	52.1	1968	48	0	2016	2064
		100(30)	61.8	58.1	54.6	59.2	71.8	50.3					
		200(61)	60.3	57.1	54.6	57.7	65.4	52.1					
10-20-77	1	50(15)	66.4	61.2	56.2	63.5	77.7	49.7	2208	60	12	2280	2376
		200(61)	57.9	54.1	49.7	55.3	64.1	46.4					
	2	100(30)	64.4	59.5	55.1	61.5	73.1	49.0	2496	54	6	2502	2628
		200(61)	58.2	54.5	51.5	55.5	65.1	46.9					
6-13-78	2	50(15)	63.3	58.1	52.8	59.9	68.7	49.5	1482	30		1512	1542
		100(30)	60.3	55.2	50.5	57.0	66.2	34.4					
		200(61)	57.4	54.0	50.3	54.7	60.8	47.2					
	3	100(30)	62.3	56.7	51.5	59.6	74.6	45.4	1626	48		1674	1722
		200(61)	60.3	55.0	50.8	57.2	70.5	44.1					
		400(122)	55.1	50.6	46.4	52.0	59.2	39.5					

TABLE A2. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 2) (5-FOOT (1.5-m) HEIGHT)

			MEASURED NOISE LEVEL						VOLUME (VPH)				
DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
10-11-76	1	50(15)	65.6	55.5	48.5	66.0	85.9	46.4	426	24	18	468	546
		100(30)	57.9	52.1	47.4	58.8	77.9	45.4					
		200(61)	54.6	51.8	48.7	53.4	65.9	46.9					
	2	50(15)	65.4	56.5	50.0	63.5	83.6	47.7	396	18	12	426	480
		100(30)	59.0	53.1	47.7	52.6	71.3	45.9					
		200(61)	56.7	52.2	49.2	53.7	65.6	46.4					
	3	50(15)	66.2	55.3	49.2	63.0	83.1	47.7	528	18	6	552	588
		100(30)	56.9	51.3	47.2	55.8	75.1	45.9					
		200(61)	52.8	50.9	48.7	51.7	64.4	47.2					
	4	50(15)	66.7	56.9	48.7	64.6	81.8	47.7	528	12	36	576	696
		100(30)	61.8	53.7	48.2	58.8	75.1	46.7					
		200(61)	56.7	52.1	48.5	54.2	65.6	46.9					
	5	50(15)	66.7	56.5	50.3	61.0	81.0	48.5	450	24	12	486	524
		100(30)	59.5	52.2	47.2	56.7	75.1	44.9					
		200(61)	54.1	50.9	47.7	52.6	66.2	41.3					
	6	50(15)	66.7	56.6	50.0	63.8	80.5	47.7	474	24	12	510	570
		100(30)	59.2	52.0	46.7	56.8	71.3	45.1					
		200(61)	54.6	50.0	47.2	51.8	63.3	46.4					
	7	50(15)	67.7	57.6	50.8	64.4	80.3	47.9	594	24	24	642	738
		100(30)	59.7	53.1	47.9	56.6	70.0	46.2					
		200(61)	54.1	50.1	47.7	51.2	63.3	46.4					
	8	50(15)	67.9	57.1	49.0	62.9	77.4	46.4	684	54	12	750	840
		100(30)	59.5	53.3	47.9	56.0	67.2	46.2					
		200(61)	54.4	50.1	47.2	51.6	65.1	45.6					
12-15-76	1	25(7.6)	71.3	59.3	48.6	68.8	84.2	42.9	318	24	24	336	438
		50(15)	65.1	55.3	44.9	62.4	80.0	39.2					
		100(30)	59.5	51.3	42.6	55.8	69.7	40.8					
		200(61)	54.4	48.4	42.1	50.9	62.8	36.7					
	2	25(7.6)	76.2	62.6	51.4	71.4	85.0	44.6	504	42	30	576	708
		50(15)	69.5	58.6	48.2	67.1	83.8	41.3					
		100(30)	62.8	53.9	45.9	60.1	75.9	40.8					
	3	25(7.6)	73.2	59.1	47.2	69.6	84.4	43.2	618	18	18	654	726
		50(15)	66.4	55.5	45.6	65.4	85.9	41.0					
		100(30)	58.7	51.0	43.8	61.4	83.6	---					
		200(61)	54.6	48.4	42.1	57.5	40.5	39.2					
	4	25(7.6)	72.7	58.4	46.4	68.6	84.0	41.7	438	18	6	462	498
		50(15)	65.1	54.8	45.4	62.8	81.0	40.5					
		100(30)	57.4	49.6	41.8	55.4	73.8	41.0					
		200(61)	52.1	46.8	42.3	49.5	62.1	35.4					
4-14-77	1	25(7.6)	69.5	59.4	47.2	65.5	82.8	41.8	462	54	6	522	594
		50(15)	67.9	56.1	44.6	65.0	84.6	40.0					
		100(30)	59.7	51.1	42.6	56.4	73.6	38.7					
	2	25(7.6)	71.5	58.9	46.4	69.2	91.3	39.5	408	12	36	456	576
		50(15)	67.2	54.2	43.3	63.3	79.0	37.9					
		100(30)	58.2	48.9	40.5	56.0	77.8	32.8					
	3	25(7.6)	70.5	57.5	46.2	68.6	86.4	39.7	318	36	24	378	486
		50(15)	68.5	54.9	44.6	66.7	86.9	39.7					
		100(30)	56.7	48.4	41.0	57.2	77.4	56.7					
	4	25(7.6)	70.3	58.0	44.1	67.7	85.6	40.0	468	24	18	510	588
		50(15)	65.1	53.3	42.8	63.6	82.6	40.0					
		100(30)	60.3	49.9	40.8	58.5	76.7	37.9					
10-20-76	1	50(15)	66.7	60.4	53.3	62.8	72.8	46.9	1260	12	6	1278	1332
		100(30)	67.6	57.5	52.6	59.3	69.2	47.7					
11-9-77	1	50(15)	63.8	57.1	49.2	61.0	75.4	39.2	1206	18	12	1236	1290
		200(61)	54.4	51.3	48.7	51.9	58.5	38.2					
	2	50(15)	64.9	56.9	49.2	61.4	75.6	39.7	1278	60	12	1350	1446
		200(61)	55.9	52.2	48.5	53.2	60.5	41.5					
	3	50(15)	65.1	57.9	51.0	61.6	75.1	37.9	1188	18	30	1236	1344
		200(61)	55.4	52.0	49.2	52.7	59.5	45.6					
	4	50(15)	64.1	57.3	51.3	60.9	74.9	44.1	1134	18	6	1158	1194
		200(61)	54.6	51.5	48.7	52.3	60.5	40.0					

TABLE A2. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	Lmax	Lmin	AUTO	LT	HT	TOTAL	EQUIV
12-2-77	1	50(15)	66.7	56.8	47.7	62.8	77.4	44.6	384	42	30	456	588
		200(61)	53.6	48.0	43.1	50.4	61.3	39.2					
	2	50(15)	69.0	58.0	51.0	65.5	83.8	45.6	318	12	12	342	390
		200(61)	51.8	46.7	43.3	54.7	76.9	38.7					
	3	50(15)	63.3	54.0	46.7	59.6	74.1	45.1	348	12		360	372
		200(61)	48.7	44.5	41.0	45.8	55.6	38.7					
	4	50(15)											
		200(61)	49.2	45.2	42.3	46.5	57.9	37.5	390	24	12	426	486
8-17-78	1	50(15)	68.7	54.4	45.4	63.6	77.9	42.8	354	30	6	354	402
		100(30)	62.6	54.1	46.2	59.6	74.1	42.6					
		200(61)	55.6	50.2	45.1	52.8	63.8						
	2	50(15)	68.7	53.9	45.4	64.6	79.5	43.3	282	48	12	342	426
		100(30)	62.6	51.1	43.8	58.3	72.8	41.8					
		200(61)	56.2	49.1	44.4	52.7	65.6	42.1					
	3	50(15)	67.9	55.6	45.9	62.4	71.5	43.1	324	42	6	372	432
		100(30)	63.3	53.6	45.6	58.8	72.1	43.3					
		200(61)	57.9	51.4	45.1	54.4	67.2	41.8					
	4	50(15)	69.2	55.9	47.7	63.7	77.4	43.6	288	0	18	306	360
		100(30)	64.6	54.1	45.9	60.8	75.4	43.1					
		200(61)	57.2	50.6	44.4	54.2	69.2	41.8					
	5	50(15)	68.2	52.9	43.8	63.7	82.1	41.3	312	6	12	330	372
		100(30)	63.1	53.2	45.4	58.6	71.3	43.1					
		200(61)	55.9	49.9	44.4	53.7	71.5	42.6					
	6	50(15)	64.4	50.5	42.8	59.8	74.6	41.3	258	6	0	264	270
		100(30)	60.0	50.6	44.9	55.3	66.7	42.8					
		200(61)	53.8	48.5	44.1	50.4	60.5	---					
8-17-78	1	50(15)	65.9	54.5	45.9	62.5	76.9	41.3	324	24	18	366	444
		100(30)	61.5	52.8	45.4	59.2	78.7	41.8					
		200(61)	58.7	52.2	45.9	55.2	69.7	41.8					
	3	50(15)	67.2	56.6	46.4	62.2	72.3	42.1	474	36	18	528	618
		100(30)	60.8	52.8	45.4	56.7	67.7	39.0					
		200(61)	58.2	51.3	44.4	54.6	66.7	40.5					
	4	50(15)	65.4	54.9	46.9	60.8	73.1	42.6	420	30	18	468	522
		100(30)	59.2	52.2	45.9	55.6	71.0	41.8					
		200(61)	54.9	49.6	44.4	52.3	68.2	39.0					
	5	50(15)	66.7	56.0	46.9	62.9	79.5	43.8	528	12	12	552	600
		100(30)	59.5	52.2	44.9	56.3	70.8	42.1					
		200(61)	52.6	46.5	40.8	49.2	61.3	39.2					
	6	50(15)	69.7	57.3	45.1	68.2	87.9	42.1	462	18	42	522	834
		100(30)	63.6	53.4	43.1	60.7	76.4	39.5					
		200(61)	59.0	49.5	41.5	55.2	71.3	39.5					

TABLE A3. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 3) (5-FOOT (1.5-m) HEIGHT)

			MEASURED NOISE LEVEL						VOLUME (VPH)				
DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
8-5-76	1	150(46)	75.6	69.3	64.6	71.4	79.7	56.9	1746	78	246	2070	2886
		300(91)	72.1	67.2	62.8	68.7	76.9	58.5					
		600(183)	69.5	64.5	60.3	66.1	74.9	55.9					
	2	150(46)	75.4	69.7	64.6	72.1	84.4	60.3	1794	120	306	2220	3258
		300(91)	72.3	67.9	63.1	69.7	82.3	51.8					
		600(183)	70.0	65.4	61.0	66.9	75.6	56.7					
	3	150(46)	78.2	70.7	64.6	73.8	84.4	58.2	1728	108	282	2118	3072
		300(91)	74.4	68.6	62.6	71.0	83.1	51.3					
		600(183)	71.0	65.8	60.3	68.3	78.5	54.9					
	4	150(46)	76.9	70.0	63.8	72.9	83.3	57.4	2280	168	336	2784	3960
		300(91)	73.6	68.3	62.8	70.2	79.7	55.6					
		600(183)	69.2	64.7	59.2	66.2	72.6	53.1					
12-15-76	1	300(91)	69.5	63.1	55.9	66.2	79.0	52.1	1080	66	312	1458	2460
	2	300(91)	68.2	62.0	54.9	64.6	74.4	49.0	996	66	258	1320	2160
	3	75(23)	77.1	68.7	59.6	72.6	82.9	52.1	924	114	336	1374	2496
		300(91)	67.9	61.7	54.4	64.1	73.1	50.3					
		600(183)	62.8	57.9	52.8	59.4	67.9	49.0					
	4	75(23)	77.3	68.4	60.1	72.8	86.2	51.9	816	84	216	1116	1848
		300(91)	66.4	60.3	53.8	67.3	69.2	50.5					
		600(183)	60.0	56.2	51.8	57.2	63.6	49.5					
	5	100(30)	75.4	67.0	59.0	71.3	84.9	51.8	1038	60	264	1362	2214
		400(122)	65.1	59.3	53.6	62.0	76.7	48.5					
		800(244)	63.3	57.3	52.6	59.4	70.5	48.5					
	6	100(30)	74.1	66.8	59.0	70.0	79.7	51.8	972	78	318	1368	2400
		400(122)	63.8	58.9	53.6	60.4	67.4	50.5					
		800(244)	60.3	60.3	52.8	57.1	65.6	50.0					
11-2-77	1	75(23)	82.1	74.4	66.9	78.3	89.0	59.5	1876	36	240	1248	2004
		300(91)	66.9	62.9	59.0	64.4	75.6	56.2					
	2	75(23)	81.0	71.9	63.6	76.8	88.2	51.4	1020	24	276	1320	2172
		300(91)	65.6	61.6	57.2	62.7	69.0	54.9					
	3	75(23)	82.6	72.8	64.6	78.3	92.3	57.2	1044	24	306	1374	2316
		300(91)	65.9	62.0	57.7	63.1	70.3	53.1					
	4	75(23)	81.3	72.6	64.9	76.6	87.2	57.7	1002	24	354	1380	2466
		300(91)	65.9	54.9	56.9	62.9	70.0	54.9					
11-9-77	1	300(91)	67.2	62.6	57.7	64.0	72.6	49.7	972	132	492	1596	3204
	2	75(23)	80.5	74.6	68.7	76.9	90.3	61.0	1224	120	600	1944	3864
		300(91)	66.2	61.7	56.9	63.3	75.4	52.6					
	3	75(23)	80.0	73.2	67.9	76.0	86.9	62.8	1374	54	474	1902	3378
		300(91)	66.2	60.8	56.2	62.6	72.8	53.1					
	4	75(23)	78.7	72.3	65.9	75.4	87.2	56.7	1230	54	522	1806	3426
10-20-77	1	75(23)	82.3	75.4	68.5	78.4	89.0	61.0	648	24	246	918	1680
		300(91)	67.4	62.7	57.7	64.0	70.3	55.6					
	2	75(23)	81.5	74.7	68.5	77.7	87.9	60.0	930	66	318	1314	2334
		300(91)	66.4	61.2	56.9	62.9	73.1	54.1					
	3	75(23)	81.3	74.8	68.5	77.5	88.2	57.9	1212	84	294	1590	2556
		150(46)	73.1	67.3	61.5	69.4	77.9	55.4					
		300(91)	63.8	59.9	51.2	60.9	66.9	52.3					
	4	150(46)	75.4	67.9	61.3	71.2	82.6	38.7	1060	96	348	1512	2652
		300(91)	66.7	60.3	54.9	62.5	71.0	52.3					
		600(183)	60.3	56.3	52.8	57.1	62.6	51.5					
10-31-77	1	75(23)	80.0	74.0	68.2	76.8	88.7	67.6	1218	96	240	1554	2370
		300(91)	71.8	66.1	61.0	67.8	75.6	57.2					
	2	75(23)	82.1	75.3	68.5	78.5	89.2	62.3	1344	90	384	1818	3060
		300(91)	72.3	67.9	62.6	69.4	77.9	54.4					
	3	75(23)	79.2	74.4	69.0	76.8	89.7	62.1	1152	96	252	1500	2352
		300(91)	71.3	66.8	62.3	68.1	75.6	46.7					
	4	75(23)	80.0	74.5	69.2	77.0	89.0	62.6	1200	66	228	1494	2244
		300(91)	71.3	66.9	63.1	68.1	75.6	55.1					
	5	75(23)	80.5	75.1	70.0	77.1	88.5	63.6	1164	54	258	1476	2304
		300(91)	71.5	68.3	65.1	69.0	75.4	62.6					
	6	75(23)	80.0	74.2	68.5	76.6	84.9	63.8	1194	48	204	1446	2106
		300(91)	67.7	64.7	61.8	65.5	74.9	59.2					

