NOISE
GUIDELINES

THE STATE OF TEXAS

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

HIGHWAY DESIGN DIVISION

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TEXAS DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

HIGHWAY DESIGN DIVISION

NOISE GUIDELINES FOR PROJECT PLANNING AND DEVELOPMENT

INTRODUCTION

This publication is intended to serve as a guide for the analysis of future noise impacts resulting from certain types of highway improvements. It provides guidance for the preparation of a noise analysis summary for appropriate environmental documents. In addition, if a separate and formal noise report is necessary, this publication provides guidance for its preparation.

These guidelines reflect currently accepted nationwide state-of-the-art procedures used by state transportation agencies to assess the impacts of highway traffic and construction noise.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1.0 DEFINITIONS

1.1 Noise

Sound that is undesirable or unwanted. Sound may be considered noise dependent on: (1) the amount and nature of the sound; (2) the amount of background sound present; and (3) the nature of the activity of persons hearing the sound. Noise travels through a medium of air forming air pressure fluctuations or waves much like waves seen on a water surface disturbed by a falling object.

1.2 Decibel - (dB)

A unit used to express the relative intensity of sounds on a logarithmic scale. The dB measure of sound intensity is ten times the logarithm of the square of the ratio between the sound pressure level of the measured sound and the reference pressure level (2.9×10^{-9} pounds per square inch). The reference pressure level is the average least perceptible sound.

1.3 dB(A)

The decibel unit of measure based upon an "A" weighted scale. Some low frequencies are filtered while the higher frequencies are emphasized. This scale closely approximates sounds as heard by the human ear and should be used on all highway noise studies.

1.4 Noise Abatement Criteria-(NAC)

The maximum noise level recommended for the various land use activity categories (see Table 1). Noise Abatement Criteria are not desirable design criteria, but rather a compromise between achievable results, using good highway design practices, and desirable noise limits. (See Section 2.0).

1.5 Traffic Noise Analysis

A variable examination of traffic noise effects predicted to occur from a proposed transportation improvement. Assessment of the relationship of such noise to abutting land uses as well as to established Noise Abatement Criteria and as appropriate, the evaluation of possible measures to mitigate significant noise impacts should all be parts of the analysis.

1.6 Construction Noise Analysis

An examination of noise effects predicted to occur during project construction. Assessment of the relationship of such noise to abutting land uses and the evaluation of possible measures to mitigate significant construction noise impacts should be considered.

1.7 Summary of Noise Analysis

A synopsis of traffic and construction noise analysis which is included in appropriate environmental documents. This summary is prepared for maximum clarity to the layman.

1.8 Traffic Noise Report

A separate formal document containing a summary of the traffic noise analysis. Such a report is required if the traffic noise summary included in appropriate environmental documents is not based on P.S.&E. design geometrics, or does not include definite commitment to accurately describe abatement measures or provide definite justification for excluding abatement measures in the P.S.&E.

1.9 Traffic Noise Impacts

A significant impact occurs when the predicted traffic noise levels equal or exceed the Noise Abatement Criteria (Table 1), or when the predicted traffic noise substantially exceeds the existing noise levels.

1.10 Existing Noise Levels

The noise resulting from natural and mechanical sources and human activities considered to be usually present in a particular area.

1.11 High Traffic Volume

An average volume of 1500 vehicles per day or more estimated for the projected year of completion.

1.12 Low Traffic Volume

An average daily traffic volume less than 1500 vehicles estimated for the projected year of completion.

1.13 L_{10}

The sound level that is exceeded 10 percent of the time (the 90TH percentile) for the period under consideration.

1.14 L_{10} (h)

The hourly value of L_{10}.

1.15 L_{eq}

The equivalent steady-state sound level which in a stated period of time contains the same acoustic energy as the time-varying sound level during the same time period.

1.16 L_{eq} (h)

The hourly value of L_{eq}.

1.17 Receptor

An individual or site location upon which emitted noise has an effect.

1.18 Type I Projects

A proposed construction of a highway on a new location or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignments or increases the number of through-traffic lanes.

1.19 Type II Projects

A proposed project solely for noise abatement on an existing highway.

2.0 THE USE OF NOISE ABATEMENT CRITERIA (NAC)

Noise impacts begin at lower levels than the NAC. The Noise Abatement Criteria should not be viewed as design criteria but rather as mitigation criteria. If the NAC are exceeded, consideration should be given to a substantial noise reduction rather than reduction only to the criteria.

The NAC shown by Table 1, are expressed by two descriptors, L_{eq} and L_{10}. The type of descriptor used in analyzing noise is optional, but both may not be used in the same analysis.

In areas of mixed land use, traffic noise analysis is based on use of the NAC for the land use activity category assigned the lowest criteria noise level. For example, in areas of mixed residential and commercial land use, the noise analysis should be based on use of a 67 dB(A) NAC which is the controlling NAC standard for residential property or land use Activity Category B using Leq (Refer to Table 1).

In land use Activity Category B areas where no outside activity occurs, noise analysis should be based on the use of the interior noise criteria, 52 dB(A), which is the controlling NAC for land use Activity Category E when using Leq. (Refer to Table 1).

3.0 LEVEL OF EFFORT

3.1 Type I Projects

As previously defined, this classification applies if a project is planned for construction on new location, the vertical or horizontal alignments are significantly changed, or the number of through traffic lanes is increased. If any one of these three conditions apply and the highway improvement will result in a high traffic volume (1500 ADT or greater in the design year), then project noise impacts should be evaluated and a summary of the noise analysis should be included in the appropriate environmental document.

3.2 Type II Projects

Any projects proposed solely for the purpose of attenuating problem noise levels on existing sections of State Highways must be justified by an appropriate noise analysis. The analysis should weigh the effectiveness, costs and benefits of noise attenuation.

3.3 Other Projects

Projects not qualifying as Type I or Type II Projects generally will not require a noise evaluation. If any environmental document is prepared, noise levels should be identified as insignificant and supported by logical reasoning. It is likely that most projects in this category will be categorical exclusions.

Figure 1 briefly summarizes the determination of level of effort described above.

3.4 General

A noise analysis may be in preparation throughout project development but it should be completed prior to submission of project plans to the Austin office. Preliminary versions of the noise analysis may be prepared as necessary, summarized in the various environmental documents, and updated, as necessary, with the project's progress. Each alternative, including the "no-build" case, must be evaluated until a final design is determined.

All environmental documents should include a summary of the analysis of noise impacts. For projects that are low volume or other than Type I or II where an environmental document is required, engineering judgment should be used to explain the anticipated noise situation. An example of this type of explanation would be:

> The proposed highway project is located in a rural area with a traffic volume of______ADT projected in the year of project completion. No nearby sensitive receptors are within ______ feet. Based on previous experience in analyzing noise impacts on similar types of improvements, the traffic noise impact of this project is regarded as insignificant.

In addition to summarizing the noise analysis in the appropriate environmental document, a separate formal noise report may be necessary later in project planning under certain conditions.

If the noise analysis and environmental document summary are based on reliable project design data, and factual statements either disproving the practicability of abatement or proving the practicability of and making a commitment for abatement (with P.S.& E. reliability) are included in the environmental document, a subsequent noise report will not be necessary. But, if such factual statements are not included in EA/EIS's, it will be necessary to prepare a separate formal noise report at the earliest subsequent point in project planning that accurate design data is available prior to P.S.& E. submission.

THE P.S.&E. must be consistent with statements on noise impacts made in environmental documents or subsequent noise reports.

3.5 Separate Noise Report

As stated above, if the environmental document is not based on reliable design data, a design change occurs, a commitment for abatement has not been proven impracticable, or exact abatement measures have not been supplied, a separate noise report is required. This report's level of effort should be the same as the type of project (i.e. Type I). The complete analysis should be kept on file and a detailed summary displaying present and future noise levels and abatement consideration, if necessary, should be sent to the Highway Design Division, prior to P.S.& E. submission.

4.0 EVALUATION OF HIGHWAY TRAFFIC NOISE IMPACTS

4.1 Type I Projects

A noise analysis should be performed on a logical highway section; i.e., it should extend from logical termini even though only a portion of those limits are planned for improvement.

Analysis outside the project area is identical to the project analysis except that impacts, construction noise, and abatement need not be considered.

4.1.1 Land use activity must be considered during the analysis. Land use activity applies to developed lands and undeveloped lands for which development is planned, designed or programmed. When the land use that may be affected by the project traffic noise has been identified, Table 1 should be used to determine the activity category and Noise Abatement Criteria. If interior levels are the deciding criteria, Table 2 may be used to determine attenuation due to certain types of buildings.

4.1.2 The next step is to determine existing and predicted noise levels. If the highway traffic noise is the only source, or if other noises in the area are very small as compared to the traffic noise, then the existing traffic noise levels may be calculated using the Traffic Noise Prediction Model (see Section 8). If there is any doubt of this condition, or if other noises are in the area, existing noise levels should be measured to determine true background levels. Approved measurements procedures are described later in these guidelines.

Future noise levels should then be predicted for the design year using projected design year traffic. It is desireable to predict future noise levels at previously measured or previously calculated sites. In this way a direct comparison can be made. Good practice is to select these sites at the right-of-way line where no obstructions are between the site and roadway. If no substantial noise increase occurs, or if the NAC are not exceeded at the right-of-way line, then it is safe to conclude that the noise impacts are insignificant. A statement to this effect, along with a comparison of present and future noise levels should be included in the appropriate environmental document. Tables and contour maps are very efficient in displaying a comparison of noise levels.

