REPORT NO. DOT-TSC-FHWA-72-2

MANUAL FOR HIGHWAY NOISE PREDICTION (SHORT VERSION)

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MARCH 1972
TECHNICAL REPORT

Prepared for:

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WASHINGTON, D.C. 20590

1. Report No.
DOT-TSC-FHWA-72-2

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
MANUAL FOR HIGHWAY NOISE PREDICTION
(SHORT VERSION)

5. Report Date
March 1972

6. Performing Organization Code

7. Author(s)
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8. Performing Organization Report No.

9. Performing Organization Name and Address
Department of Transportation
Transportation Systems Center
55 Broadway, Cambridge, MA 02142

10. Work Unit No.
R-2519

11. Contract or Grant No.
OS-207

12. Sponsoring Agency Name and Address
Department of Transportation
Federal Highway Administration
Washington, DC 20590

13. Type of Report and Period Covered
Technical Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract This manual is intended for use as a tool in predicting the noise which will be generated by freely-flowing vehicle traffic along a highway of known characteristics. The manual presents two separate approaches to the prediction problem. The first approach utilizes a simple nomograph to provide first-approximation solutions to the highway noise prediction problem. The second approach utilizes a computerized traffic noise simulation model, for more accurate and more flexible noise level predictions. This report is a short version of Report No. DOT-TSC-FHWA-72-1, consisting of only the first four sections of that longer report for more convenient use by most of those involved in highway noise predictions. This report contains a brief description of the bases for both prediction approaches, to indicate the assumptions and limitations inherent in the procedures, and a Users' Manual for the computer program. Appendicies A and B of the longer report provide a more detailed description of the prediction theory, and a Programmers' Manual.

17. Key Words Traffic Noise Prediction, Highway Noise Simulation, Traffic Noise Levels

18. Distribution Statement
Availability is Unlimited. Document may be Released To the National Technical Information Service, Springfield, Virginia 22151, for Sale to the Public.

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
47

22. Price

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ACKNOWLEDGEMENTS

Although a single author is identified for this manual, the contents are largely the work of four other individuals, whose efforts are gratefully acknowledged. The acoustical and mathematical bases for the prediction procedures and the computer programming are the work of Dr. Ulrich J. Kurze, Senior Scientist, Bolt Beranek and Newman, Incorporated, performed under Contract No. DOT-TSC-315 for the Transportation Systems Center. The method for predicting approximate highway traffic noise levels, including the preparation of the nomographs, is the work of Mr. Walter Messcher, Information Services Division, Transportation Systems Center. The adaptation of the initial computer program to the computers at the Transportation Systems Center and the development of simple input/output routines are the work of Mr. James D. Steinberg, Information Services Division, and Mr. Jack Taub, Service Technology Corporation.

1.0 INTRODUCTION

Noise is an undesirable side-product of highway traffic. Although modern passenger automobiles and highway trucks are relatively inefficient generators of noise (a typical passenger car traveling at 65 mph radiates less than 0.0002 hp of noise), the noise which they *do* generate is sufficient to be highly annoying to highway neighbors. Thus, the noise which will result from a new or expanded highway construction project is an important factor which must be considered in the planning of that project.

This manual is intended for use as a tool in predicting the noise which will be generated by freely-flowing vehicle traffic along a highway of known characteristics. The manual presents two separate approaches to this prediction problem. The first approach is intended to provide first-approximation solutions, through the use of simple pencil-and-ruler nomographs to relate traffic noise to traffic volume, traffic speed, mix of vehicles, distance from the highway, and simple topographical configurations. This method is presented in Section 3 of this manual. The second approach utilizes a computerized traffic noise simulation model for more accurate and more flexible noise level predictions, particularly for situations involving complicated topographical configurations. This method is presented in Section 4. Section 2 describes briefly the acoustical and mathematical bases for both approaches, to permit a better understanding of the capabilities and limitations of each approach. A more complete description of the basic concepts is included as Appendix A to this manual, for the benefit of those who desire a more detailed understanding of the procedures. Sample calculations are included in both Sections 3 and 4, to illustrate the use of both procedures. A complete description of the computerized simulation model and the program listing in FORTRAN IV are contained in Appendix B, which has been bound separately for convenience. Appendices A and B are included as part of Report DOT-TSC-FHWA-72-1 only.

This manual was prepared specifically for use by highway designers and highway project planners in predicting the noise levels which should result from new or improved highways. By Public Law 91-605, known as the Federal-Aid Highway Act of 1970, the Congress directed that "The Secretary (of Transportation), after consultation with appropriate Federal, state, and local officials, shall develop and promulgate standards for highway noise levels compatible with different land uses and after July 1, 1972, shall not approve plans and specifications for any proposed project on any Federal-aid system for which location approval has not yet been secured unless he determines that such plans and specifications include adequate measures to implement the appropriate noise level standards". Acting for the Secretary, the Federal Highway Administration, with the cooperation of the DOT Office of Noise Abatement, has developed highway noise level standards and will issue a Policy and Procedure Memorandum to implement their use. This Manual for Highway Noise Prediction has been prepared at the DOT Transportation Systems Center

2.0 BACKGROUND DISCUSSION

The relationship between highway traffic characteristics and the effective noise level generated at a specific receiver location is extremely complex. The sounds emanating from a particular highway depend on a number of parameters related to the types of vehicles on that highway, their numbers, speed, acceleration, and directivity of propagation. The sound level is also affected by topographical considerations such as location, orientation, shape and reflectivity of obstacles in the surrounding area; by atmospheric and ground absorption; by micrometeorological conditions of varying wind speed and direction, temperature gradients, and humidity; by the formation of shadow zones; and by certain other effects specific to each receiver location. Finally, the statistical nature of the fluctuating sound levels requires careful definition of the descriptive values used, both for statistical accuracy and for use to represent the human reaction desired ("annoyance", speech interference, activity disturbance, hearing damage). Accordingly, rather complex mathematical models for noise sources, sound propagation paths, and human reaction are required if accurate predictions of highway noise levels are to be obtained.