TABLE A3. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
4-5-78	1	75(23)	80.8	74.4	67.2	76.8	83.8	74.4	1956	156	372	2484	3756
		300(91)	73.3	68.6	63.3	70.7	84.4	49.7					
	2	75(23)	80.5	73.3	65.1	76.0	82.8	54.4	1980	150	420	2550	3960
		300(91)	72.6	68.0	63.3	71.0	83.0	56.4					
	3	75(23)	80.8	73.2	66.2	76.1	83.6	53.3	2028	78	324	2430	3480
		300(91)	72.8	67.4	63.1	69.4	82.3	59.2					
	4	75(23)	79.7	73.3	66.7	75.6	83.3	60.5	2154	78	360	2592	4470
		300(91)	71.5	67.1	63.1	68.4	76.7	60.5					
12-2-77	1	75(23)	83.8	77.1	70.3	80.4	91.0	61.0	1182	114	324	1620	2706
		300(91)	71.3	68.2	64.4	69.2	77.7	56.7					
	2	75(23)	83.8	77.1	70.3	79.9	91.5	61.0	1128	96	270	1494	2400
		300(91)	70.8	67.5	62.3	68.5	77.7	58.5					
	3	75(23)	82.1	75.9	70.0	78.6	89.2	63.3	1170	108	276	1554	2490
		300(91)	69.2	64.6	60.3	65.8	72.1	55.6					
	4	75(23)	82.6	75.6	69.0	78.8	89.2	54.1	1218	120	246	1584	2442
		300(91)	70.6	65.4	60.0	67.0	75.9	70.0					
12-16-76	1	25(7.6)	83.1	74.2	65.1	79.7	95.6	57.2	864	54	282	1200	2100
		50(15)	80.3	72.8	65.1	77.0	90.5	56.9					
		100(30)	79.6	72.3	65.5	75.1	83.5	57.8					
		200(61)	76.7	69.9	64.1	72.3	80.5	56.2					
	2	25(7.6)	81.5	73.0	64.9	78.7	94.4	53.3	1200	84	168	1452	2040
		50(15)	78.5	71.5	64.6	75.9	89.7	55.4					
		100(30)	76.7	70.8	65.3	73.4	82.9	57.1					
		200(61)	74.4	69.0	64.1	71.3	81.5	59.0					
	3	25(7.6)	84.9	75.6	66.4	81.5	95.4	58.5	1062	102	306	1470	2490
		50(15)	81.5	73.4	65.4	77.7	90.5	58.5					
		100(30)	79.7	72.6	65.9	75.5	83.6	60.8					
		200(61)	75.7	70.0	64.4	72.3	82.3	59.5					
	4	25(7.6)	82.8	73.6	64.9	79.9	94.4	54.6	1230	48	222	1500	2214
		50(15)	80.3	71.7	64.1	76.6	92.6	55.1					
		100(30)	79.0	71.0	64.5	74.4	84.2	57.6					
		200(61)	76.2	68.8	63.3	71.6	80.5	57.9					
	5	25(7.6)	85.1	76.7	68.5	82.0	95.6	59.2	1212	96	294	1602	2388
		50(15)	81.8	74.4	67.7	78.4	91.3	59.7					
		100(30)	79.9	73.7	67.9	76.0	83.8	60.5					
		200(61)	76.9	71.1	65.4	73.2	83.1	60.5					
	6	20(6.1)	84.6	76.1	67.4	82.2	95.4	54.6	1188	54	282	1524	2424
		40(12)	81.0	72.6	64.6	77.8	94.9	54.4					
		80(24)	79.6	72.4	66.3	75.4	83.7	55.8					
		160(49)	77.2	70.3	64.6	73.5	84.9	57.4					
	7	20(6.1)	84.9	77.0	68.2	82.0	98.2	60.0	1212	66	168	1446	2016
		40(12)	81.3	73.3	66.4	77.8	93.3	61.3					
		80(24)	80.0	72.8	67.1	75.3	84.0	62.7					
		160(49)	76.7	70.3	64.9	73.2	87.2	56.2					
	8	20(6.1)	83.1	75.4	65.9	80.1	94.6	53.3	1272	78	138	1488	1980
		40(12)	77.7	71.8	64.1	75.6	89.7	52.8					
		80(24)	76.4	70.6	64.6	72.8	81.7	55.5					
		160(49)	76.7	69.1	62.3	72.2	82.1	54.6					
	9	20(6.1)	84.6	76.4	68.2	81.8	96.7	60.5	1344	78	180	1602	2220
		40(12)	81.3	73.0	65.9	77.8	93.8	59.0					
		80(24)	78.7	72.1	66.0	74.6	83.7	59.9					
		160(49)	76.9	70.5	64.9	73.2	84.6	60.5					
	10	20(6.1)	82.8	74.5	65.9	80.4	95.6	53.3	1349	72	192	1608	2256
		40(12)	77.7	70.8	63.3	75.1	89.0	53.6					
		80(24)	77.1	70.3	63.8	73.1	82.7	57.1					
		160(49)	74.1	68.6	64.1	70.6	79.7	53.9					

TABLE A3. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
4-11-78	1	75(23)	74.4	66.2	58.7	73.0	89.0	54.1	786	30	180	996	1566
		150(46)	66.2	60.5	55.1	66.6	84.9	50.0					
		300(91)	64.9	55.8	47.9	57.1	81.0						
	2	75(23)	73.3	65.4	56.9	71.0	86.4	50.0	840	42	120	1002	1404
		150(46)	68.7	61.0	54.4	66.2	83.8	45.4					
		300(91)	65.6	54.7	42.6	67.8	89.5						
	3	75(23)	75.1	65.2	55.6	71.7	84.9	47.4	852	54	240	1146	1920
		150(46)	67.4	60.1	52.6	64.0	75.9	44.9					
		300(91)	64.9	54.7	43.8	60.6	73.3						
4-24-78	1	75(23)	71.5	63.2	54.2	68.3	85.4	48.2	936	36	126	1098	1512
		150(46)	67.2	59.9	52.3	64.0	78.7	45.6					
		300(91)	61.8	55.8	49.2	58.4	67.9	45.1					
	2	75(23)	74.9	64.6	55.1	71.4	85.9	43.3	780	24	192	996	1596
		150(46)	70.0	61.5	52.6	66.7	80.8	46.4					
		300(91)	65.4	57.3	50.3	60.6	69.2	43.8					
	3	75(23)	71.5	63.7	55.1	68.6	82.1	45.9	954	48	150	1152	1650
		150(46)	67.9	60.1	52.1	64.3	75.6	44.1					
		300(91)	62.3	55.4	49.0	58.2	66.9	42.3					
6-9-78	1	150(46)	69.7	60.9	52.3	64.6	72.8	46.4	1020	24	192	1236	1428
		300(91)	62.3	56.3	50.3	58.8	69.2	45.4					
	2	200(61)	68.5	59.8	52.3	65.4	83.8	43.6	996	60	168	1224	1788
		400(122)	64.9	55.1	47.3	61.0	73.6	42.1					
	3	250(76)							1026	102	198	1326	2022
		500(152)	58.5	53.4	48.2	55.2	64.9	42.1					

TABLE A4. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 4) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
6-19-78	1	50(15)	75.9	71.6	67.9	73.4	88.5	61.8	5382	126	138	5646	6186
		100(30)	69.0	66.1	63.6	66.8	72.6	57.9					
		200(61)	68.2	64.1	60.5	65.7	78.5	56.2					
	2	50(15)	75.9	71.7	67.9	74.1	87.9	63.8	4164	102	144	4398	4944
		100(30)	70.3	66.5	63.6	67.3	72.8	60.8					
		200(61)	67.7	63.5	60.0	65.3	77.4	56.7					
	3	50(15)	75.6	71.9	68.5	74.2	90.3	65.6	4770	102	174	5046	5670
		100(30)	72.3	68.4	65.1	69.2	74.6	61.0					
		200(61)	69.2	64.7	60.5	66.6	79.7	57.4					
	4	50(15)	74.6	71.2	67.9	72.4	86.2	64.4	4968	114	168	5250	5868
		100(30)	68.5	63.3	57.4	65.0	72.1	53.6					
		200(61)	66.2	62.6	59.7	63.8	76.4	57.7					
	5	50(15)	75.1	71.4	67.9	72.8	84.9	64.4	5118	102	150	5334	5922
		100(30)	70.3	66.9	63.8	67.6	72.8	59.2					
		200(61)	67.9	63.4	50.5	65.6	80.8	56.4					
	6	50(15)	75.9	71.7	67.7	74.1	86.7	63.3	5268	108	102	5448	5892
		100(30)	68.7	65.4	62.6	66.2	72.6	59.0					
		200(61)	66.9	63.3	60.0	64.9	76.9	57.4					
	7	50(15)	75.1	72.2	69.0	74.6	91.8	64.4	5064	66	108	5232	5628
		100(30)	69.7	67.0	64.6	67.7	77.9	58.5					
		200(61)	68.5	64.7	61.0	66.9	82.1	57.2					
	8	50(15)	74.4	71.3	68.2	72.1	82.6	63.3	5106	126	84	5316	5694
		100(30)	69.2	66.4	63.8	67.0	72.3	54.4					
		200(61)	65.9	62.8	60.0	63.7	76.7	51.9					
7-18-78	1	50(15)	75.9	70.4	64.9	72.6	84.6	57.9	3138	228	162	3528	4242
		100(30)	74.6	69.5	64.9	71.3	82.3	59.7					
		200(61)	63.8	59.6	55.9	60.8	67.7	50.5					
	2	50(15)	77.7	70.9	64.4	73.8	85.1	59.7	3012	150	222	3384	4200
		100(30)	77.9	71.2	65.1	74.2	87.4	61.3					
		200(61)	67.2	61.6	56.7	63.4	72.3	52.6					
	3	50(15)	75.9	70.1	64.9	73.0	86.2	57.9	2688	204	168	3050	3768
		100(30)	75.6	70.1	65.1	72.4	86.2	59.5					
		200(61)	66.9	61.6	56.9	63.6	72.6	51.5					
	4	50(15)	76.4	70.0	64.1	72.6	84.1	56.2	2106	210	198	2514	3319
		100(30)	76.2	69.8	64.4	72.2	83.3	58.2					
		200(61)	65.1	60.5	55.9	62.1	70.0	50.5					
	5	50(15)	78.5	71.5	65.4	74.6	86.7	56.7	2706	156	300	3162	4218
		100(30)	77.7	71.0	64.9	74.8	88.7	57.7					
		200(61)	67.7	62.0	56.7	64.0	72.1	47.9					
	6	50(15)	76.7	70.8	65.4	73.4	86.4	61.0	3096	120	168	3384	4008
		100(30)	75.9	70.2	65.1	73.0	85.4	60.8					
		200(61)	67.7	62.1	57.9	63.8	72.8	53.3					
	7	50(15)	76.9	71.3	66.2	74.2	88.5	60.5	3558	156	210	3924	4710
		100(30)	75.1	70.0	65.1	72.4	84.1	59.2					
		200(61)	66.2	61.0	56.4	62.5	69.7	52.3					
	8	50(15)	79.2	72.6	66.9	76.6	91.8	60.5	3798	192	168	4158	4854
		100(30)	77.7	70.7	65.4	73.8	87.7	61.5					
		200(61)	67.2	62.0	57.7	63.6	72.6	54.4					
	9	50(15)	76.4	70.8	65.6	73.9	89.5	62.3	4308	132	186	4626	5316
		100(30)	75.4	69.2	64.6	72.9	89.2	61.0					
		200(61)	66.9	61.7	57.9	63.4	73.3	52.8					
	10	50(15)	76.4	71.4	66.7	73.8	86.2	61.0	4506	84	234	4824	5610
		100(30)	74.9	69.1	64.6	71.5	84.9	60.0					
		200(61)	65.9	60.9	56.7	62.3	71.5	51.5					

TABLE A4. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
8-2-78	1	50(15)	77.4	71.1	65.1	75.0	92.3	56.7	3060	180	162	3402	4068
		100(30)	71.8	66.0	60.5	69.2	85.1	54.4					
		200(61)	67.2	62.9	58.7	64.4	76.7	54.1					
	2	50(15)	76.4	70.8	64.4	74.0	87.4	56.7	3030	216	210	3456	4302
		100(30)	73.3	66.6	60.5	69.6	80.5	55.1					
		200(61)	69.0	64.0	59.2	65.5	73.1	54.1					
	3	50(15)	76.4	70.6	65.1	73.6	88.5	57.9	3006	198	186	3390	4146
		100(30)	72.3	66.0	60.5	68.8	81.5	54.1					
		200(61)	68.7	64.0	59.7	65.6	75.1	53.8					
	4	50(15)	76.9	70.9	65.4	73.9	87.9	60.3	2982	174	126	3282	3834
		100(30)	72.8	66.2	61.0	69.4	81.5	56.7					
		200(61)	69.0	61.6	55.4	64.9	77.9	46.7					
	5	50(15)	77.2	71.3	65.6	74.2	85.9	59.0	3138	126	228	3492	4302
		100(30)	72.3	66.5	61.3	69.3	79.7	55.9					
		200(61)	66.9	61.6	57.4	64.0	76.9	53.3					
	6	50(15)	77.7	71.5	65.6	74.6	89.0	56.4	2856	132	234	3222	4056
		100(30)	72.1	65.8	60.8	68.5	82.1	55.4					
		200(61)	66.9	61.3	56.9	63.8	76.9	51.5					
	7	50(15)	77.7	72.1	65.9	75.2	88.5	59.5	2814	132	126	3072	3582
		100(30)	73.3	68.4	63.8	70.5	83.1	56.4					
		200(61)	70.0	65.1	61.0	66.5	76.4	56.2					
	8	50(15)	76.9	71.5	65.9	74.0	88.5	56.9	3054	210	162	3426	4122
		100(30)	73.8	68.8	64.1	70.6	83.8	56.9					
		200(61)	68.7	64.5	61.0	65.6	76.4	54.9					
	9	50(15)	76.4	71.6	66.2	73.7	86.2	57.7	3564	186	168	3918	4608
		100(30)	72.1	68.2	63.8	69.7	80.8	59.0					
		200(61)	68.2	64.9	61.8	65.8	73.8	52.8					
	10	50(15)	79.0	72.7	66.4	76.0	89.0	56.4	3078	144	240	3462	4326
		100(30)	74.4	69.2	64.9	71.2	82.6	56.2					
		200(61)	70.5	65.9	62.1	67.4	77.9	45.1					
	11	50(15)	77.9	72.1	66.4	75.0	87.2	59.0	3438	168	192	3798	4542
		100(30)	74.9	69.3	69.6	71.4	82.1	58.7					
		200(61)	70.0	65.1	61.0	66.7	75.9	52.3					
	12	50(15)	77.4	71.9	66.2	74.2	85.4	57.2	3546	180	222	3948	4794
		100(30)	73.3	68.4	63.8	70.2	80.0	56.4					
		200(61)	68.7	64.8	61.3	66.5	81.0	57.9					
	13	50(15)	77.7	72.6	67.4	74.8	86.2	59.5	3168	150	198	3516	4260
		100(30)	72.8	68.5	64.4	69.9	80.5	57.9					
		200(61)	68.7	65.2	61.8	66.2	74.1	57.9					
10-3-78	1	50(15)	79.3	73.2	66.7	75.7	85.9	60.5	2646	120	192	2958	3654
		100(30)	73.3	68.7	64.1	70.3	81.1	60.3					
		200(61)	68.7	65.7	62.3	66.4	75.4	59.0					
	2	50(15)	79.0	73.0	66.2	75.8	88.7	59.5	2184	144	126	2454	2976
		100(30)	74.4	69.4	64.4	72.3	85.9	60.5					
		200(61)	69.5	65.7	62.3	66.5	71.5	58.7					
	3	50(15)	80.8	74.4	68.5	77.1	86.9	60.3	2520	144	246	2910	3792
		100(30)	76.7	70.8	66.2	73.0	83.6	60.0					
		200(61)	70.5	67.3	63.6	68.1	75.1	60.8					

TABLE A5. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 5) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
9-15-76	1	25(7.6)	72.1	59.9	51.8	67.6	80.5	49.0	312	24	0	336	360
		50(15)	66.7	57.4	48.7	63.6	79.2	45.6					
		100(30)	60.0	53.7	47.9	56.4	66.7	45.1					
	2	25(7.6)	70.0	60.4	52.1	66.2	79.2	48.7	522	12	0	534	546
		50(15)	65.9	58.1	51.3	62.0	76.2	48.2					
		100(30)	58.5	54.3	50.0	55.9	67.9	46.7					
	3	25(7.6)	71.8	60.3	50.5	67.6	82.6	48.7	492	12	12	516	540
		50(15)	67.7	58.2	49.0	64.9	81.3	46.9					
		100(30)	60.3	54.2	47.9	58.7	75.4	45.9					
	4	25(7.6)	71.0	58.8	50.0	66.4	85.1	48.5	438	12	6	456	510
		50(15)	66.7	56.7	48.7	62.3	79.5	45.4					
		100(30)	58.7	52.7	47.4	56.0	73.6	43.8					
7-13-78	1	50(15)	68.5	58.5	49.0	66.4	83.6	43.8	342	6	6	354	378
		100(30)	64.4	56.4	49.2	61.1	76.4	45.1					
		200(61)	60.0	53.6	47.2	58.2	76.4	42.8					
	2	50(15)	66.9	57.4	48.2	62.8	74.9	44.6	354	6	0	360	366
		100(30)	62.6	55.3	49.2	58.5	70.3	46.9					
		200(61)	59.0	53.0	47.4	55.2	64.1	45.6					
	3	75(23)	66.7	57.8	48.5	63.8	80.5	43.8	318	18	0	336	354
		150(46)	62.3	55.7	49.2	59.1	72.8	45.1					
		300(91)	56.4	49.6	42.6	53.2	65.1	---					
	4	75(23)	66.4	56.6	47.7	62.2	75.4	42.8	378	6	0	384	390
		150(46)	61.0	54.5	47.9	58.0	71.3	42.1					
		300(91)	52.8	47.5	43.1	49.4	60.0	41.0					
	5	100(30)	62.8	54.6	46.2	61.7	81.3	38.7	366	12	12	390	462
		200(61)	60.8	54.4	47.7	57.3	66.9	44.1					
		400(122)	54.1	49.3	45.1	51.1	64.4	42.8					
	6	100(30)	62.8	54.7	46.4	59.0	71.3	43.8	426	6	0	432	438
		200(61)	60.5										
		400(122)	52.8	47.8	43.3	54.3	75.1	39.5					
	7	125(38)	60.3	53.1	45.9	60.8	79.7	39.5	396	24	6	426	480
		450(137)	53.6	48.0	43.1	52.4	67.2	40.5					
	8	125(38)	59.7	52.9	45.9	56.2	69.7	40.0	432	18	6	456	504
		450(137)	50.8	46.8	42.6	48.0	59.2	39.2					
8-4-78	1	25(7.6)	74.6	63.5	52.8	70.6	85.1	50.8	426	18	6	450	486
		50(15)	69.5	61.7	52.3	66.0	78.7	48.5					
		100(30)	65.6	57.3	48.5	61.6	75.9	43.8					
	2	25(7.6)	74.1	62.0	51.3	71.2	91.5	50.5	288	48	0	336	384
		50(15)	71.0	60.9	49.7	67.0	83.6	48.7					
		100(30)	67.4	57.7	48.2	63.2	76.7	44.1					
	3	25(7.6)	75.1	63.2	51.0	70.8	83.8	50.8	426	24	0	450	474
		50(15)	71.3	62.6	52.6	67.4	79.0	48.7					
		100(30)	67.2	58.8	49.2	63.3	75.1	44.9					
	4	100(30)	66.2	58.2	49.0	62.8	77.9	45.9	414	42	0	456	498
		200(61)	62.3	56.8	50.3	59.2	69.7	36.9					
		400(122)	56.4	50.7	44.9	53.0	64.4	40.0					
	5	100(30)	65.9	57.5	48.7	61.4	71.8	44.9	450	6	0	456	462
		200(61)	61.5	55.6	50.0	57.8	71.3	44.6					
		400(122)	54.1	49.4	44.4	51.0	59.2	41.3					
	6	100(30)	66.7	57.3	47.2	63.3	77.9	43.3	396	36	12	444	516
		200(61)	62.8	56.3	49.2	59.8	72.8	45.9					
		300(91)	58.7	52.6	46.4	55.9	69.5	42.6					
8-14-78	1	50(15)	67.2	57.7	49.5	62.4	73.1	44.9	390	30	0	420	450
		100(30)	65.6	57.4	49.0	62.4	75.9	45.1					
		200(61)	59.5	53.6	48.2	55.9	66.7	45.4					
	2	50(15)	68.5	58.4	48.2	65.0	79.2	43.8	450	12	0	462	474
		100(30)	66.2	57.5	48.2	62.1	71.3	42.3					
		200(61)	60.0	53.9	47.4	56.5	67.9	44.9					