4.1.3 At the right-of-way line, if there is a substantial increase in the noise levels or if the NAC is exceeded, then noise levels at nearby receptors, both existing and future, should be determined. Once again, if the highway is the major or only noise contributor this may be performed by calculations; otherwise, measurement of existing levels is required. The receptors evaluated should be "worst case" receptors. That is, receptors with the lowest NAC closest to the highway should be considered. The receptors include presently developed land and undeveloped land that is planned, designed, or programmed.

If these receptors do not display a substantial increase in the noise levels, and if the NAC is not exceeded, then it is safe to conclude that the noise impact from the proposed highway project is insignificant. A statement to this effect along with the results and an explanation of the effects on receptors should be included in the appropriate environmental document. Maps and tables are helpful in showing these results.

4.1.5 A substantial increase or an exceedance of the NAC at receptors along a project means that noise abatement should be considered in the noise analysis. Abatement screening criteria are presented in the next section (Section 5).

A simplified flow diagram of the previously defined evaluation procedure is presented by Figure 2.

4.2 Type II Projects

Measurement or calculations as defined above under Type I projects should be performed to identify the traffic noise impact. The evaluation should be of sufficient scope to identify the traffic noise impact, document the noise reduction from mitigation techniques suggested for use, and show the benefits of abatement that outweigh the overall costs, as well as the adverse social, economic and environmental effects of abatement.

4.3 Other Projects

Projects other than Type I and Type II require no formal evaluation or calculations. Engineering judgement should be used to evaluate noise effects on the surrounding area, especially any sensitive receptors that may be in the area (see Section 3.4). If an environmental document is prepared, a summary of the noise impacts should be included listing the reasons for no significant noise impact.

4.4 General

4.4.1 Care should be taken when evaluating the "no-build" case to insure that projected traffic volumes used in the analysis do not actually exceed the capacity of the existing facility.

4.4.2 In summarizing the noise analysis in environmental documents, the characteristics of noise should be discussed in layman's terms. Descriptive terms are especially important in putting an analysis into common terms. Definitions should be made available for any technical terms, acronyms, abbreviations, etc., used in an environmental document. A description of the decibel and loudness, as perceived by the ear, are of particular importance. It is suggested that Table 1 and Figure 3 be included in the analysis to provide typical noise levels for reference. If interior levels are the abatement criteria used Table 2 should also be included.

4.4.3 Construction noise must be considered for each project that requires an EA/EIS and is discussed in Section 6 of this paper.

5.0 ABATEMENT SCREENING CRITERIA

5.1 Abatement should be considered if there is a significant increase in noise levels or if the NAC are exceeded. Primary consideration should be given to exterior areas. Interior noise levels, in those situations where the exterior activities are physically shielded or far removed from the roadway, should be used as the basis in determining impacts (see Table 2 for interior reduction factors).

Every reasonable effort should be made to obtain a substantial noise reduction in cases where noise has a significant impact on developed lands, existing activities, or undeveloped lands that are planned, designed, or programmed. However, abatement procedures should be reasonable and feasible (practicable) before they are incorporated into the project design.

Practicability may be difficult to ascertain. To aid in the decision of mitigation, the following is intended as a guide. Because each project is unique, careful consideration should be given to any unusual circumstances.

5.2 Evaluation of the Situation

Mitigation is a measure taken to protect nearby residents. If no benefits accrue, mitigation would not be reasonable. Following the determination of any significant impact, the surrounding area should be examined. During the analysis stage, land use was determined. At this point two other questions are pertinent:

1) Is the land use changing?

2) Are there other major noise sources in the area?

If land use is changing, the trends should be determined. If subdivisions are planned on undeveloped lands, traffic noise mitigation should be considered. If residential property is changing to commercial, mitigation may not be necessary or desireable.

Other noise sources in the area may make traffic noise mitigation infeasible. If loud intrusive noises exist in the area, a change in traffic noise will probably not be noticed, making traffic noise mitigation impractical.

5.3 Design Changes

Consideration of project noise effects early in planning may make it possible for noise impacts to be avoided. General traffic control measures such as the rerouting of trucks, elimination of signalized intersections, time restrictions on certain vehicle types, change in speed limits, etc. may be effective. An early determination that a highway improvement has the potential to cause a significant noise impact and/or exceedance of the NAC increase the noise mitigation options available for consideration. Horizontal and/or vertical alignment alternatives may permit consideration of buffer zones, depressed sections, or overpasses to possibly reduce noise impacts.

5.4 Attenuation

If traffic noise impacts exist and cannot be avoided, then attenuation should be considered. The first consideration is if attenuation to desirable levels is even possible. Table 3 shows the varying degrees of attenuation possible. Notice that approximately 15 dB(A) is the limiting factor on attenuation. Beyond this value attenuation is very difficult. In some instances it may be impossible to attenuate the noise to desirable levels. In these particular cases, a lessening of the noise impact is the only feasible alternative.

Barriers, such as earth berms, metal, wood, and concrete walls, are are the most common form of traffic noise attenuation. Earth berms are desirable in that landscaping may be accomplished at the same time. Careful consideration should be given before any one type of barrier is decided upon. Cost, safety or maintenance impairment, and durability should all be considered to determine if a barrier is reasonable.

Feasibility should also be considered. If attenuation is possible and a highway is a controlled access facility, sufficient space must exist between main lanes and frontage roads to construct barriers. In addition, openings for exits and entrances may be such that the barrier is ineffective. Overlapping of barriers or other methods of attenuation may be needed. For example, to provide a significant reduction, a barrier's length is normally eight times the distance from the barrier to the receptor. If 10 percent or greater of the barrier length must be left open for access, the barrier's effectiveness is considerably reduced. In this situation the barrier may not be economically reason-able if only a small noise reduction is provided.

Uncontrolled access facilities present a special problem. Unless the property's access rights can be purchased, barriers may interfere with the land owner's or resident's access rights. If openings for local access must be left, then the barrier may not be reasonable due to the small amount of attenuation provided.

In some instances, where only public use or nonprofit institutional structures will be impacted, consideration may be given to insulating such structures. This would allow normal indoor activities while not requiring any modification to the roadway.

The monetary cost of providing noise attenuation for any project should not be used as the only justification precluding construction of abatement walls. Any decision on construction of abatement walls should reflect balanced consideration of costs, benefits and effects. A reasonable effort should be made to base decisions on abatement on factual data using a systematic approach.

5.5 Views of Abutting Property Owners/Residents

If residents of properties abutting a highway or street do not desire a noise barrier it should not be built, regardless of the significance of the traffic noise impact.

6.0 CONSTRUCTION NOISE

A discussion of construction noise should be included in the environmental document. This discussion should be guided by the following:

6.1 Land use activities which may be affected by construction noise should be identified.

6.2 If there is a construction noise effect on a land use activity, the mitigation measures which will be incorporated into project plans should be identified.

6.3 It is anticipated that the following wording may satisfy requirements for an appropriate discussion of construction noise in most environmental documents.

> "It is difficult to predict levels of construction noise at a particular receptor or group of receptors. Heavy machinery, the major source of noise in construction, is constantly moving in unpredictable patterns. The duration of daily construction normally occurs during daylight hours when occasional loud noises are more tolerable. Because of the relatively short term exposure periods imposed on any one receptor, extended disruption of normal activities is not considered likely. However, provisions will be provided in project plans to require the contractor to make every reasonable effort to minimize construction noise through abatement measures such as work hour controls and maintenance of equipment muffler systems."

7.0 TRAFFIC NOISE MEASUREMENT

7.1 General

This section describes a method for measuring the L_{10}, L_{50}, and Leq noise levels in the field as recommended in the publication entitled Fundamentals and Abatement of Highway Traffic Noise. The basic instrument used is a ANSI Type II "sound level meter" which contains a microphone and converts air pressure fluctuations into electric impulses. In turn, these electrical impulses activate a meter which displays the sound level. It is desirable, but not necessary, to collecttrafficdata concurrent with noise measurements.

7.2 Setup

The noise level meter is set in a convenient location directed so that traffic noise is measured. The exact positioning of the microphone should be determined from the instrument's instruction manual. A watch (or stop watch) is fixed to the be determined from the instrument's instruction manual. A watch (or stop watch) is fixed to the top of a clipboard holding the data sheets. With the clipboard in one hand, the sweep second-hand can be watched, and the noise level recorded on the data sheet every ten seconds. High impedance earphones, if available, are useful in judging the amount of wind noise being measured in relation to the area's ambient noise. The meter should be set on "slow response" and the A scale. The use of a tripod and earphones are not necessary for the accuracy desired, but will make the process more convenient by letting the person taking the readings have both hands free.

A sketch of the measurement site along with pertinent information about the site and measurement procedures can be extremely useful later in the office during document preparation or when reviewing older projects. Figure 4 can be copied and used for this purpose. A Noise Measurement Data Sheet has also been provided to be copied and used in data collection (Figure 5).

7.3 Procedure

After the sound level meter has been calibrated according to the manufacturer's instructions, determine a "ball park" figure of noise levels to the nearest even 10 dB(A). On a copy of the Noise Measurement Data Sheet (Figure 5) mark this level in the left-hand column at the center of the form so that 20 dB(A) can be displayed on either side. Figure 6 displays a form where 60 dB(A) was used in the form's left-hand column accordingly. Flanked on either side are 80, 70 and 50, 40 dB(A). In this way, the form is flexible and can be used for a range of 50 dB(A) at any starting point.