The inclusion of as many of these factors as possible is the goal in the prediction of highway traffic noise levels. In order to keep the problem within practical and manageable limits, however, certain limitations must be incorporated in the calculation procedures. Two basic procedures are developed in this manual for the prediction of highway traffic noise levels. The first and simpler of the two makes use of simple nomographs to relate the pertinent traffic characteristics to the noise levels generated. The second, more sophisticated procedure utilizes a computerized noise level simulation model, permitting the inclusion of more complex traffic and topographical characteristics. Both procedures incorporate the following simplifying assumptions, in order to limit computational complexity without unduly sacrificing prediction accuracy:

1. The procedures consider only freely-flowing highway traffic. Stop-and-go traffic (implying a time-dependent number of vehicles along the highway), and the effects of vehicle acceleration and braking on the radiated noise levels are not included.

2. The procedures assume a *uniform* standard atmosphere, and micrometeorological effects of refraction and resultant shadow zones are neglected. In general, strong wind gradients and temperature gradients (variations in wind velocity and temperature with height above the ground) can affect sound propagation paths at distances of 500 feet or more. This is one reason that a considerable spread is often found in field measurements of noise at longer distances. For prediction purposes, the calculation complexity required to include these effects is not warranted,

point. Other statistical descriptors are of more practical interest than the mean energy level, however, for the highway traffic noise problem. Several of these are:

a. the median sound level (L_{50}) - the sound level which is exceeded 50% of the time; the "typical" value of noise level at a point;

b. the ten-percentile level (L_{10}) - the sound level which is exceeded only 10% of the time; the level indicating the most noisy events at a point, representing generally the noisiest vehicles in a traffic flow mix;

c. the ninety-percentile level (L_{90}) - the sound level which is exceeded 90% of the time;

d. the Noise Pollution Level (L_{NP}) - a rating procedure representative of the level of annoyance from fluctuating noises, based on the assumption that public dissatisfaction depends on two factors - the mean energy of imposed noise and the range of variation in the levels; numerically, Noise Pollution Level equals the mean energy level plus 2.56 times the standard deviation of the sound levels around that mean.

Figure 1 illustrates the variation of these four statistical descriptors with mean energy level for a series of actual field measurements, taken over a 24-hour period at a distance of 270 feet from the center of a divided six-lane interstate highway (A COMMUNITY NOISE SURVEY OF MEDFORD, MASSACHUSETTS, Report No. DOT-TSC-OST-72-1, DOT Transportation Systems Center, August 1971). In these data, changes in the mean energy level are caused solely by the changes in traffic density (and to a limited extent traffic mix), since all other factors were essentially constant throughout the measurement period. Figure 2 illustrates variations in the same five statistical descriptors, solely as a function of distance from the highway. These data represent three simultaneous measurements at distances of 50, 100, and 200 feet from the near edge of a divided six-lane highway during daytime, non-rush-hour traffic. Figure 2 suggests the same general tendencies for the four statistical descriptors relative to the mean energy level as shown in Figure 1, but with a significantly greater spread between each pair of values. These data are included in this report to illustrate the general relationships among the several statistical descriptors, and also to illustrate that the exact relationship is rather complex, depending on traffic density, vehicle mix, and distance from the highway. As noted above, the basic procedures used in this manual predict the mean energy level of highway traffic noise. The ten-percentile level (L_{10}) has been selected by the Federal Highway Administration for quantitative standards, in order to limit the peak noise levels rather than just the median or mean levels. The procedure for the prediction of approximate highway noise levels, described in Section 3 of this manual, provides only the ten-percentile noise levels, for direct use with the Federal