TABLE A6. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 6) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
10-3-78	1	50(15)	72.8	68.5	63.3	70.0	80.0	59.5	3084	84	24	3192	3348
		100(30)	67.2	62.6	58.7	63.9	72.1	53.6					
		200(61)	62.6	58.8	55.4	59.9	69.2	51.3					
	2	50(15)	72.8	68.4	62.3	70.8	84.1	55.1	3054	90	102	3246	3642
		100(30)	67.4	62.6	57.2	65.4	79.2	51.5					
		200(61)	63.3	58.6	54.1	60.4	69.7	51.0					
	3	50(15)	72.6	68.3	62.8	70.4	83.1	56.4	3084	126	48	3258	3528
		100(30)	66.9	61.9	57.4	64.4	77.7	53.6					
		200(61)	62.1	58.3	54.9	59.8	70.0	51.8					
	4	50(15)	73.6	62.6	58.7	70.2	72.1	53.6	3018	186	24	3228	3486
		100(30)	67.4	62.5	57.2	64.3	72.6	53.6					
		200(61)	62.8	59.3	54.9	60.3	67.4	51.5					
10-10-78	1	50(15)	72.1	66.2	59.5	69.4	82.3	51.0	2004	138	60	2202	2720
		100(30)	67.7	60.9	55.4	63.5	72.6	48.4					
		200(61)	62.3	57.6	53.1	60.0	72.8	48.4					
	2	50(15)	72.8	66.0	57.2	70.6	85.6	52.1	1674	144	72	1890	2250
		100(30)	70.0	61.8	54.9	67.0	84.6	49.2					
		200(61)	63.6	58.2	53.1	64.6	82.0	49.7					
	3	50(15)	73.6	66.6	59.0	70.1	82.1	53.8	2016	120	126	2262	2640
		100(30)	70.2	63.0	56.1	65.7	72.6	51.5					
		200(61)	65.4	59.7	54.8	61.9	71.0	52.0					
	4	50(15)	71.0	65.0	57.9	68.7	87.4	49.0	2532	102	48	2682	2928
		100(30)	66.7	60.3	54.6	64.3	80.0	48.7					
		200(61)	60.5	55.4	51.3	58.3	74.4	47.4					
	5	50(15)	72.8	67.8	62.6	69.9	80.5	53.6	2490	168	96	2754	3210
		100(30)	69.0	62.3	57.2	64.9	77.2	53.6					
		200(61)	62.3	57.4	53.6	60.5	75.1	49.5					
	6	50(15)	70.5	66.2	61.0	67.9	81.0	51.8	2574	132	54	2760	3054
		100(30)	66.9	61.8	57.2	63.8	77.4	53.8					
		200(61)	60.0	56.7	53.6	58.1	70.8	51.0					
	7	50(15)	70.0	65.4	58.2	67.5	79.7	51.0	2682	102	78	2862	3178
		100(30)	66.7	60.8	55.6	63.2	77.7	51.0					
		200(61)	59.7	56.2	52.1	57.5	69.7	47.9					

APPENDIX B

WEATHER CONDITION DATA

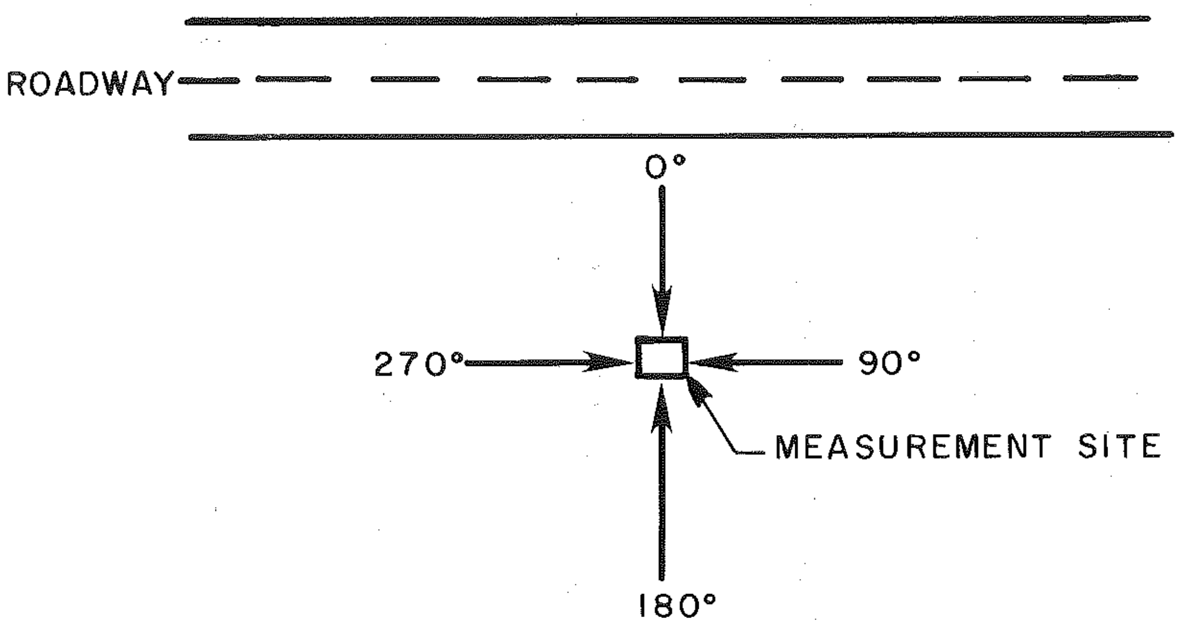

Figure B1. Wind Direction Parameter (Degrees).

TABLE B-1. WEATHER CONDITIONS DATA

DATE	SITE NUMBER	WIND SPEED (KNOTS)	WIND DIRECTION (DEGREES)	WIND VECTOR SPEED[a] (KNOTS)	TEMPERATURE (°F)	RELATIVE HUMIDITY
2-24-76	1	12.5	270°	0	54	41
6-29-76	1	10	300°	-5	85	57
10-11-76	1	7.5	200°	+7	59	50
4-3-76	1	6	0°	-6	77	45
10-18-77	1	10.5	300°	-5	59	52
10-20-77	1	5	190°	+5	58	62
11-3-77	1	7.5	200°	+7	73	66
11-9-77	1	12	250°	+4	69	70
4-10-78	1	13	300°	-7	76	56
6-13-77	1	9	70°	-3	68	54
10-11-76	2	5	200°	+5	59	70
10-20-76	2	8	330°	-7	45	96
12-15-76	2	5	255°	+1	69	54
4-14-77	2	2	45°	-1	81	34
11-9-77	2	12	220°	+9	69	70
12-2-77	2	9	260°	+2	39	86
8-17-78	2	5	290°	-2	83	65
8-17-78	2	5	160°	+5	85	61
8-5-76	3	12	340°	-11	81	58
12-15-76	3	7	30°	-6	46	54
12-16-76	3	12	0°	-12	36	75
10-20-77	3	5	180°	+5	58	62
10-31-77	3	12	290°	-4	65	62
11-2-77	3	7	210°	+6	66	57
11-9-77	3	11	280°	-2	71	65
12-2-77	3	8	340°	-7	44	76
4-5-78	3	6	210°	+5	61	56
4-11-78	3	15	180°	+15	63	48
4-24-78	3	5	120°	+2	68	39
6-9-78	3	8	230°	+5	67	56
6-17-78	4	3	345°	-3	72	79
7-18-78	4	2	190°	+2	80	45
8-2-78	4	9	235°	+5	81	60
10-3-78	4	3	135°	+2	66	75
9-15-76	5	5	320°	-4	74	57
7-13-78	5	8	250°	+3	74	86
8-4-78	5	9	50°	-6	69	68
8-14-78	5	1	350°	-1	78	77
10-3-77	6	5	300°	-2	66	75
10-10-78	6	4	230°	+3	65	56

[a] A wind vector away from the roadway was negative; toward the roadway, positive; parallel to the roadway was zero.

APPENDIX C

TRAFFIC STREAM NOISE DATA
TAKEN ON DIFFERENT GROUND COVERS

TABLE C1. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 6) (5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
			L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
10-10-78[a]	1	50(15)	69.7	63.8	55.6	66.8	82.1	51.0	1494	186	24	1704	1962
		100(30)	62.8	58.2	52.1	61.2	77.7	47.7					
		200(61)	56.9	54.0	51.0	54.9	63.1	46.7					
	2	50(15)	70.0	63.9	56.4	67.2	82.6	51.0	1752	108	36	1896	2112
		100(30)	64.1	58.6	53.6	61.8	77.2	45.1					
		200(61)	59.0	55.0	51.0	56.6	67.2	46.9					
	3	50(15)	70.5	64.8	58.2	67.2	79.7	52.3	1842	138	54	2034	2334
		100(30)	64.9	60.2	54.9	62.4	76.7	49.5					
		200(61)	60.0	56.6	53.6	57.7	66.4	47.7					
10-10-78[b]	1	50(15)	71.8	68.5	61.5	71.0	86.4	56.2	2184	84	48	2316	2544
		100(30)	73.1	66.8	59.0	72.5	93.1	53.6					
		200(61)	67.4	61.9	56.7	68.4	87.2	53.6					
	2	50(15)	66.7	58.7	51.8	61.8	70.8	43.6	2136	78	48	2262	2484
		100(30)	72.8	66.3	58.5	69.4	80.0	53.6					
		200(61)	67.2	61.1	56.4	63.2	73.6	51.0					
	3	50(15)	71.8	67.3	60.8	70.0	83.6	54.6	1974	132	48	2154	2430
		100(30)	72.6	65.8	58.5	69.9	84.4	53.8					
		200(61)	66.9	60.8	56.2	63.0	73.3	53.6					

a Ground cover was tall grass
b Ground cover was pavement

TABLE C2. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 7)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	HEIGHT (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
3-18-76[a]	1	50 (15)	5 (1.5)	65.1	58.6	53.1	65.0	84.6	51.5	510	30	12	552	618
		100 (30)	5 (1.5)	59.5	54.4	49.0	59.6	75.9	44.9					
		200 (61)	5 (1.5)	55.6	52.0	48.7	55.8	74.1	45.6					
	2	50 (15)	5 (1.5)	70.5	59.4	50.5	65.7	76.4	45.4	456	48	72	576	840
		100 (30)	5 (1.5)	63.8	55.8	48.7	61.1	76.2	45.4					
		200 (61)	5 (1.5)	59.5	53.1	47.4	56.1	65.9	44.4					
	3	50 (15)	5 (1.5)	65.6	57.7	49.2	61.9	75.6	44.1	738	0	12	750	786
		100 (30)	5 (1.5)	59.0	53.3	47.9	55.4	70.5	44.6					
		200 (61)	5 (1.5)	55.4	51.3	47.7	52.4	62.1	41.5					
	4	50 (15)	5 (1.5)	71.0	63.0	54.5	68.1	84.2	44.5	636	36	18	690	780
		100 (30)	5 (1.5)	63.1	57.7	53.3	61.2	76.9	51.8					
		200 (61)	5 (1.5)	59.5	53.0	47.2	56.8	72.1	42.3					
		400 (122)	5 (1.5)	55.9	50.4	45.9	52.9	64.9	39.7					
	5	50 (15)	5 (1.5)	71.0	63.8	55.8	69.0	84.5	50.1	612	54	24	690	816
		100 (30)	5 (1.5)	63.6	56.5	48.7	61.4	76.7	44.1					
		200 (61)	5 (1.5)	59.5	53.7	47.4	57.5	73.1	43.6					
		400 (122)	5 (1.5)	55.9	51.4	46.7	53.4	63.8	41.0					
	6	50 (15)	5 (1.5)	71.9	64.1	55.4	68.2	82.7	47.4	630	36	12	678	750
		100 (30)	5 (1.5)	65.1	57.6	49.2	62.2	75.4	44.9					
		200 (61)	5 (1.5)	61.8	55.5	49.0	60.4	74.9	44.1					
		400 (122)	5 (1.5)	61.0	53.8	48.7	56.9	65.4	43.1					
	7	100 (30)	5 (1.5)	66.3	60.6	53.8	63.9	76.5	48.2	732	12	12	756	804
		100 (30)	10 (3.0)	65.6	58.9	50.3	62.7	75.1	44.9					
		200 (61)	5 (1.5)	60.3	54.4	47.9	57.7	71.0	45.4					
		200 (61)	10 (3.0)	62.3	56.7	50.0	60.0	74.1	45.9					
	8	100 (30)	5 (1.5)	68.3	62.7	56.5	65.8	78.3	52.6	780	36	30	846	972
		100 (30)	15 (4.6)	68.5	61.7	54.1	65.2	75.1	47.9					
		200 (61)	5 (1.5)	61.8	56.6	51.3	59.4	72.6	47.4					
		200 (61)	15 (4.6)	65.1	59.7	54.4	62.4	74.4	49.5					
	9	100 (30)	5 (1.5)	65.1	57.6	49.2	62.2	75.4	44.9	678	24	18	720	798
		100 (30)	20 (6.1)	68.5	62.3	55.9	65.0	74.9	48.7					
		200 (61)	5 (1.5)	62.1	56.3	50.8	59.8	74.9	46.2					
		200 (61)	20 (6.1)	65.9	60.1	54.6	62.8	76.2	50.0					
	10	200 (61)	5 (1.5)	64.1	59.3	55.1	61.0	70.3	50.0	906	54	18	978	1086
		200 (61)	10 (3.0)	63.3	57.9	53.1	60.0	70.5	47.4					
		200 (61)	15 (4.6)	65.9	60.6	55.4	62.6	72.6	48.7					
		200 (61)	20 (6.1)	66.7	60.8	55.4	63.1	73.8	46.7					
	11	100 (30)	5 (1.5)	69.1	64.0	58.6	66.2	76.8	53.1	1218	54	36	1308	1470
		100 (30)	10 (3.0)	69.7	63.7	57.7	66.5	76.9	50.3					
		100 (30)	15 (4.6)	70.0	63.9	57.9	66.6	76.4	49.2					
		100 (30)	20 (6.1)	71.8	65.3	60.0	67.9	76.9	51.3					

TABLE C2. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	HEIGHT (FEET) (M)	MEASURED NOISE LEVEL						VOLUME (VPH)				
				L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
4-6-76	1	100[b] (30)	10 (3.0)	66.7	58.9	51.0	63.3	75.1	43.6	780	48	30	858	996
		100[a] (30)	5 (1.5)	65.9	56.6	45.9	62.1	76.2	41.5					
		100[a] (30)	10 (3.0)	68.5	60.4	48.7	65.4	76.9	43.1					
	2	100[b] (30)	5 (1.5)	68.5	58.9	51.2	64.8	79.2	41.7	648	54	36	738	900
		100[b] (30)	15 (4.6)	68.2	59.2	50.3	64.5	75.6	43.6					
		100[a] (30)	5 (1.5)	66.2	55.2	44.9	63.4	77.9	42.6					
		100[a] (30)	15 (4.6)	69.7	59.6	46.9	65.8	76.2	42.1					
	3	100[b] (30)	5 (1.5)	66.8	58.8	49.2	64.4	79.0	44.2	732	36	30	798	924
		100[a] (30)	5 (1.5)	63.3	54.8	45.6	61.6	76.2	40.5					
		100[a] (30)	20 (6.1)	69.7	62.0	53.6	65.8	75.4	42.8					
	4	100[b] (30)	5 (1.5)	66.5	59.0	48.1	64.4	80.1	42.4	948	24	24	996	1092
		100[b] (30)	10 (3.0)	64.9	57.9	47.2	62.4	75.1	42.8					
		100[a] (30)	5 (1.5)	63.3	55.7	46.2	61.0	75.6	41.8					
		100[a] (30)	10 (3.0)	67.4	59.9	50.5	64.2	75.6	43.3					
	5	50[b] (15)	5 (1.5)	69.7	61.4	52.7	67.5	84.4	42.3	1044	24	42	1110	1260
		100[b] (30)	5 (1.5)	65.6	57.6	49.0	62.8	74.9	43.1					
		50[a] (15)	5 (1.5)	71.3	62.4	53.1	67.1	76.4	43.8					
		100[a] (30)	5 (1.5)	65.4	58.3	50.0	63.1	75.9	43.3					
	6	50[b] (15)	5 (1.5)	69.4	59.5	48.8	65.9	80.5	43.3	762	54	42	858	1038
		200[b] (61)	5 (1.5)	61.5	53.4	45.6	58.2	70.8	43.1					
		50[a] (15)	5 (1.5)	69.5	59.1	46.7	65.6	75.4	43.1					
		200[a] (61)	5 (1.5)	58.5	49.7	42.1	54.8	65.9	37.7					
	7	50[b] (15)	5 (1.5)	67.6	60.0	52.3	64.4	78.8	45.9	1128	54	24	1206	1332
		300[b] (91)	5 (1.5)	58.2	50.6	44.6	54.6	65.4	39.2					
		50[a] (15)	5 (1.5)	68.5	59.3	52.6	65.7	81.0	51.0					
		300[a] (91)	5 (1.5)	49.7	44.2	38.7	48.4	64.9	35.4					
	8	50[b] (15)	5 (1.5)	69.0	58.6	44.5	66.0	81.5	40.1	1068	36	24	1128	1236
		400[b] (122)	5 (1.5)	52.8	46.1	39.2	48.8	60.0	36.7					
		50[a] (15)	5 (1.5)	70.0	59.2	47.7	65.7	75.6	42.1					
		400[a] (122)	5 (1.5)	47.9	43.3	39.2	45.2	56.4	35.4					
	9	100[b] (30)	5 (1.5)	65.4	57.9	49.0	61.8	73.7	42.3	900	30	12	942	1008
		200[b] (61)	5 (1.5)	57.9	51.4	44.9	54.6	66.7	43.1					
		100[a] (30)	5 (1.5)	63.6	54.5	45.4	59.4	74.4	42.1					
		200[a] (61)	5 (1.5)	55.4	49.0	43.3	51.8	64.6	40.3					
	10	400[b] (122)	5 (1.5)	49.5	46.2	43.8	47.0	46.2	43.8	No Data				
		200[a] (61)	5 (1.5)	54.9	48.3	42.6	51.3	64.4	38.2					
		400[a] (122)	5 (1.5)	50.0	46.1	42.8	47.2	57.9	38.2					
	11	200[b] (61)	5 (1.5)	58.8	52.0	44.7	56.6	70.6	40.3	804	25	18	847	926
		400[b] (122)	5 (1.5)	50.3	43.9	38.3	46.6	56.7	35.6					