You are now prepared to start sampling. Record the time measurement is to begin. Every ten seconds, on the mark, read the noise level from the meter and make an "X" in the appropriate window, starting on

where
does it end.

After 50 samples (8 minutes and 20 seconds), test the samples by the criterion discussed below. If the samples meet the criterion, then the measurement is complete. If not, then another 50 samples must be taken and the test repeated.

7.4 Evaluation and Criterion

After a group of 50 samples has been taken, the following test is made:

Counting the "X"s from left to right within each window, circle the first, fifth, and tenth sample. These three test samples constitute the L_{10} value flanked by it's upper and lower error limits.

If the first and tenth sample are each within 3dB(A) of the fifth sample the measurement is complete. Otherwise, another 50 samples must be taken and tested again. Sometimes the test samples will be even more [illegible] apart. In these cases, the criterion is also met.

If more than 50 samples must be taken, the appropriate test criteria is listed in Figure 4. If 100 or more samples have been taken, a statistical process called skewing is allowed. By this process, the two outer test samples (the error limits) can be shifted by one sample (not one window), both in the same direction. For example, if the criterion is not met after 100 samples by testing the fifth, tenth, and seventeenth samples, the criterion can be tested with the fourth, tenth and sixteenth samples or the sixth, tenth and eighteenth samples. Although this skewing procedure will not change the L_{10} value (nor will it change the number of samples between the upper and lower error limits) it can sometimes provide the necessary accuracy without requiring further sampling. However, if the criterion is still not met after skewing, then another 50 samples must be taken, and so on.

7.5 Results

Once the criterion has been met, the L_{10} value has been determined within the 95 percent confidence level to be between the upper and lower error limit test samples.

The results of the example shown in Figure 6 would be stated as follows:

$$L_{10} = 76 \text{ dB(A), within maximum limits of } 73 \text{ dB(A) and } 78 \text{ dB(A)}$$

In another notation,

$$L_{10} = 76 \begin{matrix} +\ 2 \\ -3 \end{matrix} \text{ dB(A)}$$

L_{50} is determined in much the same way (i.e. with 50 samples, the 25th sample).

7.6 Determination of Leq

After the L_{10} criterion has been met, Leq can be evaluated by using the worksheet columns on the right-hand portion of Figure 5.

a. Enter the number of "X"s per line in the column labeled total. Add this column to get the total and write this number in the box at the bottom of the column. This number should equal the amount of samples taken.

b. Perform the multiplication indicated on the Noise Measurement Data Sheet. That is, multiply the numbers after the multiplication sign by the number of samples on each line. Place the product, right-justified, in the boxes on the right-hand side of the form. Sum all the products. Products that have trailing zeros included in the boxes should be added as the larger number. For example, on Figure 6, the line representing 60 dB(A) has two samples. It was multiplied by 10 on the right-hand side. But, when 20 was placed in the appropriate boxes it became 2000 due to the trailing zeros. This is done to allow linear energy averaging.

c. Divide the sum of energy factors (numbers in boxes, some with trailing zeros) by the total number of samples taken and place in the box labeled EQUALS.

d. Locate the number, trailing zeros included, in the right-hand column of boxes that is the closest value to the number in the EQUALS box. The corresponding dB(A) value on the same line at the left-hand side of the form approximates Leq.

7.7 Final Step

Recheck the sound level meter calibration to assure the meter has performed properly. The ending sample time along with any unusual occurrences (i.e. dog barking into microphone) should be noted on the measurement form.

7.8 Using ANSI Type I Sound Level Meters

A Type I sound level meter is more accurate and may have a readout of statistical noise descriptors such as L_{10} and Leq. Following the manufacturer's instructions, it is set in place, allowed to sample, and the results recorded. Such meters are available from D-8 upon request for Departmental personnel use. Please allow sufficient time when making such a request in case the meter has been previously checked out.

8.0 TRAFFIC NOISE PREDICTION METHODS

8.1 The publication, research report FHWA - RD - 77 - 108, entitled FHWA Highway Traffic Noise Prediction Method is approved for use in noise analysis. However, any traffic noise methodology is approved as long as it is consistent with FHPM 7-7-3, section 10 (see Appendix C). The prediction method may be solved manually, from nomographs, with a programmable calculator, or by using the Department's computer facilities.

8.2 Manual Method

Appendix A contains complete directions and examples of how to use the Manual FHWA Traffic Noise Prediction Method. Appendix B gives the same model in a simplified, condensed version of this manual method using a calculator with "log" and "Y^x" capabilities. The use of these is appropriate for first approximations and for use on projects with simple geometry. Due to simplifications of the model some drawbacks exist with its use. No barrier calculations can be performed, contours are difficult to plot requiring several interations, and some accuracy is lost.

8.3 Nomographs

Nomographs can be used as a first approximation or for projects with simple geometry. Barrier calculations may also be performed with a nomograph. However, simplifications to the model decrease its accuracy and errors in reading the graph may occur. Nomographs are available upon request from the Highway Design Division.

8.4 Programmable Calculator Method

The Department's Highway Design Division has published and distributed a program listing for a Texas Instrument's TI 59 programmable calculator, equipped with a PC100A or PC100C printer, complete with the program listing and example problems. This method will solve the complete noise model. The most recent edition is dated May 1, 1980. Additional copies are available upon request. Limitations also exist with this method. Four magnetic cards must be read by the calculator for the complete program. Finally, simplifications have been made which result in a decrease in the accuracy of the model.

8.5 Traffic Noise Prediction Computer Model

This method also performs the entire prediction method. It is more accurate and much faster then the calculator method. In addition, an expanded "contour search" routine is incorporated in the model providing multiple contour points to be calculated in a single computer run. Input to the Department's computer is accomplished through the use of punched cards or use of a "ROSCOE" terminal. "ROSCOE" input requires less effort and is recommended. The Department has published and distributed "Traffic Noise Prediction Model, User Manual" which describes the program in detail. The only drawback to the model is it's inability to handle very complex geometric highway design configurations.

8.6 Highway Traffic Noise Prediction Computer Model, STAMINA 2.0

This program, is available for use on "ROSCOE" or with card decks. It is an involved program requiring a greater effort to input data but offers solutions to very complex highway configurations.

8.6 Highway Traffic Noise Prediction Computer Model, STAMINA 2.0

This program, is available for use on "ROSCOE" or with card decks. It is an involved program requiring a greater effort to input data but offers solutions to very complex highway configurations. Unfortunately, a "contour search" routine is not included in the model, but up to 40 receiver sites can be modeled in a single run. The user manual is available on request from the Department (D-8). A program for designing cost-effective barriers, OPTIMA, works in conjunction with STAMINA 2.0. STAMINA 2.0 is suggested for large projects or for projects with complex geometry.

8.7 General

Some restrictions apply to all methods. Noise levels should not be predicted at distances less than 7.5 meters (25 feet) for Leq and 15 meters (50 feet) for L_{10}, traffic speeds should not be less than 50 kph (30 mph) or greater than 100 kph (60 mph), and the calculated number should not be considered absolute answers. Decibels should be reported in whole numbers. For a complete list of restrictions please refer to the appropriate user manual.

When the distance and speed limitations are observed, the accuracy of the model is quite good. A correlation coefficient of greater than 0.90 with a standard deviation of 2.0 dB(A) is typical when using the computer models. The greater the distance from traffic to the observer the greater standard deviation values. However, these results are still good.

9.0 FUTURE NOISE LEVELS AND PERTINENT INFORMATION FOR LOCAL OFFICIALS

Local officials should be notified of the best estimation of future noise levels. This will assist in preventing incompatible noise levels upon the developed and undeveloped lands that have been planned for development and are abutting project. A copy of the appropriate environmental document and/or noise report which includes a summary of the noise analysis and a copy of FHPM 7-7-3 satisfies this requirement.

10.0 FUNDS FOR ABATEMENT

Federal funds may be used for abatement measures. FHPM 7-7-3, part 8, should be consulted to determine if a particular project qualifies for these funds (see Appendix C). Both Type I and Type II projects can be federally funded.

NOISE ABATEMENT CRITERIA

Activity* Category	Criteria Levels-dBA L_{eq} (h)	Criteria Levels-dBA L_{10} (h)	Description of Activity Category
A	57 (Exterior)	60 (Exterior)	Tracts of land in which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particular parks or portions of parks, open spaces, or historic districts which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
B	67 (Exterior)	70 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, and parks which are not included in Category A and residences, motels, hotels, public meeting rooms, schools, churches, libraries, and hospitals.
C	72 (Exterior)	75 (Exterior)	Developed lands, properties or activities not included in Categories A or B above.
D	--	--	Undeveloped lands. Predicted noise levels should be provided to local governments by which developers of land can design activities compatible with future noise levels.
E	52 (Interior)	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

TABLE 1

*Determined by land use

INTERIOR NOISE LEVEL REDUCTION FACTORS

Building Type	Window Condition	Noise Reduction Due to Exterior of the Structure
All	Open	10 dB
Light Frame	Ordinary Sash (Closed)	20
	Storm Windows	25
Masonry	Single Glazed	25
Masonry	Double Glazed	35

The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year, such as with air-conditioning.