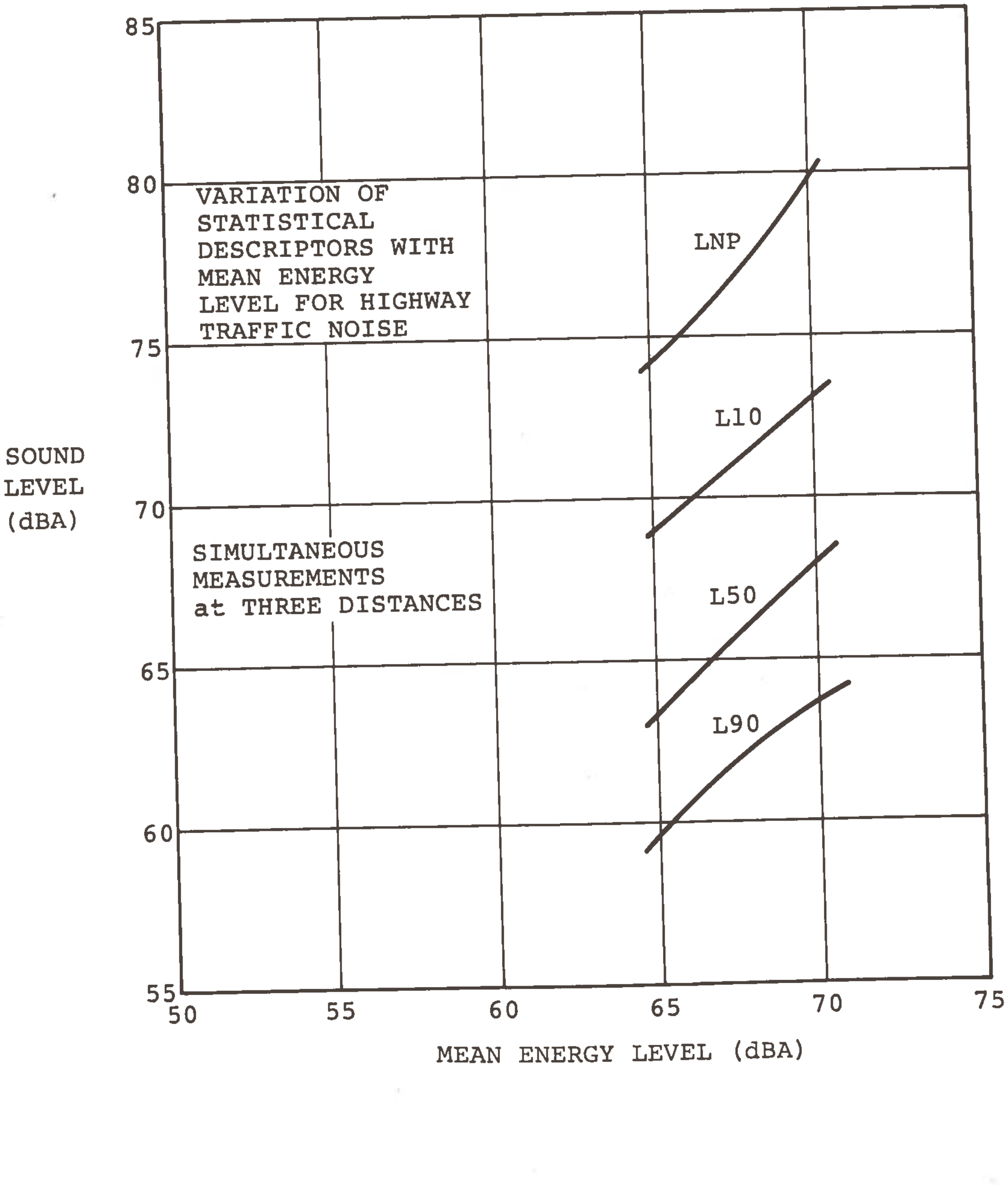

Figure 2. Variation of Statistical Descriptors With Mean Energy Level for Highway Traffic Noise.

3.0 METHOD FOR PREDICTION OF APPROXIMATE HIGHWAY NOISE LEVELS

For preliminary estimates of predicted highway noise levels, it is often convenient to employ a simple nomographic method rather than the more involved (but more accurate) computerized approach. A simplified nomograph has been developed for preliminary, pen-and-ruler predictions of highway noise levels for relatively simple situations. This section of the manual describes this approximate method, and includes an illustrated example of its use (Figures 3 and 4).

The nomograph consists of a set of calibrated scales, representing vehicle speed, percentage of trucks, vehicle volume, and distance from the roadway. This nomograph assumes typical 1972-era highway trucks, and thus should provide conservative (that is, high) predictions of highway noise levels in future situations for which quieter trucks may be anticipated.

Use of the nomographs may best be explained through the use of an example. Consider the following simplified highway situation:

1. Vehicle flow over the four lanes of a new highway is expected to be 5000 vehicles per hour;

2. Average operating speed of these vehicles is 60 mph;

3. Approximately 5% of the vehicles are highway trucks; and

4. The effective distance, or single-lane-equivalent distance, from the desired observer point to the four-lane highway is 100 feet. (Effective distance may be considered as the geometric mean of the distances from the observer to the nearest lane and to the farthest lane center lines, or:

$$D_e = \sqrt{D_n \, D_f} \;.)$$

The approximate ten-percentile noise level in A-weighted decibels (dBA) is found from the nomograph as follows:

1. Draw a straight line (an isopleth) from the left pivot point on the nomograph through the "5 percent trucks" point on the "60 mph" calibrated line, and extend that isopleth to Turning Line A. For this example, the intersection is marked "A1".

2. Draw a second isopleth between Point A1 and the "5,000 vehicles per hour" calibration on Line Q. Note the intersection of this isopleth on Turning Line B, marked "B1" on the example nomograph.

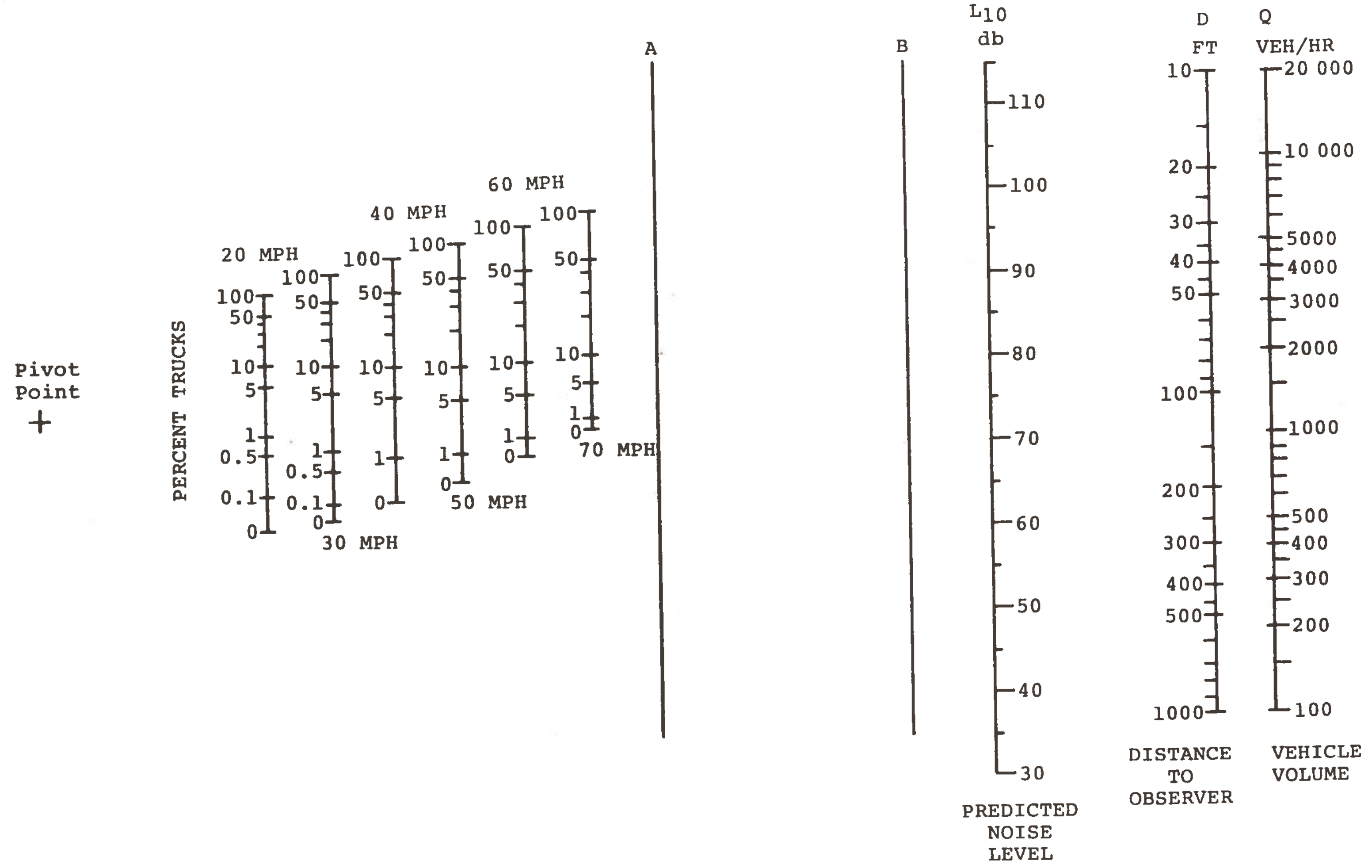

Figure 4. Nomograph for Approximate Prediction of Highway Noise Levels (Conventional Trucks).