[a] Ground cover was plowed field
[b] Ground cover was short grass

TABLE C3. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 8)(5-FOOT (1.5-m) HEIGHT)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
10-13-76[a]	1	60(18)	66.2	57.8	49.7	64.2	82.8	45.6	576	42	12	630	708
		120(37)	60.0	54.6	48.5	60.1	81.8	45.6					
		240(73)	55.4	51.3	47.2	54.0	69.5	43.8					
	2	60(18)	65.4	57.0	49.2	62.2	77.7	43.1	546	48	16	600	666
		120(37)	59.5	53.5	47.9	56.2	68.7	44.6					
		240(73)	53.3	49.6	46.4	50.6	60.3	44.9					
	3	60(18)	66.2	55.9	47.4	63.2	82.8	43.1	570	24	6	600	642
		120(37)	59.2	52.7	47.2	57.5	78.5	43.1					
		240(73)	52.6	48.7	45.1	50.9	66.9	43.1					
	4	60(18)	64.1	54.6	46.4	61.8	80.0	43.3	444	18	0	462	480
		120(37)	56.9	51.6	46.2	55.4	71.5	43.8					
		240(73)	52.6	49.0	45.6	51.9	67.7	39.7					
	5	60(18)	66.7	57.4	49.2	62.8	77.4	43.6	582	36	12	630	702
		120(37)	60.3	53.8	47.9	56.9	70.8	39.7					
		240(73)	55.1	50.7	46.7	52.6	66.9	40.5					
	6	60(18)	66.7	57.5	48.7	62.9	78.7	44.9	546	72	0	618	690
		120(37)	60.0	53.8	47.4	57.0	68.5	42.8					
		240(73)	54.6	50.4	46.2	55.3	74.1	43.6					
10-13-76[b]	1	25(7.6)	71.3	63.8	57.7	67.3	79.7	53.6	696	36	36	768	912
		50(15)	65.6	61.2	56.9	62.9	74.4	52.3					
		100(30)	64.6	60.7	57.2	61.8	70.3	54.1					
	2	25(7.6)	72.1	63.6	56.7	68.0	82.8	52.1	714	12	12	737	785
		50(15)	65.4	59.8	55.4	62.0	74.4	51.0					
		100(30)	64.4	59.3	55.4	60.8	70.8	53.1					
	3	25(7.6)	70.3	62.2	56.2	66.2	79.5	53.3	624	24	0	648	672
		50(15)	64.4	59.1	54.4	61.1	73.8	47.4					
		100(30)	61.8	58.2	54.1	59.2	70.3	50.5					
	4	25(7.6)	71.0	62.6	56.2	67.5	85.4	51.8	546	48	24	618	738
		50(15)	66.2	60.3	55.4	63.5	80.5	53.3					
		100(30)	65.6	59.9	55.4	62.3	75.6	51.8					
	5	25(7.6)	70.3	63.0	56.7	67.1	82.3	51.8	720	30	0	750	780
		50(15)	64.9	59.8	55.6	62.6	80.3	48.2					
		100(30)	64.1	59.5	55.9	61.1	74.1	51.8					
	6	25(7.6)	70.3	62.8	56.9	66.2	77.9	52.3	792	30	18	840	924
		50(15)	64.4	59.6	55.4	61.4	74.4	51.3					
		100(30)	62.3	58.7	55.4	59.8	70.3	52.1					

[a] Ground cover was plowed field
[b] Ground cover was pavement

TABLE C4. TRAFFIC STREAM NOISE DATA SUMMARY (SITE 9) (5-FOOT (1.5-m) HEIGHT)

			MEASURED NOISE LEVEL						VOLUME (VPH)				
DATE	MEASUREMENT NUMBER	DISTANCE (FEET) (M)	L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	AUTO	LT	HT	TOTAL	EQUIV
10-23-76[a]	1	20(6.1)	76.4	71.2	65.9	73.4	87.4	59.0	1962	78	12	2052	2166
		40(12)	73.3	68.8	63.8	70.6	82.8	58.2					
		80(24)	72.8	68.2	63.6	70.4	85.1	56.9					
	2	20(6.1)	76.2	71.3	65.9	73.2	86.9	53.3	2070	60	12	2142	2238
		40(12)	73.1	69.0	64.6	70.6	82.6	52.1					
		80(24)	72.3	67.6	63.3	69.8	82.8	52.8					
	3	20(6.1)	76.7	71.4	65.4	73.6	85.4	58.5	2058	90	42	2180	2406
		40(12)	73.8	69.2	64.1	71.0	82.6	57.7					
		80(24)	73.3	68.6	63.3	70.6	83.6	56.7					
	4	15(4.6)	79.2	72.8	66.2	81.3	104.1	60.0	2068	66	12	2142	2244
		30(9.1)	79.7	73.9	68.2	76.6	90.5	61.8					
		60(18)	72.3	67.9	63.3	69.9	83.3	58.2					
	5	15(4.6)	78.7	72.9	66.9	75.3	87.2	56.9	2064	78	12	2154	2268
		30(9.1)	78.5	73.6	68.5	75.7	88.2	59.2					
		60(18)	72.3	67.9	63.3	69.2	78.5	56.9					

a Ground cover was pavement

APPENDIX D

EFFECT OF GROUND COVER
ON NOISE LEVELS FOR
VARIOUS OCTAVE BANDS
(USING RANDOM NOISE GENERATOR)

TABLE D1. SUMMARY OF NOISE DATA ON SHORT GRASS

		NOISE LEVEL (dB)											
				DISTANCE (FEET) (M)									
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)	225(69)	250(76)
White Noise	A-Weighted	95	48.0	84.1	79.0	72.0	65.0	57.0	53.0	50.0			
	Linear	90	65.0	86.2	81.7	77.5	72.5						
	Octave Band Geometric Mean Frequency (Hertz)												
Pink Noise	63	95	61.0	79.0	73.5	70.2	68.0						
	125	95	61.0	82.7	77.0	74.2	70.5	72.0	69.7	68.0	66.0		
	250	95	48.0	84.1	79.0	74.5	72.0	72.0	69.5	66.5	66.0	63.3	61.5
	500	95	36.0	87.5	81.2	74.5	72.5	66.5	63.0	62.0	56.0	52.5	52.0
	1000	95	40.0	80.2	71.7	64.0	59.5	54.0	50.0				
	2000	95	38.0	86.6	77.5	71.0	63.0	60.0	51.0	48.0			
	4000	95	30.0	83.0	78.0	73.0	67.7	68.0	65.0	60.5			
	8000	95	30.0	77.5	71.5	65.5	59.7						

a The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D2. SUMMARY OF NOISE DATA ON PAVEMENT

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	51.5	83.8	78.3	74.5	72.0	72.0	70.0	65.5	63.0
	Linear	90	62.0	82.3	75.0	73.5	70.5	70.0	68.5	66.0	65.0
	Octave Band Geometric Mean Frequency (Hertz)										
Pink Noise	63	95	60.5	79.5	77.5	70.0	67.0	68.0	66.0	64.0	
	125	95	58.0	82.5	76.0	72.5	67.5	70.5	68.5	67.0	66.0
	250	95	52.0	85.0	78.8	75.5	72.0	73.0	71.0	69.0	67.5
	500	95	47.5	87.7	81.7	78.0	73.3	73.5	72.5	70.0	67.0
	1000	95	45.0	84.3	79.0	73.5	70.3	72.5	70.0	69.5	67.0
	2000	95	40.0	80.7	80.5	77.5	73.7	76.0	74.0	72.0	70.0
	4000	95	35.5	81.0	71.8	67.0	64.0	70.0	68.0	63.0	58.0
	8000	95	32.5	86.5	77.3	68.0	63.0	67.0	64.5	63.0	56.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D3. SUMMARY OF NOISE DATA ON HIGH WEEDS

		NOISE LEVEL (dB)					
				DISTANCE (FEET) (M)			
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)
White	A-Weighted	95	45.0	80.0	70.0	61.0	56.5
Noise	Linear	90	57.0	72.0	65.0		
	Octave Band Geometric Mean Frequency (Hertz)						
	63	95	49.0	78.5	72.0	69.0	66.0
	125	95	54.0	79.0	73.5	70.0	67.5
	250	95	42.0	84.0	76.5	74.0	70.5
Pink	500	95	34.0	80.5	72.0	66.0	62.0
Noise	1000	95	34.0	77.5	70.5	63.0	57.5
	2000	95	33.0	81.5	73.0	61.0	57.5
	4000	95	26.0	80.0	69.5	58.0	53.5
	8000	95	42.0	74.5	56.0	53.0	44.5

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D4. SUMMARY OF NOISE DATA ON GRAVEL

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White	A-Weighted	95	49	83.5	78.0	74.0	70.0				
Noise	Linear	90	64	79.0	74.0	72.0	70.0	68.5	67.0	65.0	63.0
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	63	79.5	75.5	71.5	68.5	66.0	64.5	63.0	
	125	95	58	81.7	76.2	72.5	70.0	68.0	65.0	63.5	62.0
	250	95	49	87.0	82.0	78.0	75.0	74.5	72.5	70.5	68.5
Pink	500	95	46	86.0	81.0	76.2	73.5	72.0	70.5	68.0	66.0
Noise	1000	95	42	81.5	76.0	71.5	66.5	61.0	59.0	57.5	56.0
	2000	95	37	87.0	79.0	71.2	66.7	68.0	62.0	59.0	55.0
	4000	95	35	81.5	77.5	74.5	70.0	70.5	66.0	62.0	58.0
	8000	95	37	83.5	76.5	71.0	66.5	68.0	62.0	55.0	47.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D5. SUMMARY OF NOISE DATA ON HIGH GRASS

		REFERENCE[a]	AMBIENT	NOISE LEVEL (dB) DISTANCE (FEET) (M) 25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	46.0	82.5	75.0	69.0	64.0	63.0	61.0	58.0	57.0
	Linear	90	66.0	79.0	73.0	72.0	70.0	68.0	66.0		
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	59.0	81.0	76.0	72.0	70.0	69.0	67.0	65.0	64.0
	125	95	60.0	83.0	78.0	74.0	72.0	70.0	69.0	68.0	66.0
	250	95	45.0	86.0	81.0	76.0	74.0	70.0	69.0	66.0	64.0
Pink Noise	500	95	41.0	83.5	73.5	67.0	61.5	52.0	50.0		
	1000	95	41.0	76.0	67.0	63.0	60.0	59.0	57.0	52.0	50.0
	2000	95	38.0	86.0	78.5	74.4	70.0	69.0	65.0	63.0	59.0
	4000	95	31.0	80.5	74.0	67.5	59.5	62.0	57.0	55.0	52.0
	8000	95	31.0	83.0	75.5	69.0	60.5	64.0	59.0	55.0	53.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D6. SUMMARY OF NOISE DATA ON MEDIUM GRASS

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	45.0	83.3	78.7	72.7	65.7	58.5	54.5	51.5	50.0
	Linear	90	63.0	80.0	76.0	71.5	67.0	64.0	58.0		
	Octave Band Geometric Mean Frequency (Hertz)										
Pink Noise	63	95	57.0	80.5	74.5	71.0	68.0	66.0	63.7	62.0	60.0
	125	95	53.5	81.0	74.5	71.0	69.0	66.5	64.7	63.2	62.0
	250	95	45.0	84.0	77.5	73.2	70.0	67.7	66.2	63.5	67.0
	500	95	38.0	83.2	77.0	71.2	66.5	62.0	59.0	56.0	54.5
	1000	95	36.0	78.2	70.5	66.0	61.0	55.5	52.5	50.0	47.5
	2000	95	29.5	87.2	78.0	69.7	64.8	61.0	55.5	50.5	46.5
	4000	95	29.5	86.5	82.5	74.5	67.0	59.0	54.0	50.0	46.0
	8000	95	34.5	81.0	76.0	68.7	61.7	56.5	52.0	52.0	45.0

[a] The reference noise was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D7. SUMMARY OF NOISE DATA ON PLOWED FIELD

				NOISE LEVEL (dB)							
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	42.0	82.5	77.7	72.2	67.7	64.0	58.5	55.5	54.0
	Linear	90	63.5	79.2	74.7	71.5	68.0				
	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	52.0	80.0	74.0	70.0	67.0	65.0	62.5		
	125	95	49.5	80.4	73.2	69.0	65.7	62.5	61.5		
	250	95	35.5	79.7	73.2	67.5	63.7	60.0	57.0		
Pink Noise	500	95	30.0	78.2	69.7	63.6	58.2	53.5	51.0	48.0	41.5
	1000	95	34.5	81.7	74.3	68.7	64.3	60.5	57.5	54.5	53.5
	2000	95	33.0	86.7	80.3	75.3	69.3	64.5	61.5	60.0	
	4000	95	25.5	82.3	77.3	72.0	67.3	63.0	59.0	55.5	52.5
	8000	95	35.5	82.7	76.0	69.0	63.0	58.0	55.2	52.0	50.0

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

TABLE D8. SUMMARY OF NOISE DATA ON SNOW

		NOISE LEVEL (dB)									
				DISTANCE (FEET) (M)							
		REFERENCE[a]	AMBIENT	25(7.6)	50(15)	75(23)	100(30)	125(38)	150(46)	175(53)	200(61)
White Noise	A-Weighted	95	48.5	82.2	76.0	71.7	67.5				
	Linear	90	68.0	85.0	80.0	76.0	74.0				
Pink Noise	Octave Band Geometric Mean Frequency (Hertz)										
	63	95	65.0	80.0	74.0	70.5	68.0				
	125	95	60.0	79.0	73.0	67.0	63.0				
	250	95	48.5	76.0	66.5	59.5	57.0				
	500	95	44.0	72.5	63.5	55.5	55.0	52.0			
	1000	95	44.0	82.0	73.0	66.5	62.5	60.0	58.0	56.0	55.0
	2000	95	39.5	86.5	80.5	74.5	69.0	65.5	63.0	61.0	59.5
	4000	95	34.5	80.5	75.0	71.5	66.5	62.5	61.0	58.5	55.5
	8000	95	32.0	83.0	78.0	71.0	66.5	65.0	63.0	59.0	54.5

[a] The reference noise level was taken 3 feet (0.9 m) from the speaker at a height of 5 feet (1.5 m) above the ground.

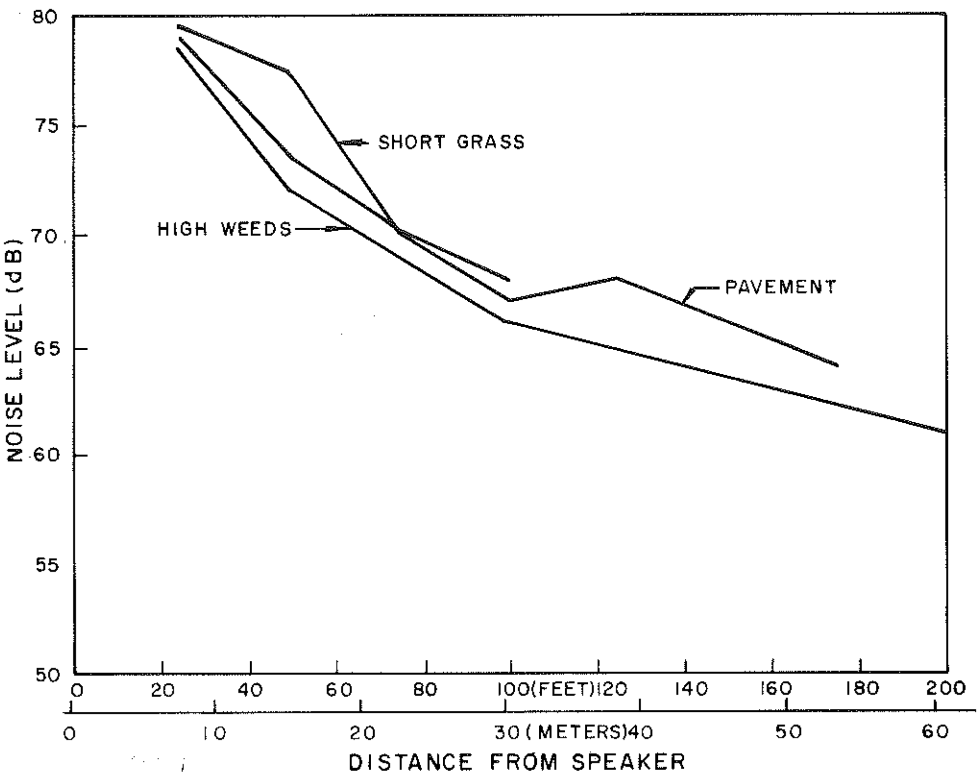

Figure D1. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (63 Hz Center Frequency) for Various Distances.