TABLE 2

RELATIONSHIP BETWEEN DECIBELS, ENERGY AND LOUDNESS

Noise Decrease	Energy Removal %	Divide Loudness By	Ease Of Attainment
3 dB(A)	50	1,2	Simple
6 dB(A)	75	1,5	Attainable
10 dB(A)	90	2	Difficult
15 dB(A)	95	~ 3	Very Difficult
20 dB(A)	99	4	Nearly Impossible
30 dB(A)	99,9	8	Impossible to Achieve Outdoors

TABLE 3

FIGURE I

LEVEL OF EFFORT REQUIRED FOR NOISE ANALYSIS ON HIGHWAY PROJECTS

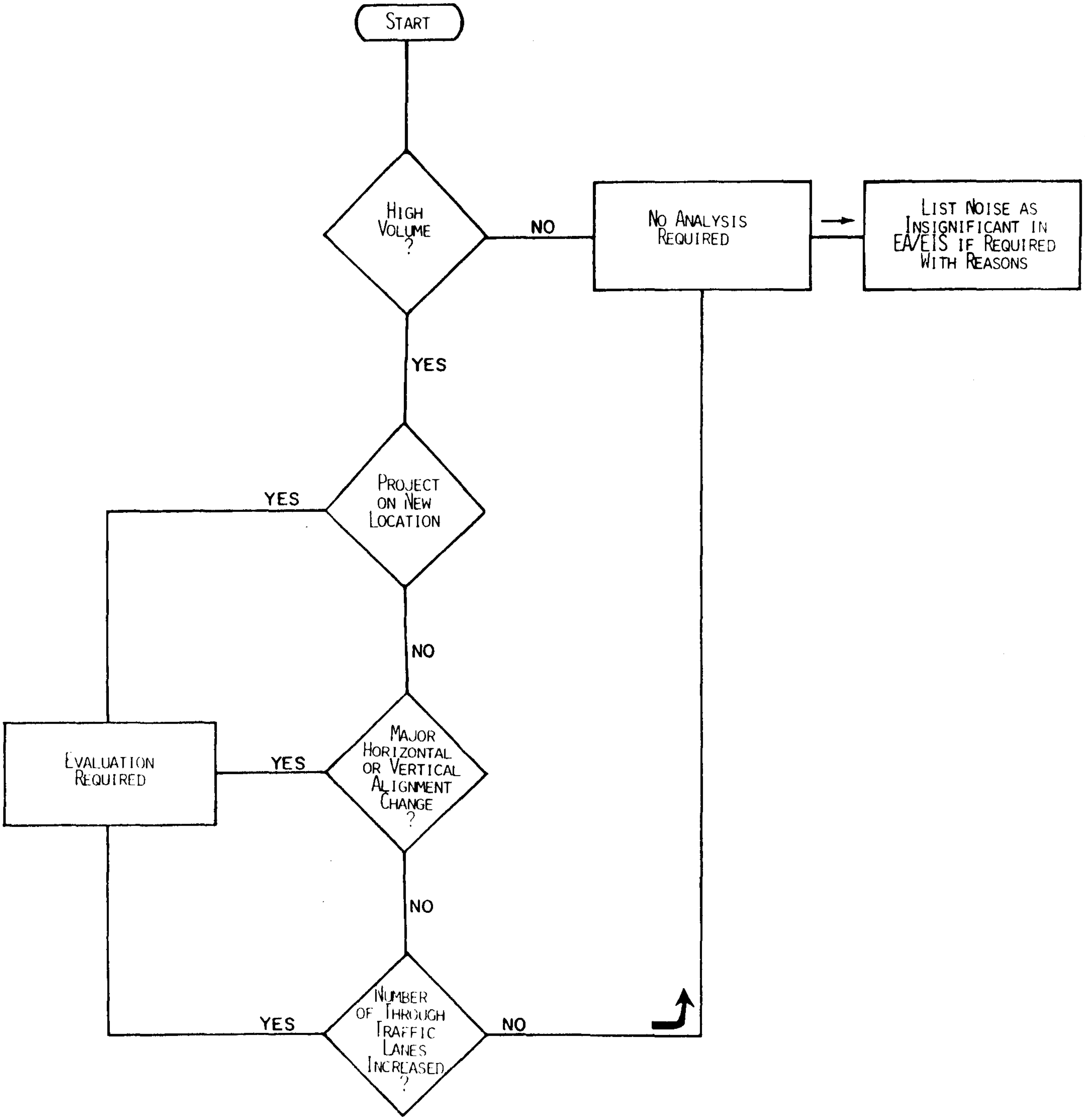
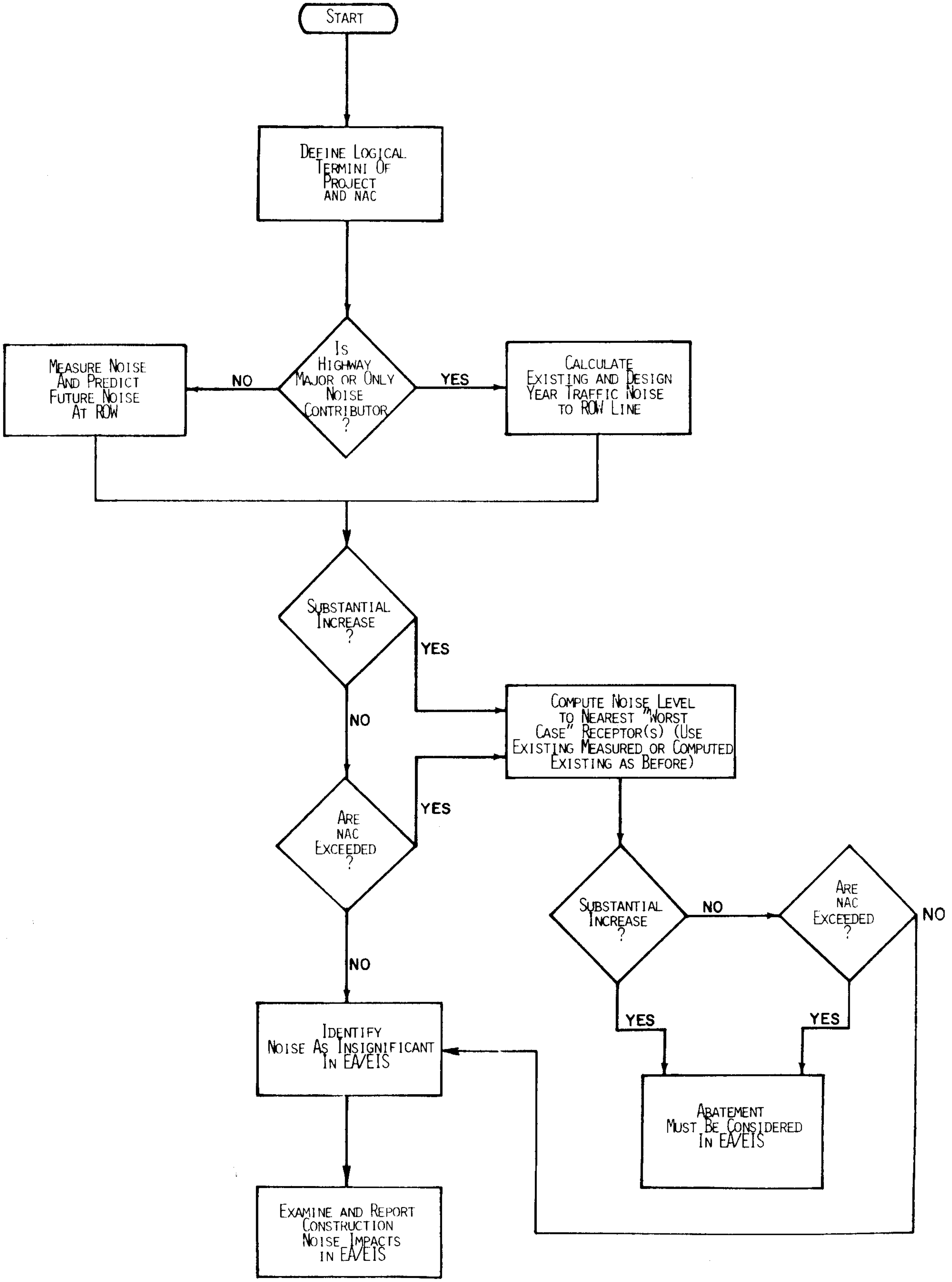
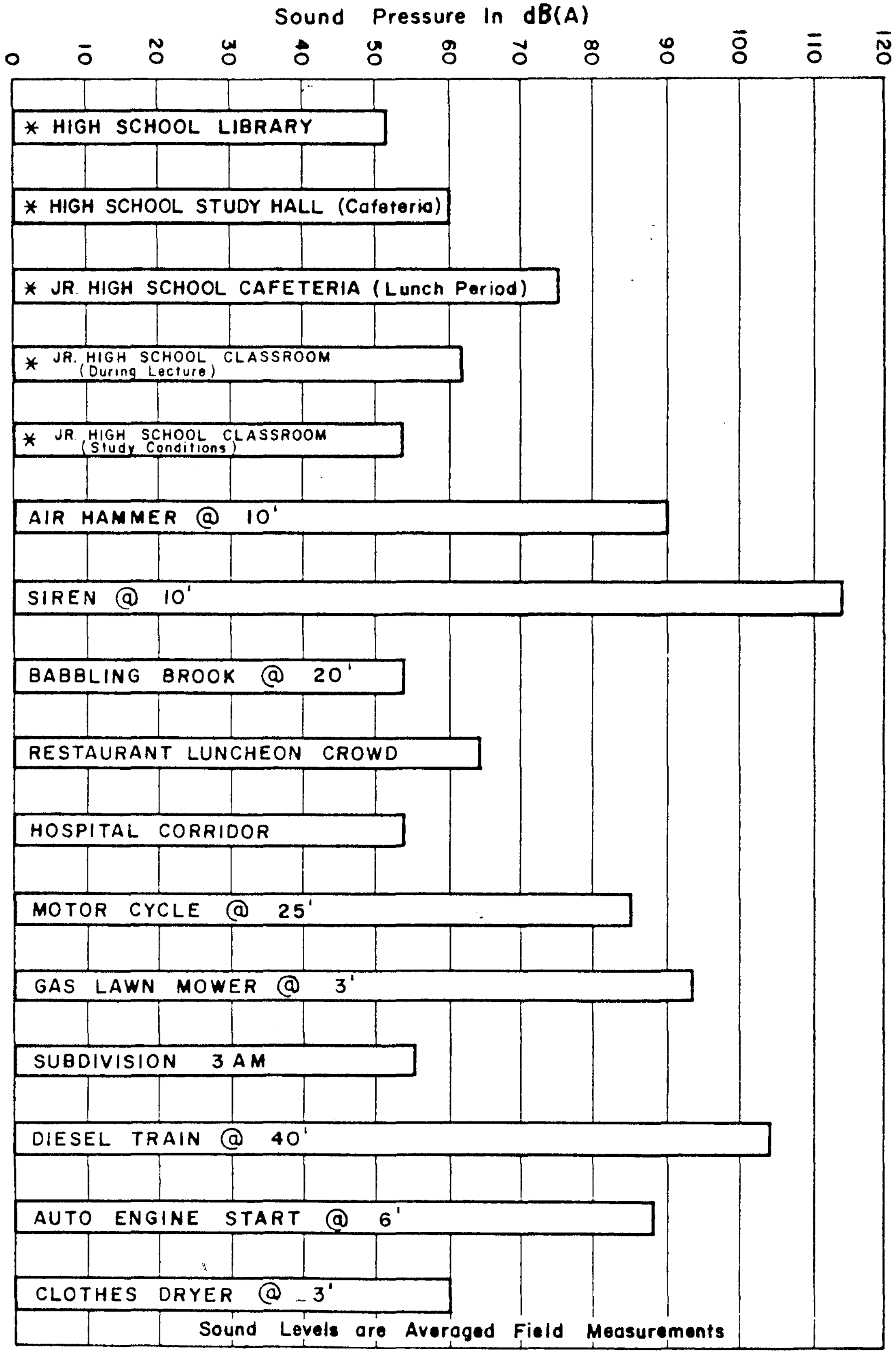