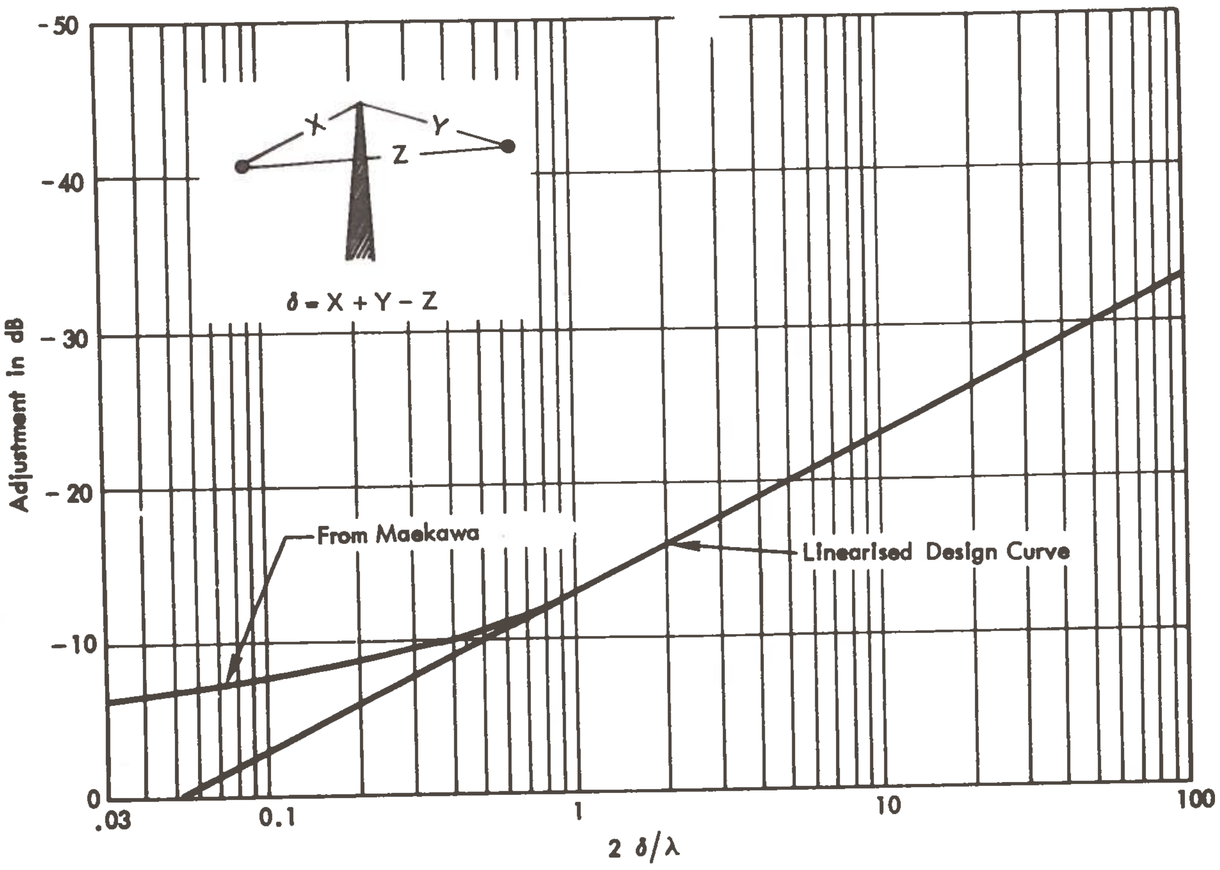

Figure 5. Attenuation by Acoustic Shielding

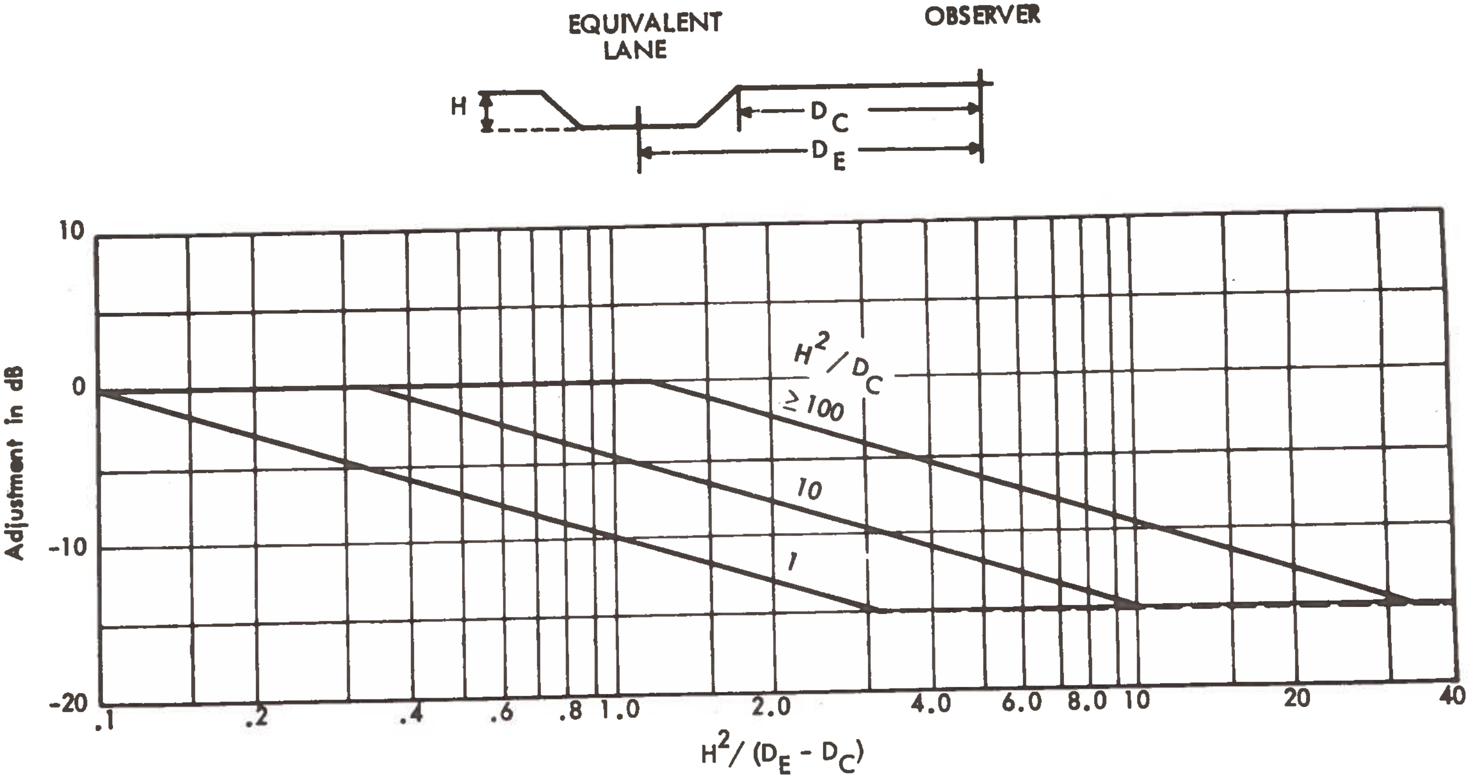

Figure 7. Adjustment for Depressed Roadway

If desired, alphanumeric information may be included in columns 31 through 80, for convenience and specific indentification. If no alphanumeric information is included in columns 31 through 80, parameter identification in agreement with the above list will be printed automatically in the output listing. The last of the set of six cards (if only the first two types of vehicles are being considered) or eight cards (if the "new vehicles" are being included) must contain the letter L in column 20 to signify the end of the initialization parameters.

If the "new vehicle" option is to be included in the series of problems for which initialization information has been entered, and eight data card entries have been included above, a ninth card must also be included to contain the overall A-weighted noise level of the desired "new vehicle", and the eight A-weighted octave-band noise levels, all at the standard reference distance of 50 feet. These values are entered as nine real constants (that is, with decimal points), each left-justified in the fields bounded by columns 1 through 5, 6 through 10, 11 through 15, etc. Thus, five columns are allowed for each of the nine values including the required decimal point.

To indicate more clearly the use and purpose of each of the initialization parameters, they are discussed in more detail below. The receiver height adjustment (Item 1) is a height in feet to be added to the Z-coordinate of all receivers specified in data block 5. For normal conditions, it will be 0.0. For special cases, such as the comparison of noise levels at the ground floor of a building with noise levels at a higher floor, a height adjustment of 10.0 feet per floor is recommended. Similarly, to adjust for the normal ear height of a person standing at each of the specified receiver locations, a height adjustment of 5.0 feet is recommended. Negative height adjustments are allowable, and will not cause the program to assume that the receiver is shielded by the ground.

The number of frequency bands for which calculations are to be performed is indicated by a real constant from 1.0 through 9.0. By using the number 1.0, all attenuations due to atmospheric absorption, ground absorption, and barrier diffraction will be calculated for a frequency of 500 Hertz, and the overall A-weighted noise level of each vehicle type will be considered as the source level. Calculations using only the frequency band centered around 500 Hz provides a fair approximation for typical road traffic noise conditions. By using the number 9.0 for this initialization parameter, calculations will be made for all eight octave-bands, with center frequencies from 62.5 through 8,000 Hz. The final results will be more accurate, with some increase in total computer time. By using any number N between 1.0 and 9.0, the attenuations will be calculated for the 500 Hz. band and for N - 1 octave-bands, beginning with the 62.5 Hz. band. Normally, all octave-bands are specified (that is, the number 9.0 entered) to obtain maximum accuracy in the resulting noise level predictions.