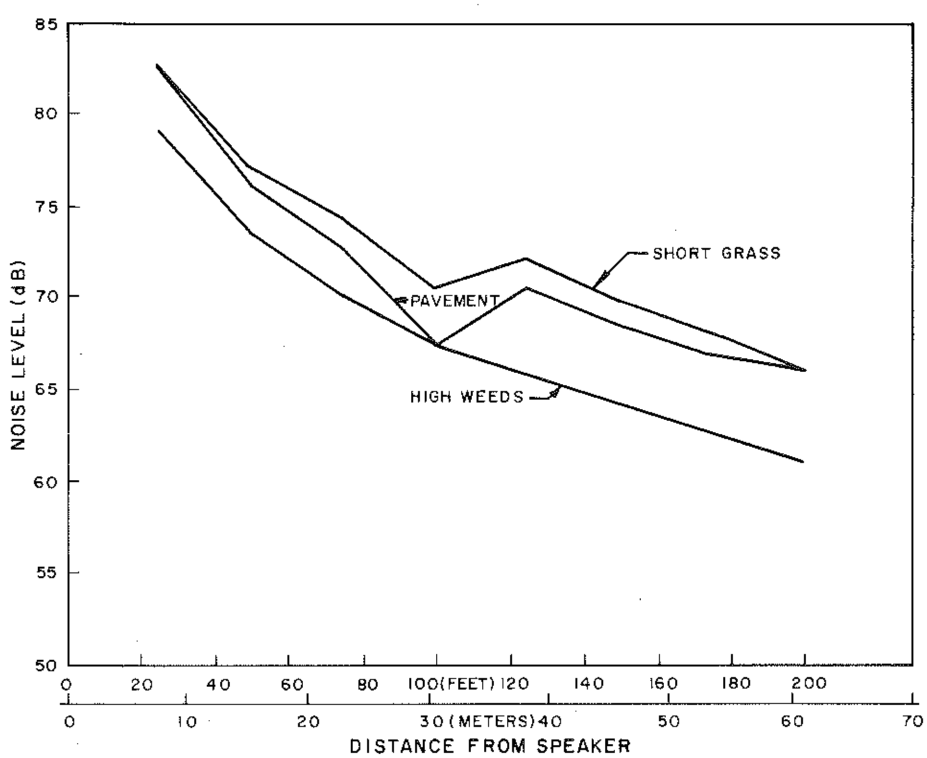

Figure D2. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (125 Hz Center Frequency) for Various Distances.

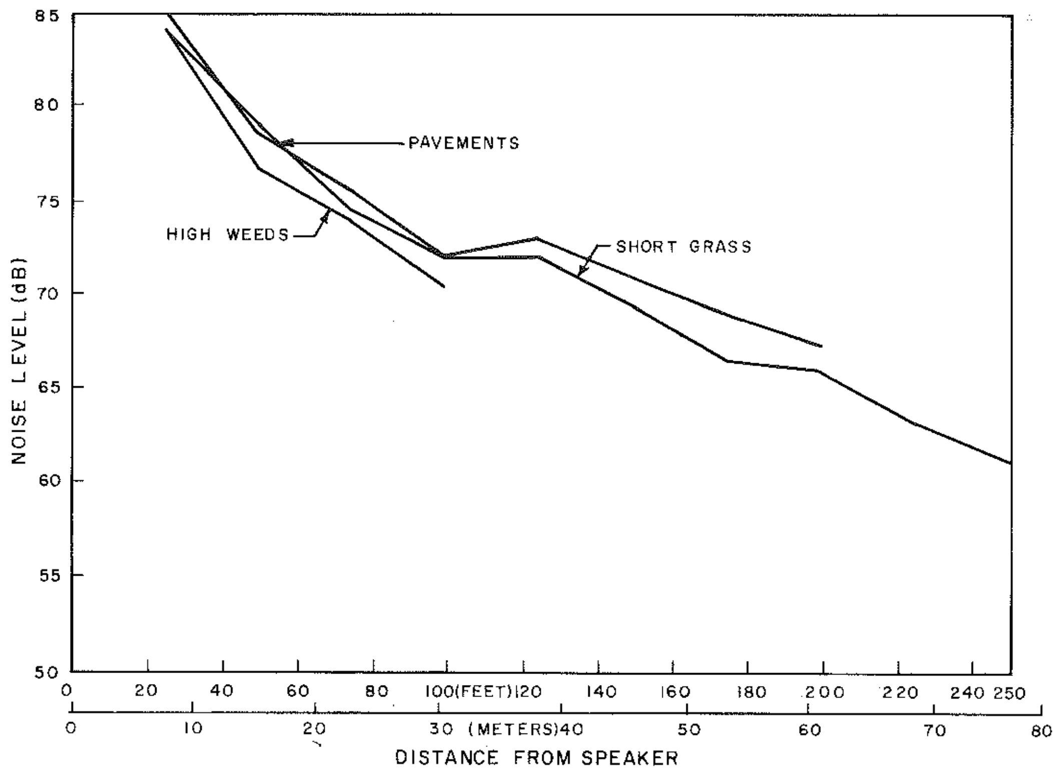

Figure D3. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (250 Hz Center Frequency) for Various Distances.

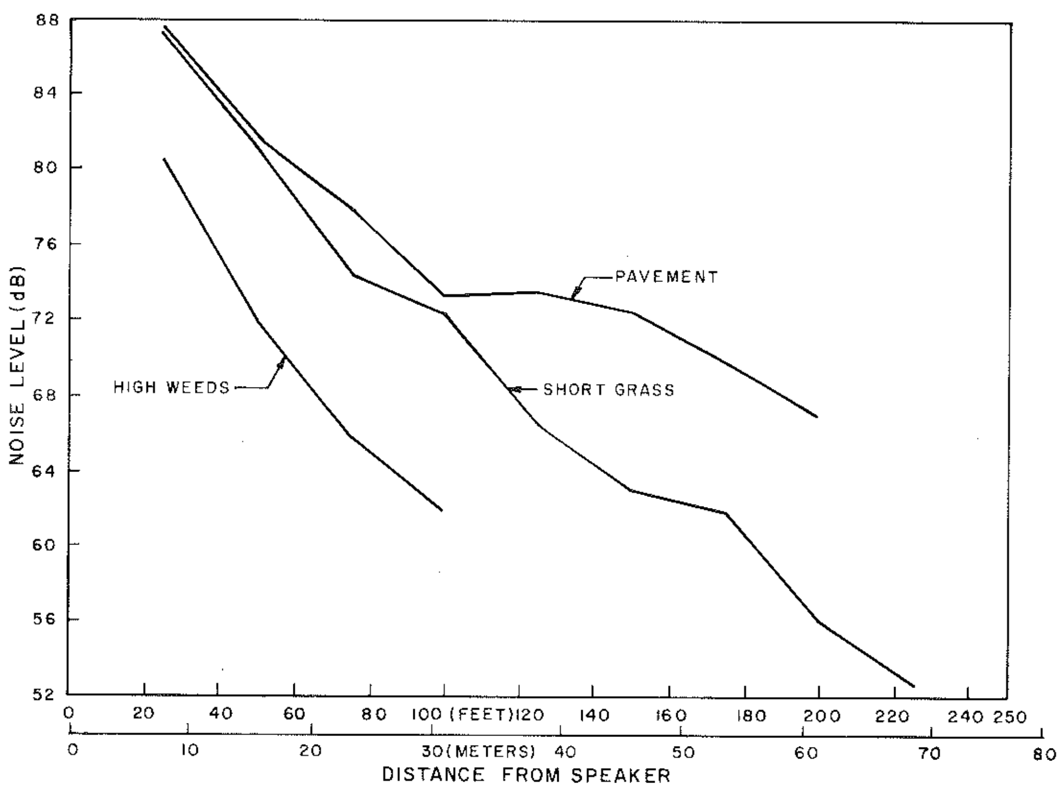

Figure D4. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (500 Hz Center Frequency) for Various Distances.

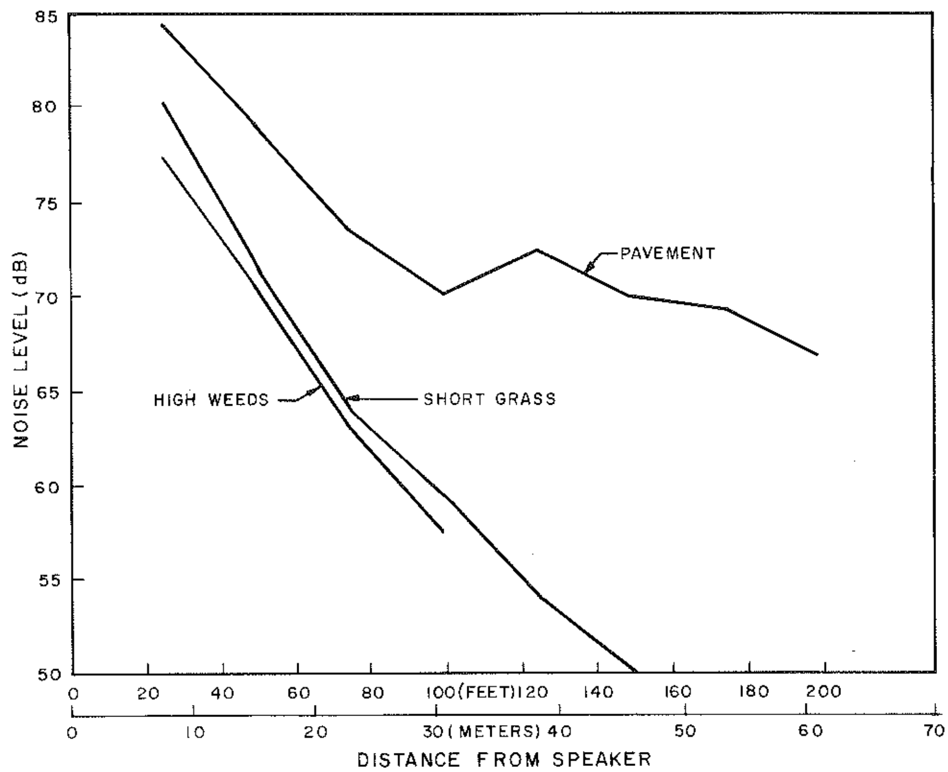

Figure D5. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (1,000 Hz Center Frequency) for Various Distances.

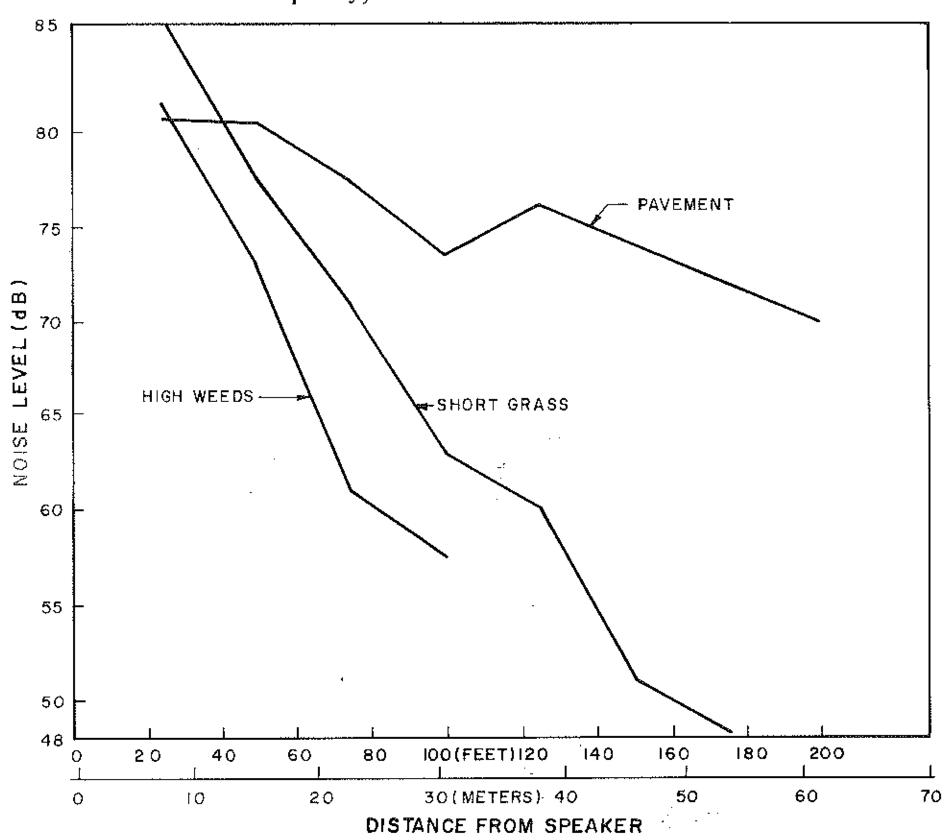

Figure D6. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (2,000 Hz Center Frequnecy) for Various Distances.

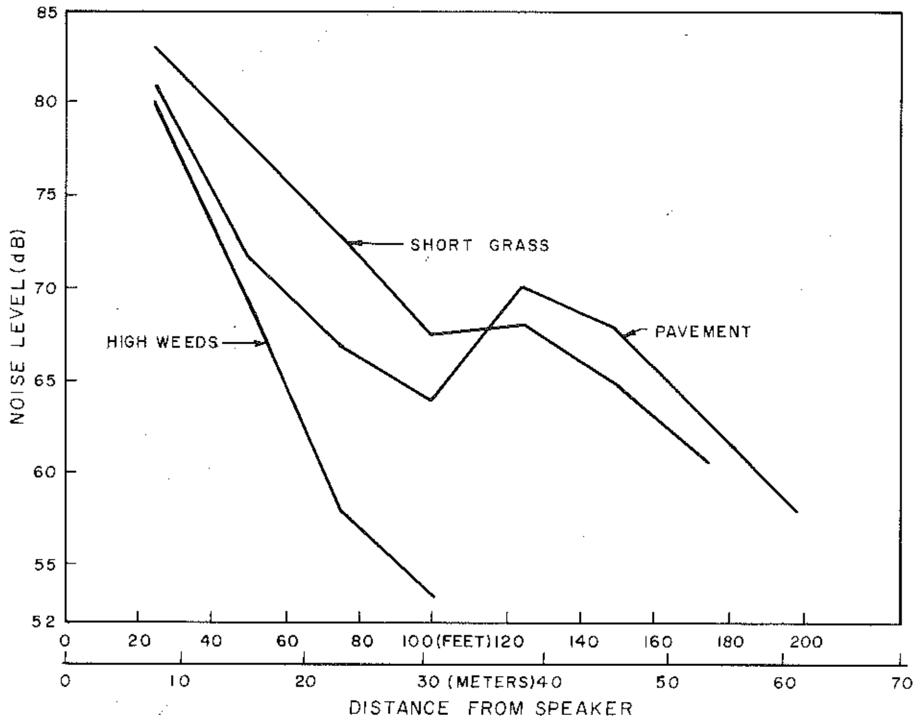

Figure D7. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (4,000 Hz Center Frequency) for Various Distances.

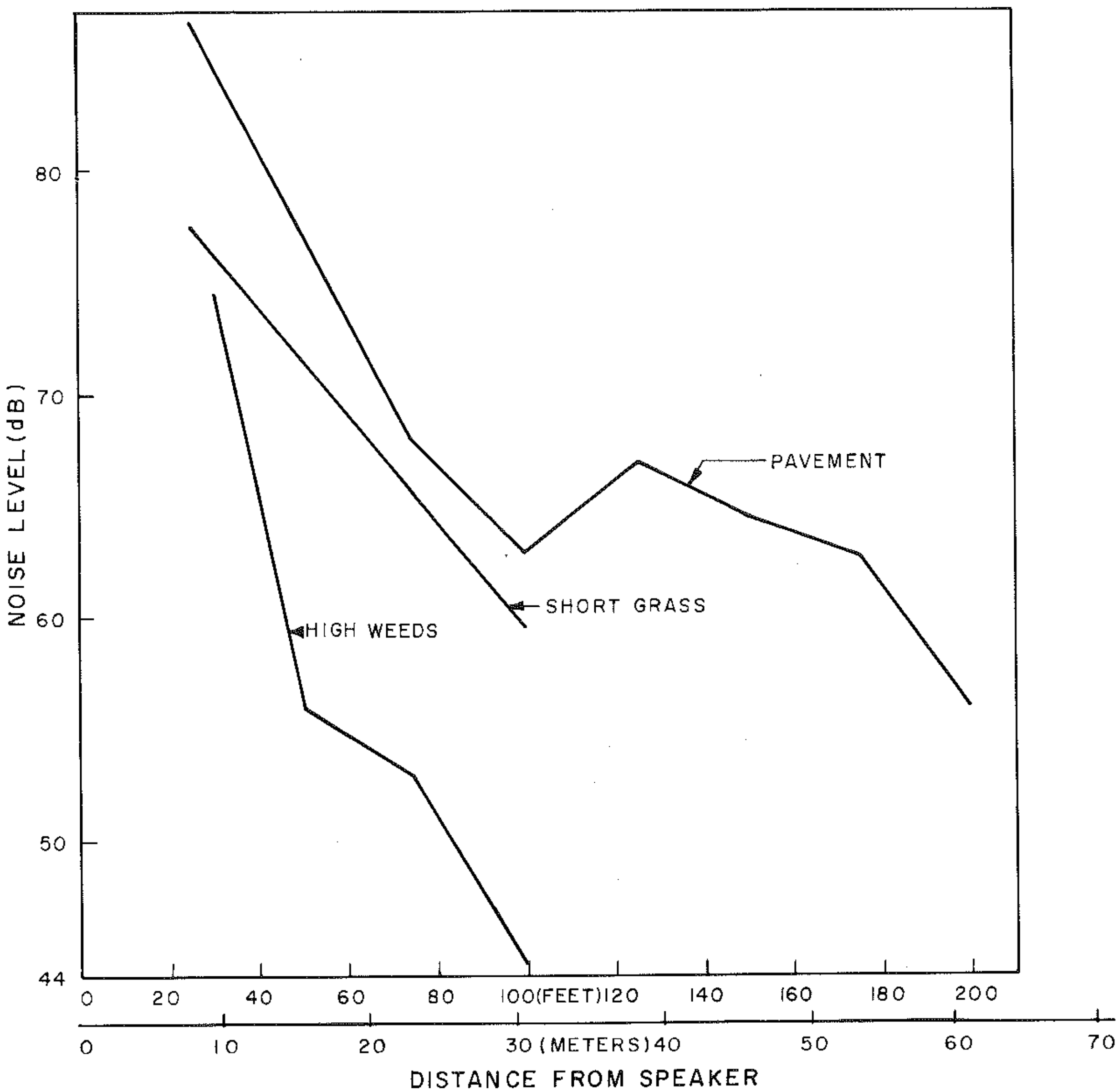

Figure D8. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (8000 Hz Center Frequency) for Various Distances.