FIGURE 2

EVALUATION PROCEDURES OF NOISE IMPACTS ON HIGHWAY PROJECTS



TYPICAL SOUND LEVELS



Sound Levels are Averaged Field Measurements

* Selected Schools not near Highway

FIGURE 3

FIGURE 4

EQUIPMENT: METER ____________ CALIBRATOR ____________

CALIBRATION: START ____________ DB END ____________ DB

RESPONSE: ___ FAST ___ SLOW ___ A-WEIGHTING ___ BATTERY CHECK

WEATHER DATA ____

TRAFFIC DATA			
ROAD			
AUTOS			
MED. TRKS.			
HVY. TRKS.			
DURATION			

CRITERION: ± 3DB			
NUMBER OF SAMPLES	UPPER LIMIT	L10	LOWER LIMIT
50	1ST	5TH	10TH
100	5TH	10TH	17TH
150	8TH	15TH	23RD
200	12TH	20TH	29TH

SITE SKETCH

BACKGROUND NOISE ____

MAJOR SOURCES ____

UNUSUAL EVENTS ____

OTHER NOTES ____

FIGURE 5

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION 15

NOISE MEASUREMENT DATA SHEET

NAME: ______________________________ DATE ________

PROJECT: ______________________________ TIME:

SITE: ______________________________ START ________

______________________________ END ________

RESULTS: L10 _____ + ___ - ___ L50 _____ LEQ _____

HOW TO USE: 2 X 80 = 1600000

FILL IN OTHER SIDE

		TOTAL			
9			X 80 =	0000	
8			X 63 =	0000	
7			X 50 =	0000	
6			X 40 =	0000	
5			X 32 =	0000	
4			X 25 =	0000	
3			X 20 =	0000	
2			X 16 =	0000	
1			X 13 =	0000	
0			X 10 =	0000	
9			X 80 =	000	EQUALS 100,000
8			X 63 =	000	
7			X 50 =	000	
6			X 40 =	000	
5			X 32 =	000	
4			X 25 =	000	
3			X 20 =	000	
2			X 16 =	000	
1			X 13 =	000	
0			X 10 =	000	
9			X 80 =	00	EQUALS 10,000
8			X 63 =	00	
7			X 50 =	00	
6			X 40 =	00	
5			X 32 =	00	
4			X 25 =	00	
3			X 20 =	00	
2			X 16 =	00	
1			X 13 =	00	
0			X 10 =	00	
9			X 80 =	0	EQUALS 1,000
8			X 63 =	0	
7			X 50 =	0	
6			X 40 =	0	
5			X 32 =	0	
4			X 25 =	0	
3			X 20 =	0	
2			X 16 =	0	
1			X 13 =	0	
0			X 10 =	0	
9			X 80 =		EQUALS 100
8			X 63 =		
7			X 50 =		
6			X 40 =		
5			X 32 =		
4			X 25 =		
3			X 20 =		
2			X 16 =		
1			X 13 =		
0			X 10 =		
DBA	10 20 30 40 50 NUMBER OF SAMPLES	TOTAL	DIVIDED INTO	TOTAL	

EQUALS ________

FIGURE 6

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION 15

NOISE MEASUREMENT DATA SHEET

NAME: W.A. HENWAY III

DATE 8/21/84

PROJECT: NOISEVILLE BYPASS FUTURE LOCATION

TIME:

SITE: 120' E OF NB I-9999
(1012 HICKORY HOLLOW ROAD) SOFT SITE

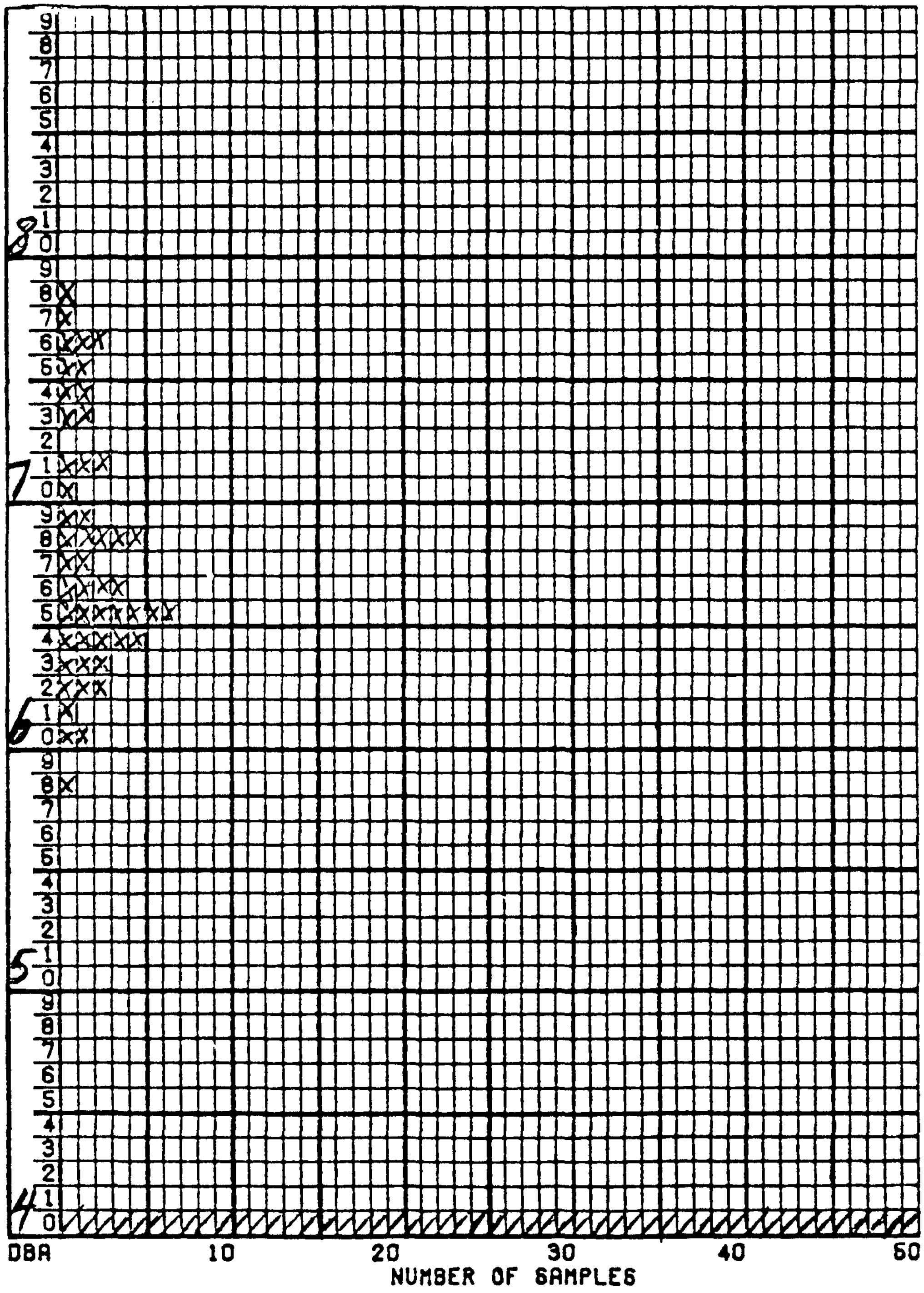
START 9Am

END 9:09

RESULTS: L10 76 + 2 - 3 L50 66 LEQ 70

HOW TO USE: 2 X 80 = 160000

FILL IN OTHER SIDE



TOTAL		
	X 80 =	0000
	X 63 =	0000
	X 50 =	0000
	X 40 =	0000
	X 32 =	0000
	X 25 =	0000
	X 20 =	0000
	X 16 =	0000
	X 13 =	0000
	X 10 =	0000
	X 80 =	000
1	X 63 =	63000
1	X 50 =	50000
3	X 40 =	120000
2	X 32 =	64000
2	X 25 =	50000
2	X 20 =	40000
	X 16 =	000
3	X 13 =	39000
1	X 10 =	10000
2	X 80 =	16000
5	X 63 =	31500
2	X 50 =	10000
4	X 40 =	16000
7	X 32 =	22400
5	X 25 =	12500
3	X 20 =	6000
3	X 16 =	4800
1	X 13 =	1300
2	X 10 =	2000
	X 80 =	0
1	X 63 =	630
	X 50 =	0
	X 40 =	0
	X 32 =	0
	X 25 =	0
	X 20 =	0
	X 16 =	0
	X 13 =	0
	X 10 =	0
	X 80 =	
	X 63 =	
	X 50 =	
	X 40 =	
	X 32 =	
	X 25 =	
	X 20 =	
	X 16 =	
	X 13 =	
	X 10 =	

EQUALS 100.000
EQUALS 10.000
EQUALS 1.000
EQUALS 100

TOTAL 50 DIVIDED INTO TOTAL 559130

EQUALS 11183

Appendix A

Condensation of FHWA Traffic Noise Prediction Model

CONDENSATION OF FHWA TRAFFIC NOISE PREDICTION MODEL

EXCLUDING BARRIER EVALUATION

HIGHWAY DESIGN DIVISION

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

REV. 4-2-80

To obtain a single L_{10} value in dB(A)'s for a particular site, proceed as follows:

1) Determine whether the site is hard or soft from page A-4.

2) Find Emissions Levels from Figure 2 on page A-5 and enter on line 8 of work sheet.

3) Find Real Traffic Flow adjustment from Figure 3 on page A-6 and enter on line 9 of work sheet.

4) Find Distance Adjustment for hard <u>or</u> soft site from Figure 4 on page A-7 and enter on line 10 for hard site <u>or</u> line 12 for soft site of work sheet.

5) Determine ϕ_1 and ϕ_2, from Figure 5 on page A-8 (for infinite highway section $\phi_1 = -90°$; $\phi_2 = +90°$) and enter on lines 6 and 7 of work sheet.

6) Find Finite Length adjustment for hard site from Figure 6 on page A-9 <u>or</u> for soft site from Figure 7 on page A-10 and enter on line 11 (hard) or line 13 (soft) of work sheet. For infinite hard sites ($\phi_1 = 90°$; $\phi_2 = +90°$) the adjustment is zero. For infinite soft sites the adjustment is always = -1.2 db(A).

7) Sum all columns, including line 19, of work sheet and enter the sums on line 20. These sums are the L_{eq} values for Autos, Medium Trucks and Heavy Trucks.

8) Find the L_{10}-L_{eq} adjustments from Figure 15 on page A-11 and enter on line 24 of the work sheet.

9) Sum lines 20 and 24 of the work sheet and enter resulting L_{10} values on line 25.

10) Combine these three L_{10} values into one L_{10} value using the figure on page A-12 and enter the single L_{10} value on line 26 of the work sheet.

11) The procedure is complete.

12) Example situations are displayed by the work sheets on pages A-13, A-14, and A-15.

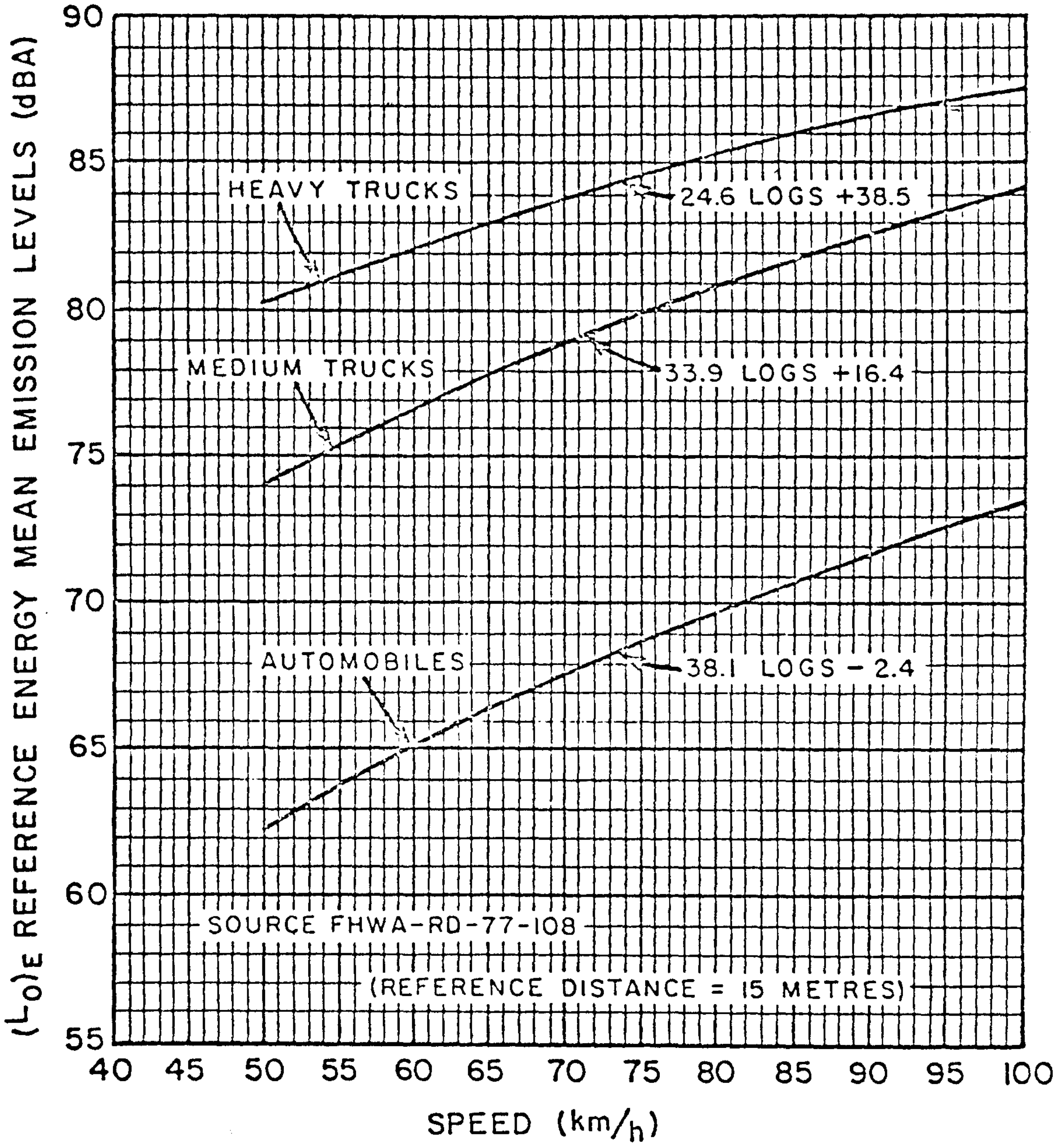
13) A blank work sheet is presented on page A-16. This sheet may be copied and used during analysis.

HOW TO DETERMINE WHETHER A SITE IS "HARD OR SOFT"

Situation	Drop-Off Rate
1. All situations when the sound or the receiver is located 3 metres above the ground or whenever line-of-sight* averages more than 3 metres above the ground.	3 dB Hard Site
2. All situations involving propagation over the top of a barrier 3 metres or more in height.	3 dB Hard Site
3. Where the height of the line-of sight is less than 3 metres and	
(a) There is a clear (unobstructed view of the highway, the ground is hard and there are no intervening structures.	3 dB Hard Site
(b) The view of the roadway is interrupted by isolated buildings, clumps of bushes, scattered trees, or the intervening ground is soft or covered with vegetation.	4.5 dB Soft Site

*The line-of sight (L/S) is a direct line between the noise source and the observer.