ROAD AND VEHICLE DATA

This data block describes the roadways and the vehicular traffic flowing on each roadway. The identifying control card preceding this data block must have the integer 2 in column 5, and a second integer right-adjusted in columns 6 through 10 to indicate the number of roadways.

The number of roadways to be specified depends on the number of traffic arteries with constant hourly traffic flow and the relative distance of the observer points at which noise levels are to be predicted. For a receiver located far from a multi-lane highway without ramps, consideration of a single roadway is sufficient, with that single roadway assigned the total traffic flow of the multi-lane highway. For receiver locations close to the highway, each parallel traffic lane should be described individually. Ramps onto highways and independent nearby highways are treated as separate roadways.

Following the control card, a set of one or more cards is required to provide vehicle data for the first roadway. Each such vehicle card must contain a real constant (that is, with a decimal point included) in columns 1 through 10 to indicate the traffic flow in vehicles per hour, a real constant in columns 11 through 20 to indicate vehicle operating speed in miles per hour, and the integer 1, 2, or 3 in column 25 to indicate the vehicle type. The final card of the vehicle input set must have, in addition to the other information, a letter L in column 31.

An integer 1 in column 25 indicates that the described vehicle data on that card are for passenger cars, an integer 2 indicates highway trucks, and an integer 3 indicates that the vehicles are "new vehicles". Up to five cards can be used for each vehicle type for each roadway section, in random order, to specify traffic flow at different operating speeds. Unless the speed distributions are known from measurements, the Highway Capacity Manual 1965 is recommended for determining the average operating speed from the hourly traffic volume assumed.

Following the vehicle information for the first roadway, the end-points of that roadway are defined by Cartesian coordinates, assuming a straight-line section. The X-Y plane is parallel to sea level, and the Z-coordinate specifies the height above sea level or any other reference plane parallel to sea level. All coordinates are in feet. The X-, Y-, and Z-coordinates are entered as real constants (that is, with the decimal point included) in the fields bounded by columns 1 and 10, 11 and 20, and 21 and 30, respectively. The card with the last end-point of a roadway must have the letter L in column 31. A roadway may consist of as many as ten straight-line sections (that is, have eleven end-points defined). A roadway containing more than ten sections should be treated as two or more roadways, each have ten or fewer sections.

BARRIER PARAMETERS

The data block with information about obstacles (i.e., "barriers") in the sound propagation paths is headed by a card having a 3 in column 5 and an integer right-justified in columns 6 through 10 to indicate the number of barriers.