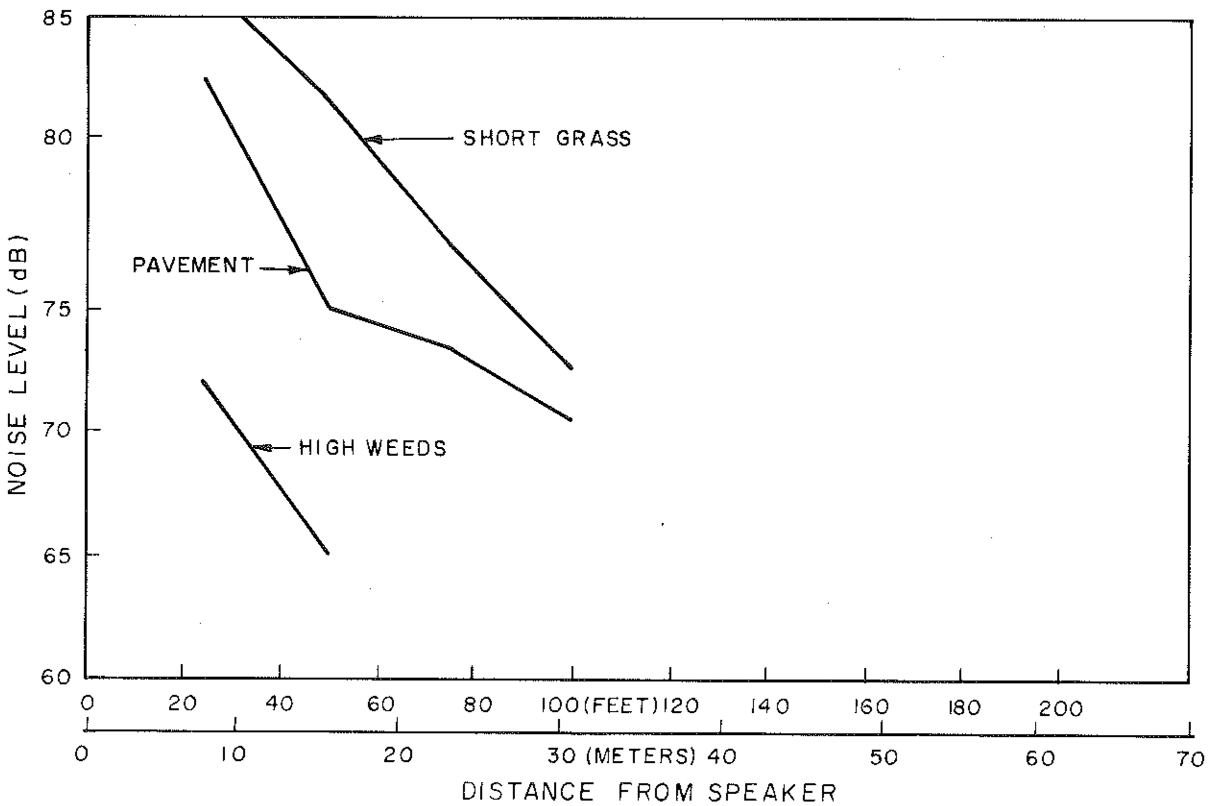

Figure D9. Effect of Short Grass, Pavement, and High Weeds on Noise Levels (Unweighted (Linear) Noise) for Various Distances.

APPENDIX E

NOISE OVER SHORT GRASS
COMPARED TO OTHER GROUND
COVERS FOR VARIOUS FREQUENCIES

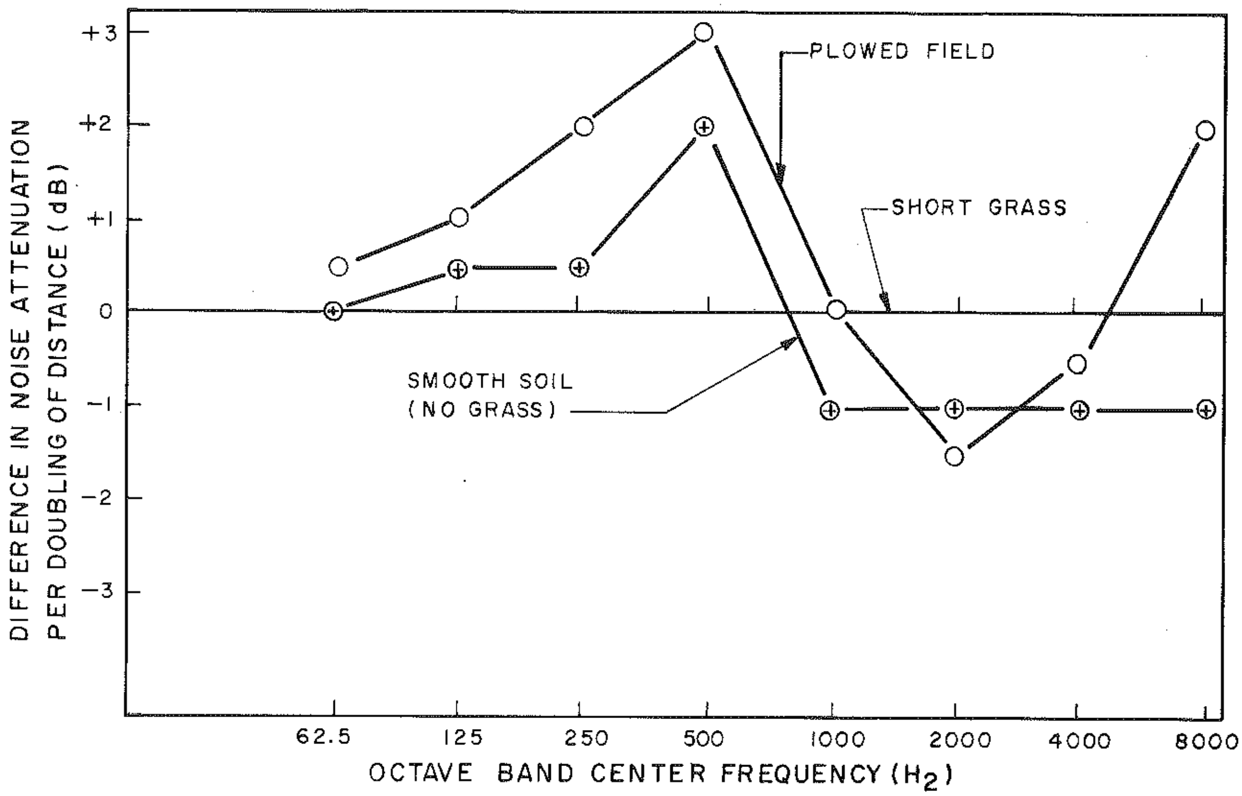

Figure E1. Noise Attenuation per Doubling of Distance over Short Grass Compared to Plowed Field and Smooth Ground for Various Frequencies.

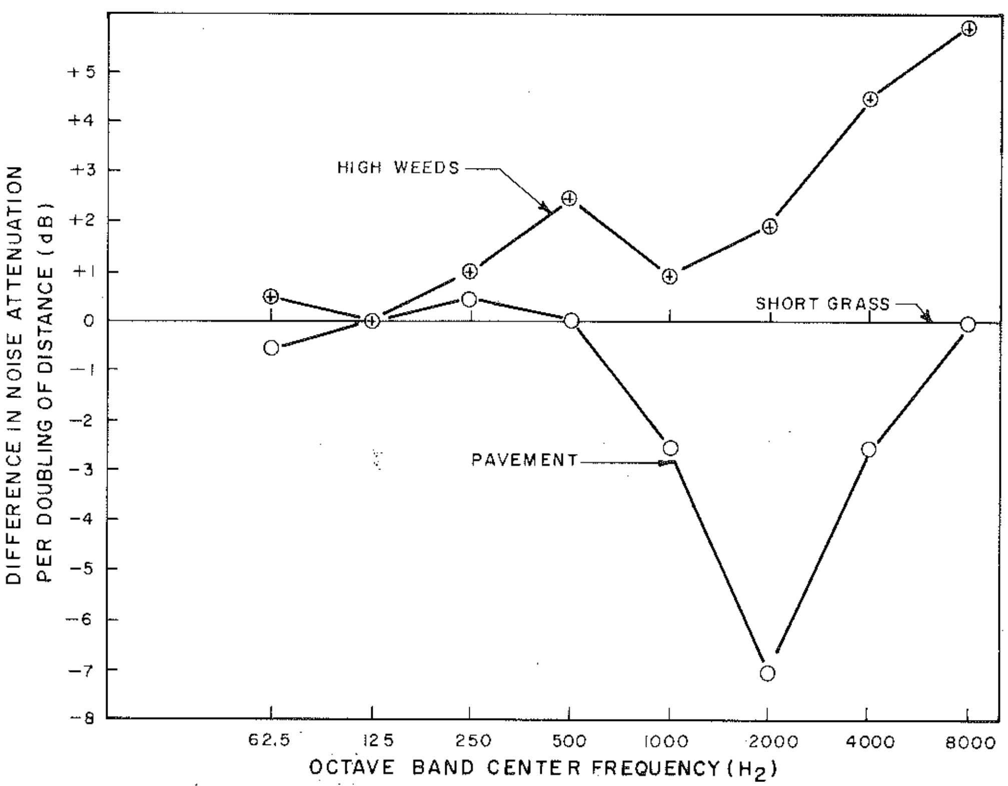

Figure E2. Noise Attenuation per Doubling of Distance over Short Grass Compared to Pavement and High Weeds for Various Frequencies.

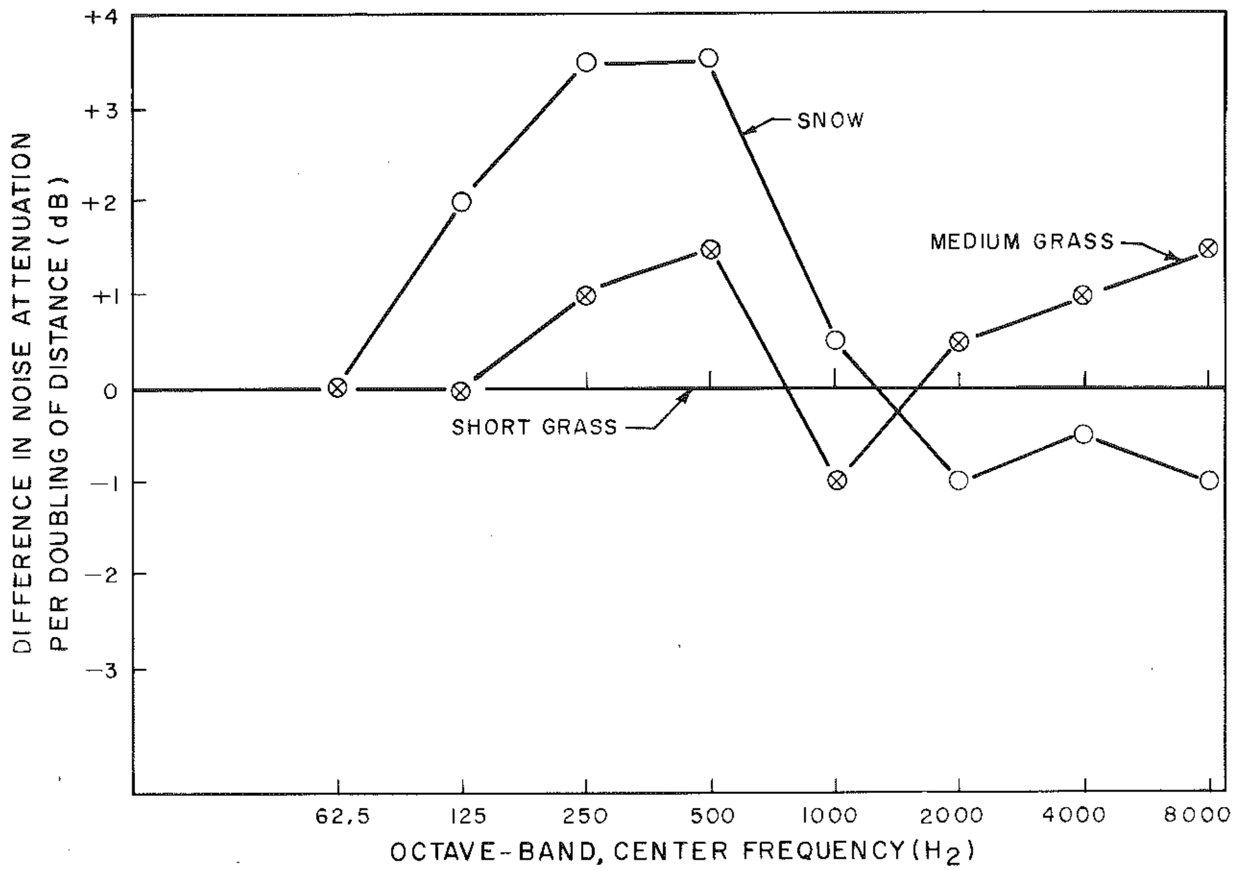

Figure E3. Noise Attenuation per Doubling of Distance over Short Grass Compared to Snow and Medium Grass for Various Frequencies.

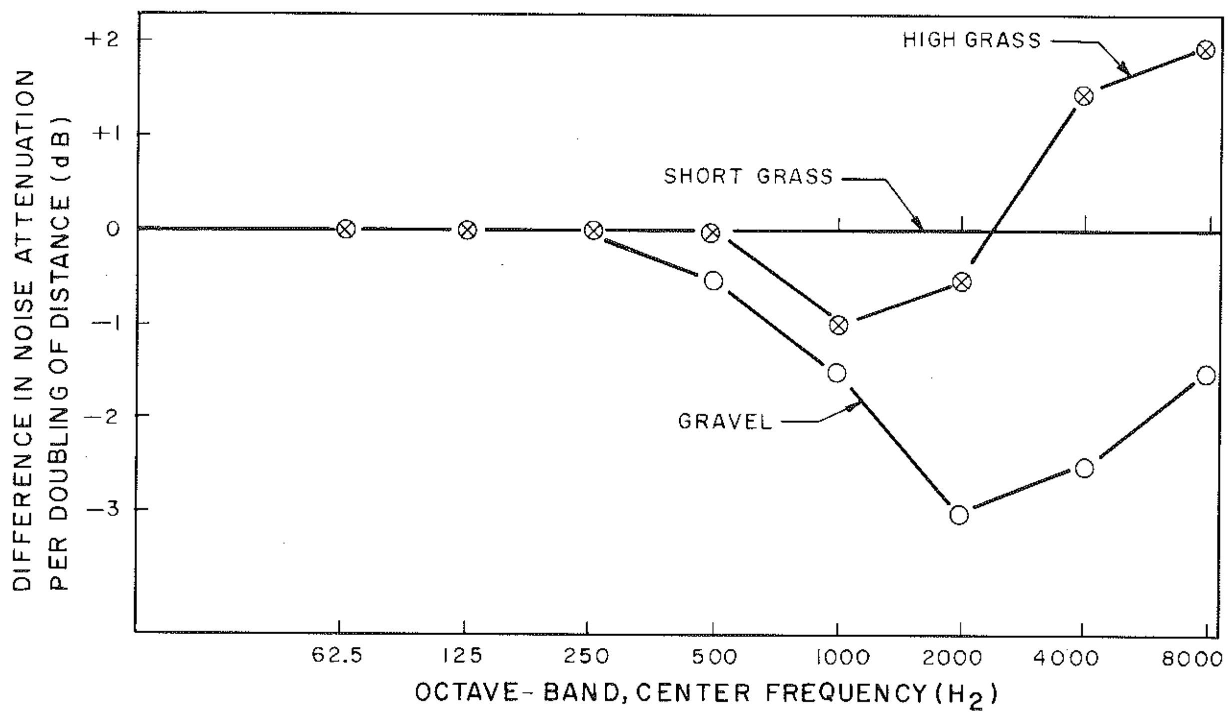

Figure E4. Noise Attenuation per Doubling of Distance over Short Grass Compared to High Grass and Gravel for Various Frequencies.