Drop-Off Rate Per Doubling of Distance



Enter chart with speed in KPH and read $(L_O)_E$ for Autos, Medium Trucks and Heavy Trucks. Enter these values on Line 8 of worksheet. (MPH x 1.609 = KPH)

FIGURE 2: Reference Energy Mean Emission Levels as a Function of Speed

Revised September 1978
April 1979

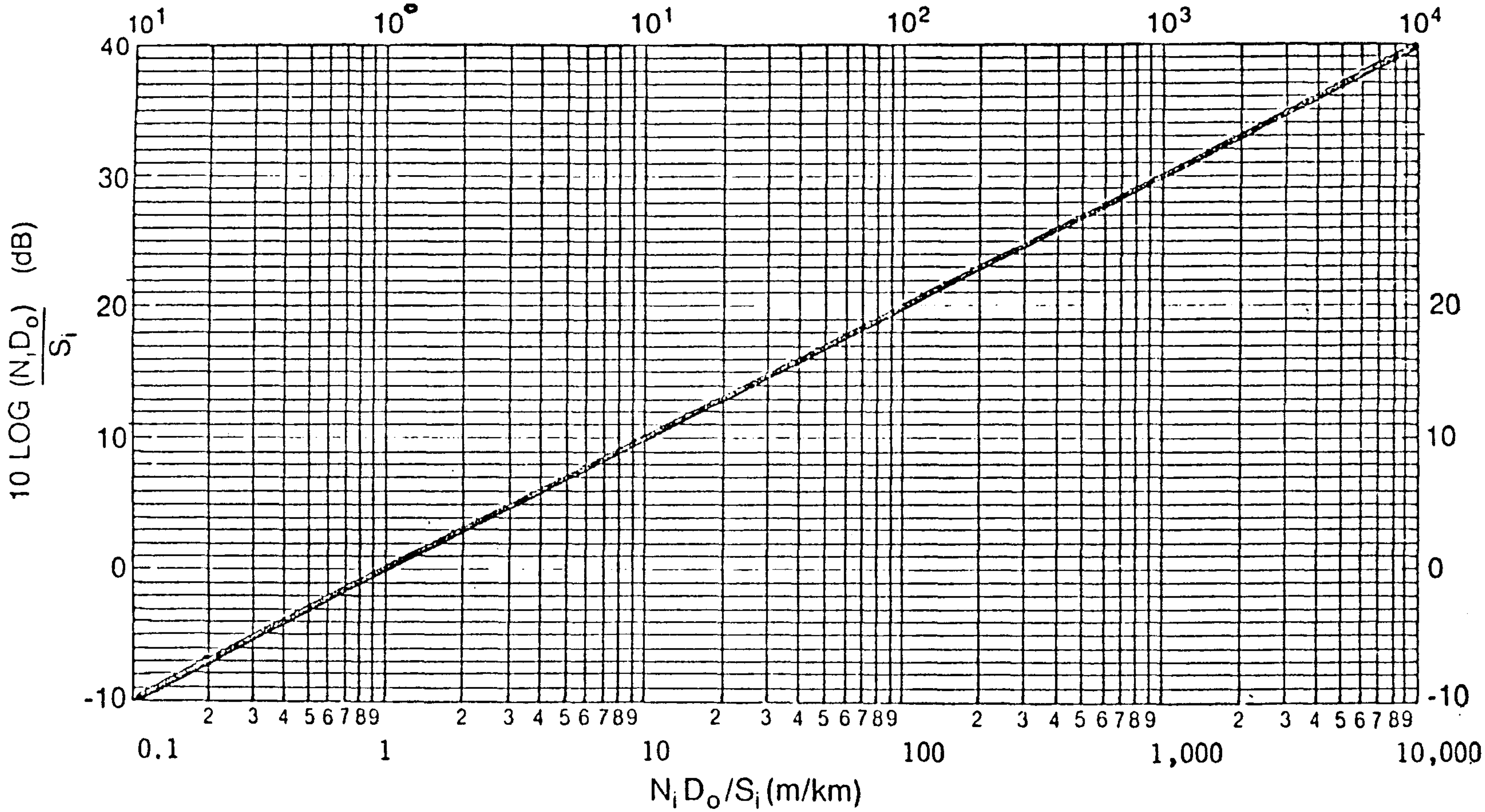


Figure 3: Adjustment for Real Traffic Flows

Enter chart with N=VPH; D_O=15m; S=Speed in KPH) and read 10 Log ND_O/S for Autos, Medium Trucks and Heavy Trucks. Enter these values on Line 9 of work sheet. (MPH x 1.609 = KPH)

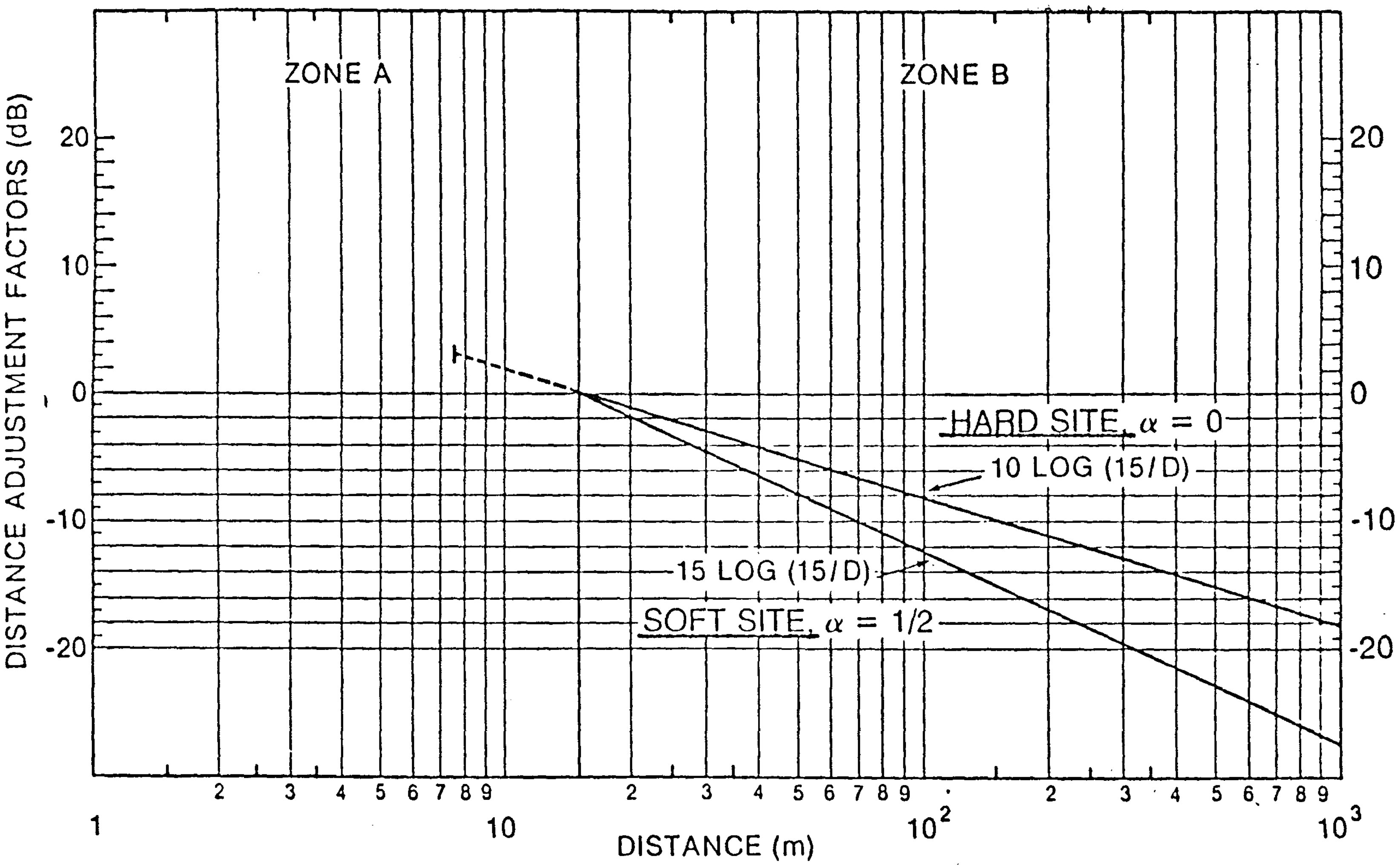
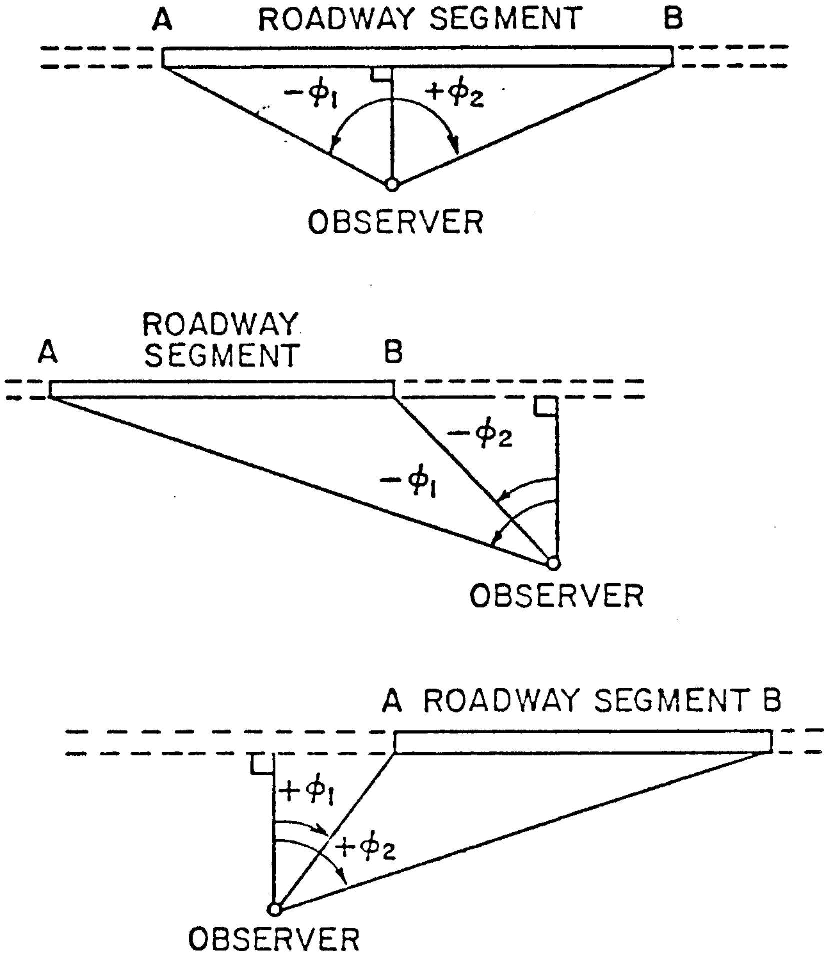