The top contour of a barrier is approximated by a straight-line segment, and no sound is assumed to penetrate below this contour. A single barrier may contain up to ten sections. The end points of these sections are specified in the same format as the end points of road sections, except that the last point of a line is identified by an A or an R in column 31 (rather than L as for roads).

An R in column 31 indicates that the preceding points describe the top line of a rigid plane oriented perpendicularly to the ground, such as artificial barriers without absorbing material, facades of buildings, rigid walls of a depressed highway, etc. (i.e., a reflecting barrier).

An A in column 31 inidcates that the preceding points describe the top line of a tilted barrier, a barrier with absorbing material, an earth berm, a hill, or some other obstacle that reflects sound either weakly or towards the sky, directly or via a ground reflection (i.e., an absorbing barrier).

The following illustration represents a sample input data block for barrier parameters.

Name 1 8	10	Operation 14	16 20	Operand 25 30	35
3	2				
-100.		-20.	20.		
200.		-20.	20.	R	
100.		20.	6.		
10000.		20.	6.	A	

GROUND COVER PARAMETERS

The control card for this data block must contain the integer 4 in column 5 and an integer right-adjusted in columns 6 through 10 to indicate the number of absorptive ground strips. The areas of ground cover are described by the center line and the width of rectangles. The X-, Y-, and Z-coordinates of one end point of the center line are given as real constants in the fields between

ERROR MESSAGES

Errors are detected by the computer in the following cases.

1. If the top line of an obstacle intersects a roadway, the computer prints out

   ILLEGAL BARRIER INTERSECTS ROADWAY

   together with the following data: receiver number, roadway number, road section number, barrier number, barrier section number.

   The computer then proceeds with the next case.

2. If the center line of a ground absorbent strip intersects a roadway, the computer prints out

   ILLEGAL GROUND STRIP INTERSECTS ROADWAY

   together with the following data: receiver number, roadway number, road section number, ground strip number.

   The computer then proceeds with the next case.

3. If the number of reflections contributing to the sound level at a receiver exceeds 10, the computer prints out

   TOO MANY REFLECTIONS

   together with the following data: receiver number, roadway number, road section number.

   The computer then proceeds with the next receiver.

4. Should the geometry of the situation be such that a line segment that is needed for computation appears to have zero length, the program continues with the next receiver without giving an error message.

DATA OUTPUT

The data output starts immediately after the input file is read. The heading TRAFFIC NOISE PREDICTION is typed and input data are then typed in the following order:

Title card;

Program initialization parameters (for the first of a series of cases only);

Vehicle and road parameters, where all parameters of Type 1 vehicles (passenger cars) on a given road are typed first, following by parameters for Type 2 vehicles (trucks), and Type 3 vehicles ("new vehicles").

which another situation is desired.

Figure 9 illustrates a sample highway situation, consisting of a two-lane highway, with 12-foot wide lanes and no median strip. A single feeder lane joins the highway, and traffic flow consists of passenger automobiles and highway trucks. A 20-foot-high barrier wall is located on one side of the intersection, with the inner side of the wall relatively smooth and vertical. Thus, this wall will act as a reflecting surface. A six-foot-high earth berm is also located near the highway, acting as an absorptive barrier. A stand of trees is located along the feeder lane. Noise levels are desired at five locations along the highway, at a distance of 100 feet from the highway centerline. This is the sample case which has been used for illustration of each of the five data blocks, previously shown in this section of the manual.

The input data for this sample problem are repeated below, and the resultant output data are also shown.

As Sample Problem 2, it is desired to determine the effect of the 20-foot-high reflecting barrier wall alongside the highway. To determine this effect, the first sample problem can be repeated, eliminating that barrier, and the results compared. This new problem may be run simply by redefining the barrier parameter data block only, using a new title card for identification, and the remainder of the input data from the first problem will be retained. This is illustrated as Sample Problem 2 input, with the output results following Sample Problem 1 below.

As a third comparison, it is desired to determine if the stand of trees alongside the feeder lane has any effect on the predicted noise levels. Again, this third problem may be run back-to-back with the two preceding problems, by eliminating the tree absorbing strip. In this instance, data block 4 is redefined after the new title card by entering the integer 0 right-adjusted in the field bounded by columns 6 through 10, as shown in the data input coding below. Again, all other input data are retained, and the third sample problem is then run as shown.

As a final example, it is desired to determine if the possible future introduction of quieter trucks will reduce the predicted noise levels significantly. Again, the fourth sample problem may be run back-to-back with the three preceding problems by redefining only the road and vehicle data block. In this case, the initialization parameter data block already contains the estimated description of the noise characteristics of the predicted quieter highway trucks. If this were not the case, the initialization parameter data block, and the entire problem situation, would have to be reentered as input data. In this case, however, the anticipated quieter truck was estimated on the basis of tire noise becoming the dominant source of noise, and that tires similar to currently-used neutral rib tread pattern types would be standard. Thus, the height adjustment for this source was assumed to be 0.0 feet, and the standard deviation was assumed to be 3.5 dB. The road and vehicle data block are redefined, following the new title card, and the fourth sample problem then run as shown.

For general information using the IBM 7094 computer at the Transportation Systems Center, these four sample problems required 1.50 minutes of computer time to compile and execute.

Quite often, a rough data work sheet is useful in translating engineering data from maps or charts into the general format for coding as computer input. An example of such a work sheet is also included in the following example for the first sample problem described above. Because of the vast variety of possible highway situations, a uniform work sheet may be impractical. Users may find it convenient to prepare similar work sheets for their own particular repetitive situations.

It is of interest to compare the results of the four sample problems, to obtain some feeling for the relative importance of the reflecting barrier and tree strip in the magnitude of the predicted noise levels, and also to compare the relative advantages to be gained through the use of quieter trucks on a highway such as the case assumed. Removal of the reflecting wall opposite the receiver locations reduced the median (L_{50}) noise levels by approximately 1 1/2 dBA at the receivers nearest the feeder lane intersection, and approximately 1/2 dBA opposite the end of the barrier wall. The ten-percentile-levels were similarly reduced. Removal of the tree strip increased the levels at the first receiver location by approximately one decibel, but had little effect on the more distant receiver locations. The introduction of the quieter trucks, even though trucks constitute only about 7% of the vehicular traffic in the sample problems, reduced the median noise levels roughly 3 to 5 dBA, and the ten-percentile-levels roughly 6 to 7 dBA. The greater reduction in the L_{10} levels was expected, since trucks are the major contributor to the higher value, less frequent noise levels.