APPENDIX F

TRAFFIC STREAM NOISE DATA TAKEN AT
DIFFERENT RECEIVER HEIGHTS (SHORT GRASS)

TABLE F1. TRAFFIC STREAM NOISE DATA SUMMARY FOR VARIOUS RECEIVER HEIGHTS (SITE 1)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET)	(M)	HEIGHT (FEET)	(M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
2-24-76	6	100	(30)	5	(1.5)	65.9	62.2	58.5	63.4	72.8	53.8	2394	24	18	2436	2514
		100	(30)	10	(3.0)	67.7	64.2	60.8	65.2	73.3	53.8					
		200	(61)	10	(3.0)	63.6	60.1	56.9	60.8	65.4	53.8					
	7	100	(30)	5	(1.5)	65.9	62.5	59.0	63.8	75.9	53.6	2244	36	6	2286	2340
		100	(30)	15	(4.6)	65.9	66.1	62.3	67.2	75.9	54.9					
		200	(61)	15	(4.6)	64.1	60.9	57.7	61.5	65.1	53.3					
	8	100	(30)	5	(1.5)	65.4	62.3	59.0	63.0	69.5	55.4	2322	72	0	2394	2466
		100	(30)	20	(6.1)	70.3	67.3	63.8	67.9	73.3	61.3					
		200	(61)	20	(6.1)	64.6	62.2	59.5	62.6	65.6	57.4					
	9	200	(61)	10	(3.0)	63.1	60.3	57.2	60.9	68.2	51.0	2328	78	0	2406	2484
		200	(61)	15	(4.6)	63.7	61.6	59.2	61.9	66.8	54.7					
		200	(61)	20	(6.1)	63.8	61.1	58.5	61.7	71.0	51.0					
	10	100	(30)	10	(3.0)	67.4	64.0	60.3	64.8	72.3	55.9	1998	102	12	2112	2250
		100	(30)	15	(4.6)	68.7	64.9	60.5	65.9	73.1	54.6					
		100	(30)	20	(6.1)	70.0	66.3	62.1	67.3	74.4	54.9					
	11	100	(30)	10	(3.0)	66.2	63.4	60.0	64.0	70.5	56.7	2328	60	0	2388	2448
		100	(30)	15	(4.6)	68.5	65.2	61.3	66.0	73.6	55.6					
		100	(30)	20	(6.1)	71.8	65.3	60.0	67.9	76.9	51.3					
	12	50	(15)	10	(3.0)	71.3	68.0	63.1	69.1	80.5	57.2	2484	66	18	2568	2688
		50	(15)	15	(4.6)	72.6	69.2	64.4	70.4	82.1	56.4					
		50	(15)	20	(6.1)	72.8	69.5	64.6	70.7	82.8	57.4					
6-29-76	1	100	(30)	5	(1.5)	63.3	59.4	54.9	60.7	68.7	45.1	2172	66	6	2244	2328
		100	(30)	10	(3.0)	65.1	61.7	57.7	62.9	71.5	46.7					
	2	100	(30)	5	(1.5)	64.1	60.6	56.4	61.6	69.7	53.8	2100	42	12	2154	2232
		100	(30)	15	(4.6)	67.2	64.0	59.7	65.0	74.9	56.2					
	3	100	(30)	5	(1.5)	64.6	61.0	56.9	62.1	70.5	52.8	2316	48	6	2370	2436
		100	(30)	20	(6.1)	68.7	65.1	61.3	66.0	71.8	55.4					
		200	(61)	20	(6.1)	65.1	61.5	57.9	62.4	68.7	53.8					
	4	200	(61)	10	(3.0)	61.5	58.2	53.6	59.3	67.9	49.7	2400	24	12	2436	2496
		200	(61)	15	(4.6)	63.8	61.0	57.7	61.5	70.3	54.1					
		200	(61)	20	(6.1)	64.1	61.7	59.0	62.3	70.0	54.9					
	5	200	(61)	10	(3.0)	61.5	58.8	55.6	59.4	64.9	50.8	2526	48	0	2574	2622
		200	(61)	15	(4.6)	63.8	61.4	58.7	61.8	66.2	55.4					
		200	(61)	20	(6.1)	63.6	60.9	58.2	61.3	66.7	54.1					
7-19-77	1	25	(7.6)	5	(1.5)	75.8	70.4	63.8	72.7	84.0	53.3	1920	42	6	1968	2028
		25	(7.6)	10	(3.0)	76.4	70.6	63.6	73.1	83.6	52.3					
		25	(7.6)	20	(6.1)	75.1	69.9	63.8	72.0	82.8	54.4					
		25	(7.6)	30	(9.1)	76.2	71.0	66.7	72.8	83.1	57.9					
	2	25	(7.6)	5	(1.5)	74.7	68.7	59.0	71.6	83.3	49.5	2142	60	0	2202	2362
		25	(7.6)	10	(3.0)	74.9	69.0	60.8	71.6	83.1	49.5					
		25	(7.6)	20	(6.1)	73.8	68.8	61.5	70.8	81.8	51.0					
		25	(7.6)	30	(9.1)	75.1	69.9	63.8	71.8	81.5	53.6					
	3	25	(7.6)	5	(1.5)	74.7	69.3	61.2	71.9	84.4	50.9	2916	54	6	2976	3048
		25	(7.6)	10	(3.0)	75.1	69.6	61.3	72.0	83.3	51.0					
		25	(7.6)	20	(6.1)	74.4	69.3	62.3	71.5	83.1	53.8					
		25	(7.6)	30	(9.1)	75.1	70.6	65.9	72.3	83.8	57.4					
	4	50	(15)	5	(1.5)	69.4	64.7	58.6	66.9	80.6	50.6	2034	36	18	2088	2178
		50	(15)	10	(3.0)	70.8	66.2	60.0	68.4	81.5	51.0					
		50	(15)	20	(6.1)	71.8	67.7	62.3	69.4	80.0	54.6					
		50	(15)	30	(9.1)	71.8	69.7	66.2	71.1	82.8	58.5					
	5	50	(15)	5	(1.5)	68.1	64.3	60.1	65.5	74.2	52.6	1884	54	18	1956	2064
		50	(15)	10	(3.0)	70.5	66.5	62.3	67.7	75.1	53.6					
		50	(15)	20	(6.1)	71.3	67.6	63.6	68.6	75.6	56.4					
		50	(15)	30	(9.1)	71.5	69.6	67.2	70.0	77.7	59.7					
	6	50	(15)	5	(1.5)	68.5	65.0	60.6	66.5	79.4	54.7	2370	54	6	2430	2502
		50	(15)	10	(3.0)	71.0	67.1	62.6	68.4	79.2	55.6					
		50	(15)	20	(6.1)	71.3	68.0	64.1	69.0	80.3	59.5					
		50	(15)	30	(9.1)	71.8	70.0	66.9	70.7	81.5	63.8					
	7	100	(30)	5	(1.5)	65.8	62.3	58.7	63.3	72.1	52.4	3336	84	18	3438	3576
		100	(30)	10	(3.0)	67.9	64.7	61.3	65.7	74.4	53.3					
		100	(30)	20	(6.1)	67.7	64.5	61.3	65.4	76.2	52.6					
		100	(30)	30	(9.1)	70.3	68.0	65.4	68.5	76.4	57.9					
	8	100	(30)	5	(1.5)	65.3	61.7	57.6	62.7	71.9	52.9	2610	48	0	2658	2706
		100	(30)	10	(3.0)	67.4	63.9	59.7	64.9	72.8	53.3					
		100	(30)	20	(6.1)	67.2	63.9	60.0	64.7	71.0	53.1					
		100	(30)	30	(9.1)	70.0	67.5	64.6	68.0	75.6	58.7					
	9	100	(30)	5	(1.5)	65.1	62.0	58.7	62.7	69.0	55.6	2712	54	6	2772	2844
		100	(30)	10	(3.0)	66.7	63.1	59.2	63.9	69.2	55.6					
		100	(30)	20	(6.1)	68.5	65.4	61.3	----	----	56.7					
		100	(30)	30	(9.1)	69.7	67.4	64.6	67.7	71.5	62.1					
	10	100	(30)	5	(1.5)	66.4	62.1	56.5	64.2	79.1	50.9	1986	30	12	2028	2094
		100	(30)	10	(3.0)	67.7	63.3	57.9	65.4	79.5	52.1					
		100	(30)	20	(6.1)	68.7	64.5	59.2	66.6	81.3	52.8					
		100	(30)	30	(9.1)	70.0	66.7	62.3	68.2	82.8	56.4					

TABLE F1. (CON.)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET)	(M)	HEIGHT (FEET)	(M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
	11	200	(61)	5	(1.5)	63.1	59.4	55.6	60.6	72.7	51.0	2094	60	18	2172	2286
		200	(61)	10	(3.0)	60.8	57.5	53.8	58.6	70.5	47.4					
		200	(61)	20	(6.1)	64.9	61.7	57.9	62.6	71.8	51.5					
		200	(61)	30	(9.1)	66.9	64.4	61.0	65.0	72.6	54.1					
	12	200	(61)	5	(1.5)	62.7	59.2	55.6	60.0	66.3	52.4	1908	54	12	1974	2064
		200	(61)	10	(3.0)	60.8	58.1	54.4	58.8	65.4	51.0					
		200	(61)	20	(6.1)	65.4	62.4	58.7	63.2	70.8	54.9					
		200	(61)	30	(9.1)	67.2	64.7	61.5	65.2	71.3	67.2					
	13	200	(61)	5	(1.5)	62.6	58.9	55.4	60.0	68.6	51.7	2064	54	18	2136	2244
		200	(61)	10	(3.0)	61.5	57.9	54.4	59.0	66.7	----					
		200	(61)	20	(6.1)	66.4	62.6	58.5	63.8	70.8	----					
		200	(61)	30	(9.1)	68.7	65.2	61.8	66.0	72.1	----					
7-28-78	1	400	(122)	10	(3.0)	56.4	52.7	49.5	54.6	67.7	45.9	1776	60	6	1842	1920
		400	(122)	20	(6.1)	58.7	55.5	53.6	57.5	74.1	49.5					
		400	(122)	30	(9.1)	61.0	57.7	54.1	59.8	73.8	52.1					
	2	400	(122)	10	(3.0)	53.6	50.8	48.2	52.0	67.7	46.7	1608	30	0	1638	1668
		400	(122)	20	(6.1)	58.7	55.6	52.6	59.8	82.3	50.3					
		400	(122)	30	(9.1)	60.8	58.0	54.9	59.6	74.4	52.6					
	3	400	(122)	10	(3.0)	55.6	52.0	48.7	52.9	61.5	46.2	1740	78	6	1824	1932
		400	(122)	30	(9.1)	62.3	58.2	53.6	59.4	67.2	48.5					
	4	400	(122)	5	(1.5)	54.0	50.9	47.1	51.7	59.1	45.2	1812	48	12	1872	1956
		400	(122)	20	(6.1)	57.4	54.5	51.0	55.3	62.6	46.7					
		400	(122)	30	(9.1)	59.2	56.0	52.8	56.8	63.3	48.2					
	5	200	(61)	5	(1.5)	60.4	56.7	53.2	57.7	64.7	46.5	2472	66	12	2550	2642
		200	(61)	10	(3.0)	61.0	58.2	54.9	58.9	66.2	48.5					
		200	(61)	20	(6.1)	62.6	58.9	54.9	59.9	66.9	47.4					
		200	(61)	30	(9.1)	64.4	60.7	56.4	61.7	68.5	51.5					
	6	200	(61)	5	(1.5)	58.3	56.2	53.8	56.6	61.7	50.1	2268	54	0	2322	2376
		200	(61)	10	(3.0)	60.5	58.1	56.2	58.6	65.4	52.8					
		200	(61)	20	(6.1)	60.3	58.0	55.6	58.4	64.6	48.5					
		200	(61)	30	(9.1)	61.5	59.2	56.2	59.7	66.4	49.5					
	7	100	(30)	5	(1.5)	65.0	61.3	58.1	62.5	71.7	52.6	2232	60	12	2304	2400
		100	(30)	10	(3.0)	67.2	63.3	59.7	64.5	73.3	53.6					
		100	(30)	20	(6.1)	67.2	63.6	60.0	64.9	75.1	56.2					
		100	(30)	30	(9.1)	68.2	64.5	61.0	65.7	74.6	55.9					
	8	100	(30)	5	(1.5)	63.8	60.4	56.8	61.4	69.2	52.6	2208	30	0	2238	2268
		100	(30)	10	(3.0)	64.6	61.1	57.9	62.0	71.0	54.6					
		100	(30)	20	(6.1)	66.4	63.1	59.5	64.0	72.3	56.4					
		100	(30)	30	(9.1)	67.4	63.7	59.2	65.2	76.2	52.8					
	9	50	(15)	5	(1.5)	65.0	60.0	54.2	62.1	72.7	48.7	2154	78	0	2232	2310
		50	(15)	10	(3.0)	67.9	64.6	60.5	65.6	72.8	52.1					
		50	(15)	20	(6.1)	70.0	65.6	60.3	67.8	83.1	51.0					
		50	(15)	30	(9.1)	70.8	66.2	61.0	68.4	82.3	53.6					
	10	50	(15)	5	(1.5)	68.2	63.2	57.4	65.4	78.5	48.5	1800	60	0	1860	1920
		50	(15)	10	(3.0)	67.7	64.2	60.0	65.2	73.3	52.8					
		50	(15)	20	(6.1)	72.1	66.1	60.0	68.4	79.2	53.8					
		50	(15)	30	(9.1)	71.3	67.0	61.3	68.7	80.8	55.4					
	11	25	(7.6)	5	(1.5)	72.7	67.7	61.2	70.3	83.7	53.8	1872	60	0	1932	2052
		25	(7.6)	10	(3.0)	73.3	67.8	62.6	70.1	85.1	54.1					
		25	(7.6)	20	(6.1)	72.3	67.9	62.3	70.1	82.1	52.8					
		25	(7.6)	30	(9.1)	72.6	68.2	62.6	70.3	83.1	53.6					
	12	25	(7.6)	5	(1.5)	72.1	66.7	60.4	69.1	79.7	49.5	1980	36	6	2022	2076
		25	(7.6)	10	(3.0)	73.1	68.9	64.1	70.6	86.7	55.4					
		25	(7.6)	20	(6.1)	72.3	67.5	62.3	69.5	81.3	52.8					
		25	(7.6)	30	(9.1)	72.1	67.4	62.6	69.1	79.5	53.6					

TABLE F2. TRAFFIC STREAM NOISE DATA SUMMARY FOR VARIOUS RECEIVER HEIGHTS (SITE 3)

DATE	MEASUREMENT NUMBER	DISTANCE (FEET)	(M)	HEIGHT (FEET)	(M)	MEASURED NOISE LEVEL L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	L_{min}	VOLUME (VPH) AUTO	LT	HT	TOTAL	EQUIV
8-5-76	5	125	(38)	5	(1.5)	77.9	70.8	64.1	73.5	82.8	57.2	2010	114	246	2370	3222
		125	(38)	10	(3.0)	78.5	72.1	66.2	74.6	83.8	59.7					
		125	(38)	15	(4.6)	80.3	73.3	67.2	76.2	85.6	61.3					
	6	125	(38)	5	(1.5)	77.2	71.1	64.9	73.5	82.8	55.4	2370	78	276	2724	3630
		125	(38)	10	(3.0)	79.0	73.3	67.4	75.3	83.6	59.7					
		125	(38)	20	(6.1)	80.3	73.4	67.4	76.2	85.6	45.9					
	7	250	(76)	5	(1.5)	73.6	68.3	63.3	70.3	80.0	56.7	2052	144	258	2454	3372
		250	(76)	10	(3.0)	75.1	69.2	63.3	71.2	80.5	58.5					
	8	250	(76)	5	(1.5)	73.3	69.4	65.1	70.9	83.1	60.3	2142	108	288	2538	3510
		250	(76)	10	(3.0)	73.8	69.2	64.9	70.6	81.0	60.3					
		250	(76)	15	(4.6)	75.4	70.8	66.9	72.1	80.8	64.4					
	9	500	(152)	10	(3.0)	68.5	64.5	60.8	65.6	74.4	57.4	2028	66	240	2334	3120
		500	(152)	15	(4.6)	69.0	65.5	61.8	66.4	76.9	58.7					
	10	500	(152)	10	(3.0)	67.9	64.0	60.0	65.1	72.3	55.1	1962	90	198	2250	2934
		500	(152)	20	(6.1)	69.2	65.5	61.8	66.4	72.3	58.2					
7-14-77	1	80	(24)	5	(1.5)	79.6	72.5	65.6	75.9	87.3	60.4	1932	18	288	2238	3120
		80	(24)	10	(3.0)	81.0	74.4	68.2	77.6	90.5	61.8					
		80	(24)	20	(6.1)	80.5	74.2	68.7	77.2	89.7	61.3					
		80	(24)	30	(9.1)	79.0	73.8	69.2	75.5	83.3	62.8					
	2	80	(24)	5	(1.5)	79.9	73.0	66.2	76.2	86.2	56.8	2148	42	342	2532	4284
		80	(24)	10	(3.0)	82.1	75.2	68.7	78.4	89.7	60.8					
		80	(24)	20	(6.1)	81.8	75.2	69.5	77.9	88.5	63.1					
		80	(24)	30	(9.1)	80.0	74.7	70.0	76.1	82.3	64.1					
	3	140	(43)	5	(1.5)	73.6	66.6	60.8	70.0	81.3	54.6	2166	54	348	2568	3666
		140	(43)	10	(3.0)	78.5	72.1	66.4	74.7	85.4	58.7					
		140	(43)	20	(6.1)	78.5	72.5	67.4	74.8	84.9	62.6					
		140	(43)	30	(9.1)	77.4	70.8	66.7	73.3	84.6	63.1					
	4	140	(43)	5	(1.5)	73.3	67.0	61.0	69.6	78.6	52.3	2334	48	414	2796	4086
		140	(43)	10	(3.0)	78.2	71.9	66.2	74.1	82.8	56.4					
		140	(43)	20	(6.1)	77.7	71.8	66.4	73.7	81.5	59.0					
		140	(43)	30	(9.1)	77.2	70.4	65.9	72.5	81.3	60.5					
	5	200	(61)	5	(1.5)	68.2	61.5	55.1	64.2	75.8	49.5	1992	54	306	2352	3324
		200	(61)	10	(3.0)	74.4	68.1	62.1	70.5	78.5	53.1					
		200	(61)	20	(6.1)	76.2	70.7	65.1	72.6	81.0	57.7					
		200	(61)	30	(9.1)	74.6	68.6	63.8	70.5	78.5	58.5					
	6	200	(61)	5	(1.5)	67.7	61.8	56.3	64.0	76.0	52.4	1962	120	300	2382	3402
		200	(61)	10	(3.0)	73.8	68.2	62.6	70.6	82.1	56.7					
		200	(61)	20	(6.1)	76.7	70.9	65.4	73.0	82.6	62.3					
		200	(61)	30	(9.1)	74.1	68.7	64.4	70.7	81.5	62.1					
	7	300	(91)	5	(1.5)	64.0	57.6	51.8	59.9	67.7	46.8	2070	138	366	2574	3810
		300	(91)	10	(3.0)	67.7	60.8	54.4	63.6	73.3	48.7					
		300	(91)	20	(6.1)	71.5	65.4	59.2	68.0	77.4	52.1					
		300	(91)	30	(9.1)	71.3	66.7	61.8	68.5	78.2	54.9					
	8	300	(91)	5	(1.5)	63.8	59.1	54.2	61.2	75.1	49.0	1914	108	342	2364	3498
		300	(91)	10	(3.0)	66.7	61.0	55.6	63.8	78.7	49.0					
		300	(91)	20	(6.1)	71.3	65.4	59.5	67.8	78.5	52.6					
		300	(91)	30	(9.1)	71.8	67.3	63.1	68.9	79.7	55.4					
	9	400	(122)	5	(1.5)	57.9	52.7	47.9	54.6	63.5	44.7	1770	66	258	2094	2934
		400	(122)	10	(3.0)	62.6	56.7	51.5	58.7	68.5	44.1					
		400	(122)	20	(6.1)	68.5	61.8	55.6	64.3	72.1	50.5					
		400	(122)	30	(9.1)	69.0	64.1	59.0	65.6	73.8	55.6					
	10	400	(122)	5	(1.5)	57.4	53.7	49.1	54.8	61.9	46.9	2106	66	258	2430	3270
		400	(122)	10	(3.0)	62.3	58.4	54.1	59.6	69.5	46.9					
		400	(122)	20	(6.1)	66.4	62.4	58.2	63.5	71.8	54.9					
		400	(122)	30	(9.1)	68.2	65.1	61.3	65.8	71.0	58.5					
	11	500	(152)	5	(1.5)	56.4	52.2	48.1	53.4	60.5	45.3	2154	114	276	2544	3486
		500	(152)	10	(3.0)	61.0	56.4	52.3	57.6	66.4	47.7					
		500	(152)	20	(6.1)	65.6	60.4	55.9	61.8	68.7	51.5					
		500	(152)	30	(9.1)	67.2	61.7	58.5	63.0	71.0	55.6					
	12	500	(152)	5	(1.5)	54.1	50.0	45.9	51.1	58.2	43.1	2232	60	246	2538	3336
		500	(152)	10	(3.0)	57.9	53.5	49.5	55.0	62.8	46.7					
		500	(152)	20	(6.1)	62.3	57.0	52.6	58.6	67.2	49.2					
		500	(152)	30	(9.1)	62.8	59.6	55.6	61.0	70.0	51.8					
	13	600	(183)	5	(1.5)	55.0	51.0	47.1	52.0	57.7	44.4	2238	36	372	2646	3798
		600	(183)	10	(3.0)	59.0	54.7	50.5	55.9	63.1	46.4					
		600	(183)	20	(6.1)	61.8	57.9	53.8	58.8	64.1	49.8					
		600	(183)	30	(9.1)	61.5	59.3	56.4	59.7	65.4	53.6					
	14	600	(183)	5	(1.5)	53.1	49.0	44.5	50.1	57.4	39.2	2040	96	318	2454	3504
		600	(183)	10	(3.0)	56.7	52.6	47.4	54.2	66.4	44.1					
		600	(183)	20	(6.1)	60.5	55.8	50.3	58.0	73.6	46.9					
		600	(183)	30	(9.1)	60.3	56.7	52.3	57.5	62.3	49.7					