WORK SHEET PAGE 2

ROADWAY #3

100 CARS/HR @ 45 MPH
25 TRUCKS/HR @ 45 MPH
- NEW VEHICLES/HR @ - MPH
X = -10^4, Y = $-5x10^3$, Z = 0
X = 0, Y = 6, Z = 0

ROADWAY #4

500 CARS/HR @ 60 MPH
50 TRUCKS/HR @ 60 MPH
- NEW VEHICLES/HR @ - MPH
X = -10^4, Y = -6, Z = 0
X = 10^4, Y = -6, Z = 0

BARRIER PARAMETERS:

BARRIER #1(R)
X = -100, Y = -20, Z = 20
X = 200, Y = -20, Z = 20

BARRIER #2(A)
X = 100, Y = 20, Z = 6
X = 10^4, Y = 20, Z = 6

GROUND COVER PARAMAMETERS:

STRIP #1 (T)
X = 0, Y = 50, Z = 0
X = -200, Y = 150, Z = 0
WIDTH = 50

RECEIVER PARAMETERS:

RECEIVER #1 X = 0, Y = 100, Z = 0
RECEIVER #2 X = 50, Y = 100, Z = 0
RECEIVER #3 X = 100, Y = 100, Z = 0
RECEIVER #4 X = 150, Y = 100, Z = 0
RECEIVER #5 X = 200, Y = 100, Z = 0
RECEIVER #6 X = -, Y = -, Z = -

```
0.          6.          0.
10000.      6.          0.              L
1250.       50.             1
50.         50.             3       L
-10000.     6.          0.
0.          6.          0.              L
100.        45.             1
25.         45.             3       L
 -10000.    5000.       0.
 0.         6.          0.              L
 500.       60.             1
 50.        60.             3       L
 -10000.    -6.         0.
 10000.     -6.         0.              L
     6
```

```
                  TRAFFIC NOISE PREDICTION

 SAMPLE PROBLEM 1

 PROGRAM INITIALIZATION PARAMETERS
  0.50000E 01          1      RECEIVER HEIGHT ADJUSTMENT
  0.90000E 01          2      NUMBER OF FREQUENCY BANDS
  0.25000E 01          3      STANDARD DEVIATION FOR CARS          (TYPE 1 VEHICLES)
  0.00000E-38          4      SOURCE HEIGHT FOR CARS
  0.35000E 01          5      STANDARD DEVIATION FOR TRUCKS        (TYPE 2 VEHICLES)
  0.80000E 01          6      SOURCE HEIGHT FOR TRUCKS
  0.35000E 01          7      STANDARD DEVIATION FOR NEW VEHICLES (TYPE 3 VEHICLES)
  0.00000E-38          8      SOURCE HEIGHT FOR NEW VEHICLES
     OPTIONAL NOISE SPECTRUM
        77.0    52.0    62.0    68.0    72.0    72.0    70.0    64.0    50.0

 ROADWAY      1

 NUMBER OF                VEH/H          MPH
 TYPE 1 VEH
     1                    0.1350E 04     0.5000E 02

 NUMBER OF                VEH/H          MPH
 TYPE 2 VEH
     1                    0.7500E 02     0.5000E 02
                         SOURCE COORD IN FT

 NUMBER        X            Y              Z
     1      0.0000E-38   0.6000E 01     0.0000E-38
     2      0.1000E 05   0.6000E 01     0.0000E-38

 ROADWAY      2

 NUMBER OF                VEH/H          MPH
 TYPE 1 VEH
     1                    0.1250E 04     0.5000E 02
```

```
   1      0.0000E-38    0.5000E 02    0.0000E-38    0.5000E 02
   2     -0.2000E 03    0.1500E 03    0.0000E-38

RECEIVER                RECEIVER COORD IN FT
NUMBER        X             Y             Z
   1      0.0000E-38    0.1000E 03    0.5000E 01
   2      0.5000E 02    0.1000E 03    0.5000E 01
   3      0.1000E 03    0.1000E 03    0.5000E 01
   4      0.1500E 03    0.1000E 03    0.5000E 01
   5      0.2000E 03    0.1000E 03    0.5000E 01


SAMPLE PROBLEM 1
RECEIVER              XRC            YRC            ZRC
    1                 0.0          100.0            5.0

                            OCTAVE BAND LEVELS (A)
              63      125      250      500     1000     2000     4000     8000
            49.0     61.2     66.0     70.9     70.4     68.0     61.4     51.6

          LE(A)     LNP      L90      L50      L10
           75.6    91.2     63.5     71.4     79.2

RECEIVER              XRC            YRC            ZRC
    2                50.0          100.0            5.0

                            OCTAVE BAND LEVELS (A)
              63      125      250      500     1000     2000     4000     8000
            48.7     60.8     65.6     70.6     70.1     67.8     61.2     51.4

          LE(A)     LNP      L90      L50      L10
           75.3    88.2     65.9     72.4     78.9

RECEIVER              XRC            YRC            ZRC
    3               100.0          100.0            5.0

                            OCTAVE BAND LEVELS (A)
              63      125      250      500     1000     2000     4000     8000
            47.9     60.0     64.9     69.8     69.3     66.9     60.4     50.7

          LE(A)     LNP      L90      L50      L10
           74.5    89.5     63.1     70.6     78.1

RECEIVER              XRC            YRC            ZRC
    4               150.0          100.0            5.0

                            OCTAVE BAND LEVELS (A)
              63      125      250      500     1000     2000     4000     8000
            46.8     58.9     63.8     68.7     68.1     65.5     59.0     49.1

          LE(A)     LNP      L90      L50      L10
           73.3    90.2     59.9     68.3     76.8

RECEIVER              XRC            YRC            ZRC
```

```
NUMBER        X              Y              Z
   1     -0.1000E 05    0.5000E 04    0.0000E-38
   2      0.0000E-38    0.6000E 01    0.0000E-38

ROADWAY     4

NUMBER OF                   VEH/H          MPH
TYPE 1 VEH
   1                     0.5000E 03    0.6000E 02

NUMBER OF                   VEH/H          MPH
TYPE 2 VEH
   1                     0.5000E 02    0.6000E 02
                        SOURCE COORD IN FT

NUMBER        X              Y              Z
   1     -0.1000E 05   -0.6000E 01    0.0000E-38
   2      0.1000E 05   -0.6000E 01    0.0000E-38

BARRIER     1  (A)          BARRIER COORD IN FT

NUMBER        X              Y              Z
   1      0.1000E 03    0.2000E 02    0.6000E 01
   2      0.1000E 05    0.2000E 02    0.6000E 01

ABSORBING STRIP     1  (T)

PT            X              Y              Z             WIDTH
   1      0.0000E-38    0.5000E 02    0.0000E-38    0.5000E 02
   2     -0.2000E 03    0.1500E 03    0.0000E-38

RECEIVER                 RECEIVER COORD IN FT
NUMBER        X              Y              Z
   1      0.0000E-38    0.1000E 03    0.5000E 01
   2      0.5000E 02    0.1000E 03    0.5000E 01
   3      0.1000E 03    0.1000E 03    0.5000E 01
   4      0.1500E 03    0.1000E 03    0.5000E 01
   5      0.2000E 03    0.1000E 03    0.5000E 01


 SAMPLE PROBLEM 2
 RECEIVER                 XRC            YRC            ZRC
      1                   0.0          100.0            5.0

                            OCTAVE BAND LEVELS (A)
                 63      125     250     500     1000     2000     4000     8000
                47.5     59.7    64.5    69.4    68.9     66.4     59.0     50.7

           LE(A)     LNP      L90      L50      L10
            74.1     89.8     61.9     69.8     77.6

 RECEIVER                 XRC            YRC            ZRC
      2                  50.0          100.0            5.0
```

```
    2      0.1000E 05    0.6000E 01    0.0000E-38

ROADWAY     2

NUMBER OF                VEH/H          MPH
TYPE 1 VEH
    1                    0.1250E 04    0.5000E 02

NUMBER OF                VEH/H          MPH
TYPE 2 VEH
    1                    0.5000E 02    0.5000E 02
                       SOURCE COORD IN FT

NUMBER       X              Y              Z
    1     -0.1000E 05    0.6000E 01    0.0000E-38
    2      0.0000E-38    0.6000E 01    0.0000E-38

ROADWAY     3

NUMBER OF                VEH/H          MPH
TYPE 1 VEH
    1                    0.1000E 03    0.4500E 02

NUMBER OF                VEH/H          MPH
TYPE 2 VEH
    1                    0.2500E 02    0.4500E 02
                       SOURCE COORD IN FT

NUMBER       X              Y              Z
    1     -0.1000E 05    0.5000E 04    0.0000E-38
    2      0.0000E-38    0.6000E 01    0.0000E-38

ROADWAY     4

NUMBER OF                VEH/H          MPH
TYPE 1 VEH
    1                    0.5000E 03    0.6000E 02

NUMBER OF                VEH/H          MPH
TYPE 2 VEH
    1                    0.5000E 02    0.6000E 02
                       SOURCE COORD IN FT

NUMBER       X              Y              Z
    1     -0.1000E 05   -0.6000E 01    0.0000E-38
    2      0.1000E 05   -0.6000E 01    0.0000E-38

BARRIER     1   (A)           BARRIER COORD IN FT

NUMBER       X              Y              Z
    1      0.1000E 03    0.2000E 02    0.6000E 01
    2      0.1000E 05    0.2000E 02    0.6000E 01

RECEIVER                   RECEIVER COORD IN FT
```

```
          44.8    57.0    61.9    66.8    66.2    63.6    57.5    43.0

       LE(A)     LNP      L90      L50      L10
        71.4     88.4     57.9     66.4     74.9


             TRAFFIC NOISE PREDICTION

SAMPLE PROBLEM 4

ROADWAY     1

NUMBER OF                 VEH/H          MPH
TYPE 1 VEH
   1                      0.1350E 04    0.5000E 02

NUMBER OF                 VEH/H          MPH
TYPE 3 VEH
   1                      0.7500E 02    0.5000E 02
                         SOURCE COORD IN FT

NUMBER        X             Y              Z
   1      0.0000E-38    0.6000E 01    0.0000E-38
   2      0.1000E 05    0.6000E 01    0.0000E-38

ROADWAY     2

NUMBER OF                 VEH/H          MPH
TYPE 1 VEH
   1                      0.1250E 04    0.5000E 02

NUMBER OF                 VEH/H          MPH
TYPE 3 VEH
   1                      0.5000E 02    0.5000E 02
                         SOURCE COORD IN FT

NUMBER        X             Y              Z
   1     -0.1000E 05    0.6000E 01    0.0000E-38
   2      0.0000E-38    0.6000E 01    0.0000E-38

ROADWAY     3

NUMBER OF                 VEH/H          MPH
TYPE 1 VEH
   1                      0.1000E 03    0.4500E 02

NUMBER OF                 VEH/H          MPH
TYPE 3 VEH
   1                      0.2500E 02    0.4500E 02
                         SOURCE COORD IN FT

NUMBER        X             Y              Z
   1     -0.1000E 05    0.5000E 04    0.0000E-38
```

```
      3              100.0          100.0           5.0

                              OCTAVE BAND LEVELS (A)
                 63       125       250       500      1000      2000      4000      8000
                42.1     50.9      55.6      60.1      62.4      61.8      53.8      44.3

           LE(A)      LNP       L90       L50       L10
            67.0      76.7      60.5      65.4      70.2

RECEIVER                 XRC            YRC            ZRC
      4              150.0          100.0           5.0

                              OCTAVE BAND LEVELS (A)
                 63       125       250       500      1000      2000      4000      8000
                41.0     49.6      54.2      58.5      60.6      59.2      51.7      41.7

           LE(A)      LNP       L90       L50       L10
            65.3      77.4      56.6      62.7      68.8

RECEIVER                 XRC            YRC            ZRC
      5              200.0          100.0           5.0

                              OCTAVE BAND LEVELS (A)
                 63       125       250       500      1000      2000      4000      8000
                40.2     48.7      53.1      57.2      59.1      58.2      49.7      38.8

           LE(A)      LNP       L90       L50       L10
            63.8      77.4      53.7      60.5      67.4
```