APPENDIX G

EFFECT OF DISTANCE
ON NOISE LEVELS

TABLE G1. NOISE LEVELS FOR VARIOUS DISTANCES FROM THE ROADWAY (SITE 4)

DISTANCE FT	(M)	NUMBER DATA POINTS	AVERAGE L_{10}	AVERAGE L_{50}	AVERAGE L_{90}	AVERAGE L_{eq}
50	(15)	34	77.0	71.6	66.4	74.2
100	(31)	34	73.3	68.2	63.6	70.3
200	(61)	34	67.8	63.3	59.3	64.9

TABLE G2. NOISE LEVELS FOR VARIOUS DISTANCES FROM THE ROADWAY (SITE 5)

DISTANCE FT	(M)	NUMBER DATA POINTS	AVERAGE L_{10}	AVERAGE L_{50}	AVERAGE L_{90}	AVERAGE L_{eq}
25	(8)	7	72.7	61.2	51.4	68.6
50	(15)	11	68.2	58.9	49.7	64.5
100	(31)	16	63.8	56.1	48.3	60.5
200	(61)	8	60.7	54.7	48.4	57.5
400	(122)	4	54.4	49.3	44.4	52.4

TABLE G3. NOISE LEVELS FOR VARIOUS DISTANCES FROM THE ROADWAY (SITE 6)

DISTANCE FT	(M)	NUMBER DATA POINTS	AVERAGE L_{10}	AVERAGE L_{50}	AVERAGE L_{90}	AVERAGE L_{eq}
50	(15)	11	72.2	66.5	60.2	69.6
100	(31)	11	67.8	61.9	56.5	64.6
200	(61)	11	62.2	57.8	53.7	60.1

TABLE G4. NOISE DROPOFF PER DOUBLING OF DISTANCES (SITE 4)

DISTANCE		DROPOFF PER DOUBLING DISTANCE	
FT	M	L_{10}	L_{eq}
50 to 100	15 to 31	3.7	3.9
100 to 200	31 to 61	5.5	5.4
Average		4.6	4.6

TABLE G5. NOISE DROPOFF PER DOUBLING OF DISTANCES (SITE 5)

DISTANCE		DROPOFF PER DOUBLING DISTANCE	
FT	M	L_{10}	L_{eq}
25 to 50	8 to 15	4.5	4.1
50 to 100	15 to 31	4.4	4.0
100 to 200	31 to 61	3.1	3.0
200 to 400	61 to 122	6.3	5.1
Average		4.6	4.1

TABLE G6. NOISE DROPOFF PER DOUBLING OF DISTANCES (SITE 6)

DISTANCE		DROPOFF PER DOUBLING DISTANCE	
FT	M	L_{10}	L_{eq}
50 to 100	15 to 31	4.4	5.0
100 to 200	31 to 61	5.6	4.5
Average		5.0	4.8

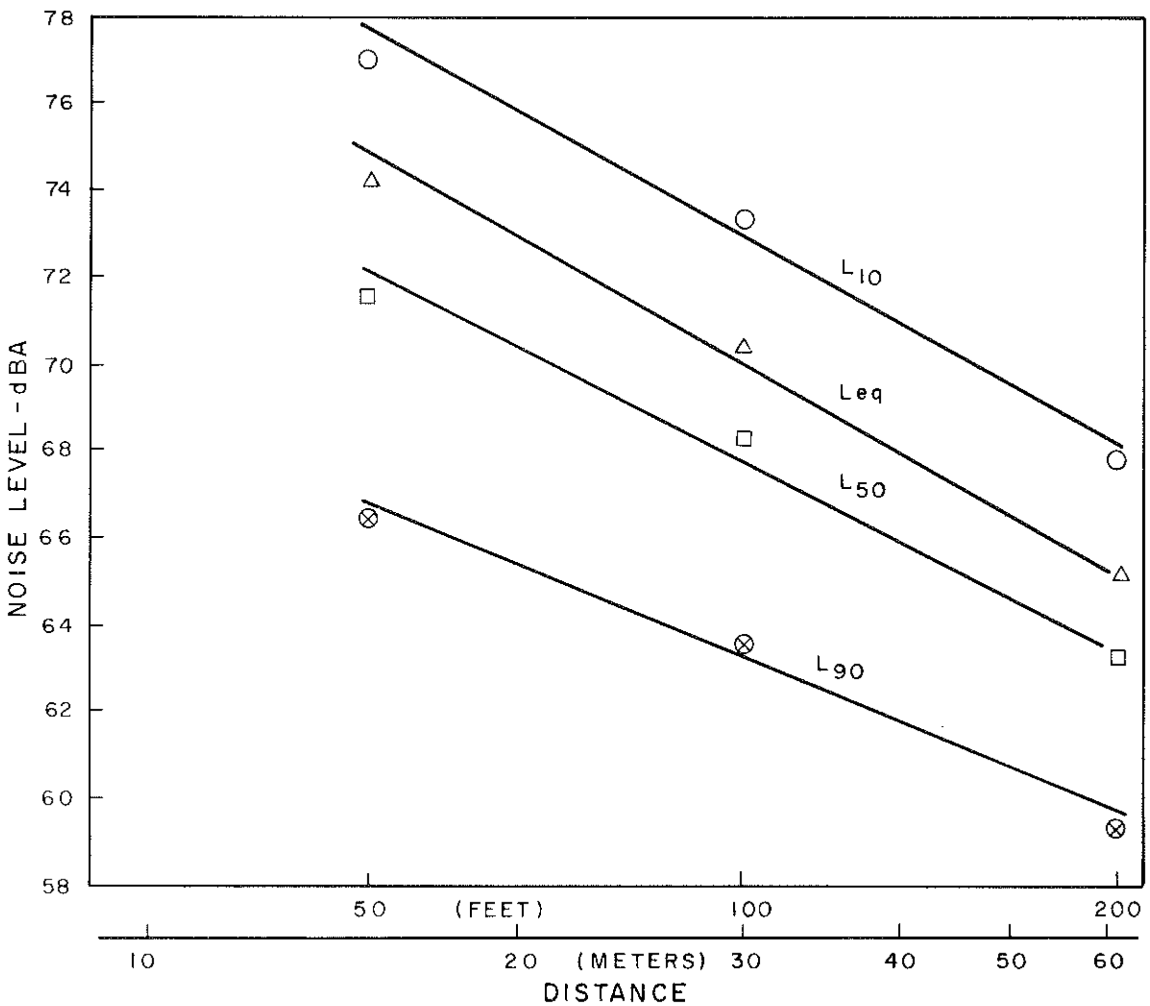

Figure G1. Effect of Distance on Noise Level (Site 4).

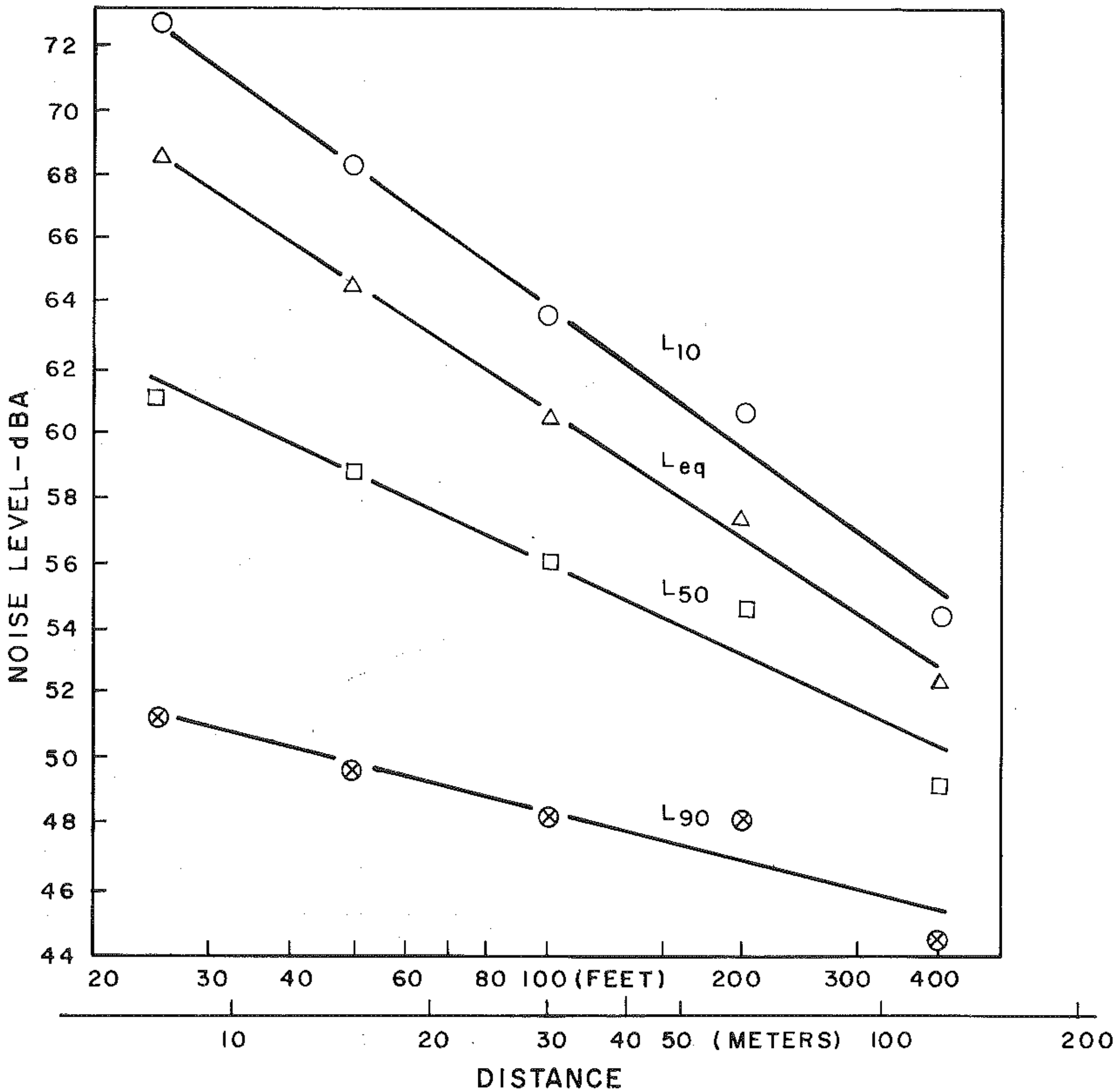

Figure G2. Effect of Distance on Noise Level (Site 5).

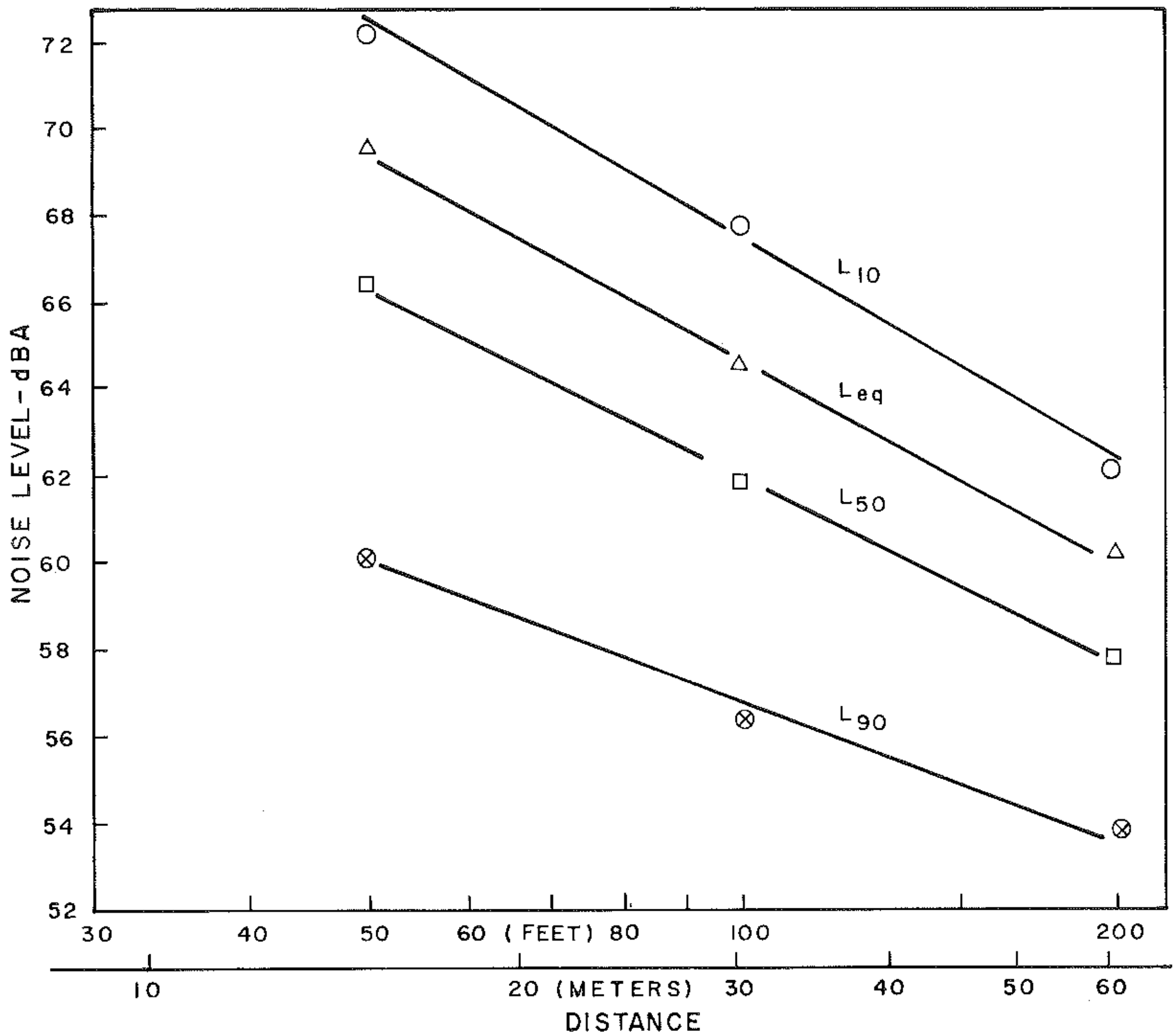

Figure G3. Effect of Distance on Noise Level (Site 6).