Figure 4: Adjustments for Distances Other Than 15 Metres (Feet x 0.305 = metres)

Enter chart with distance (in metres) and read one adjustment factor for HARD SITE or SOFT SITE (do not use distance<7.5m)
If HARD SITE adjustment is read, enter on line 10 of work sheet.
If SOFT SITE adjustment is read, enter on line 12 of work sheet.

FOR SOFT SITES



FOR HARD SITES

In all cases $\Delta\phi$ will be positive and will be numerically equal to the included angle subtended by the observer and the roadway segment.

ANGLE INDENTIFICATION OF ROADWAY SEGMENTS

FIGURE 5

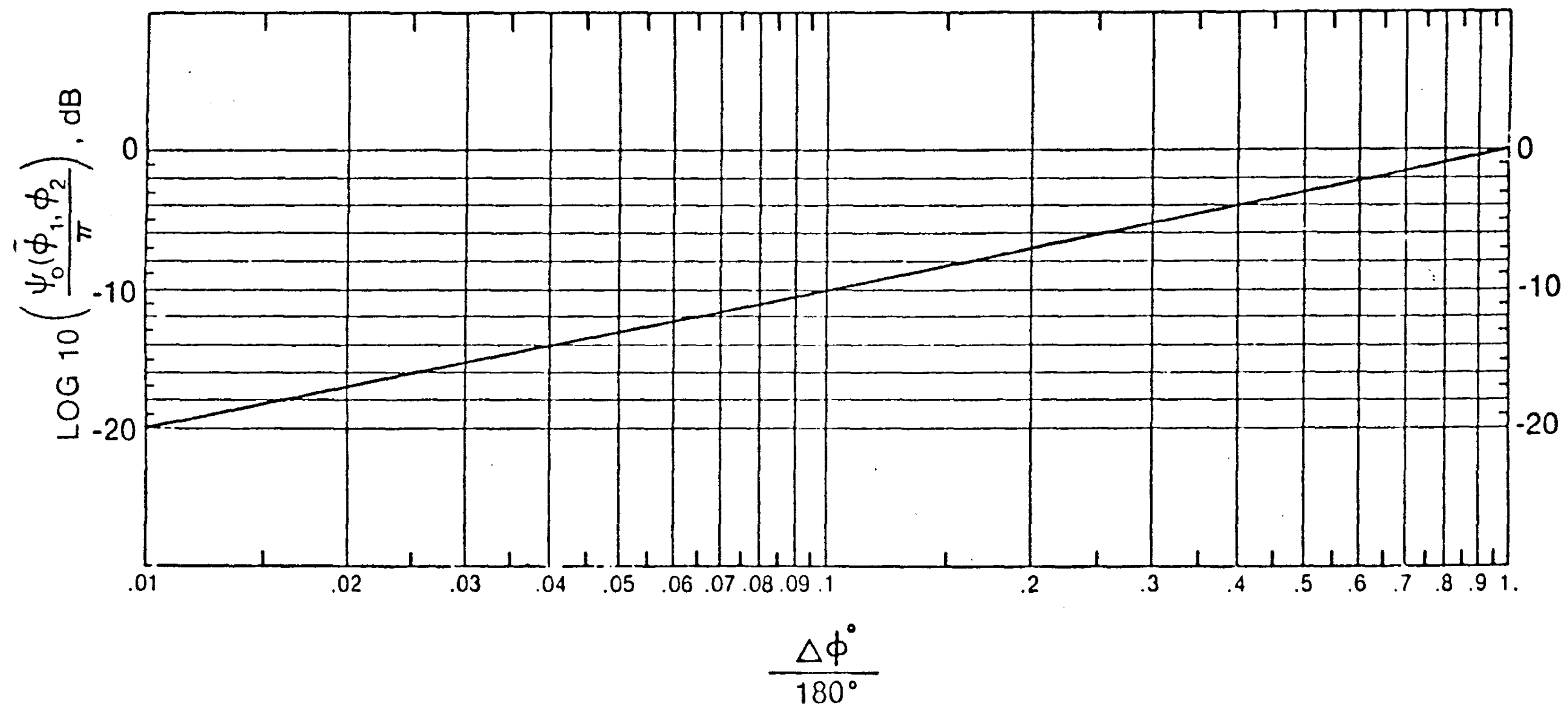
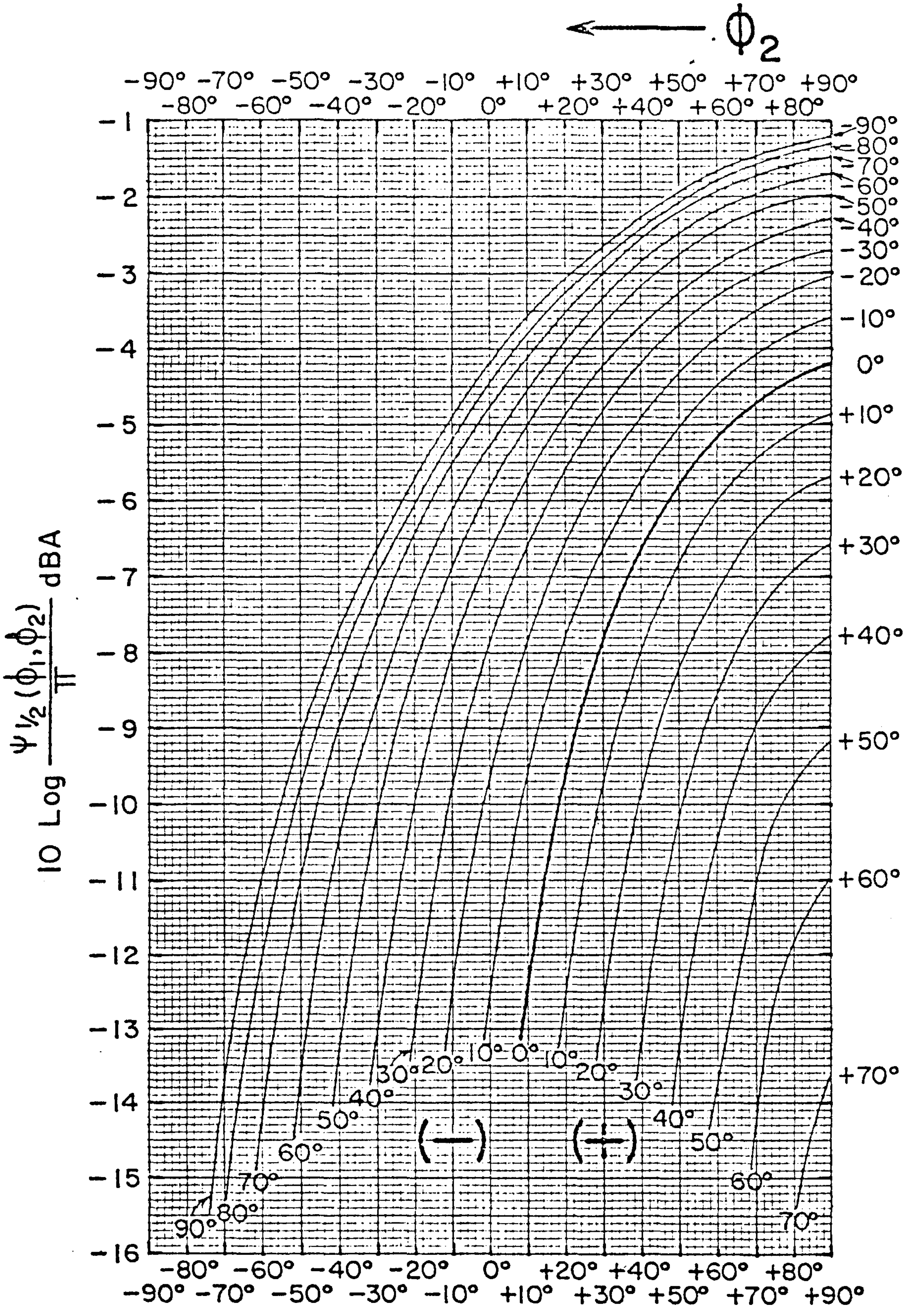


Figure 6: Adjustment Factor for Finite Length Roadways for Hard Sites ($\alpha = 0$)

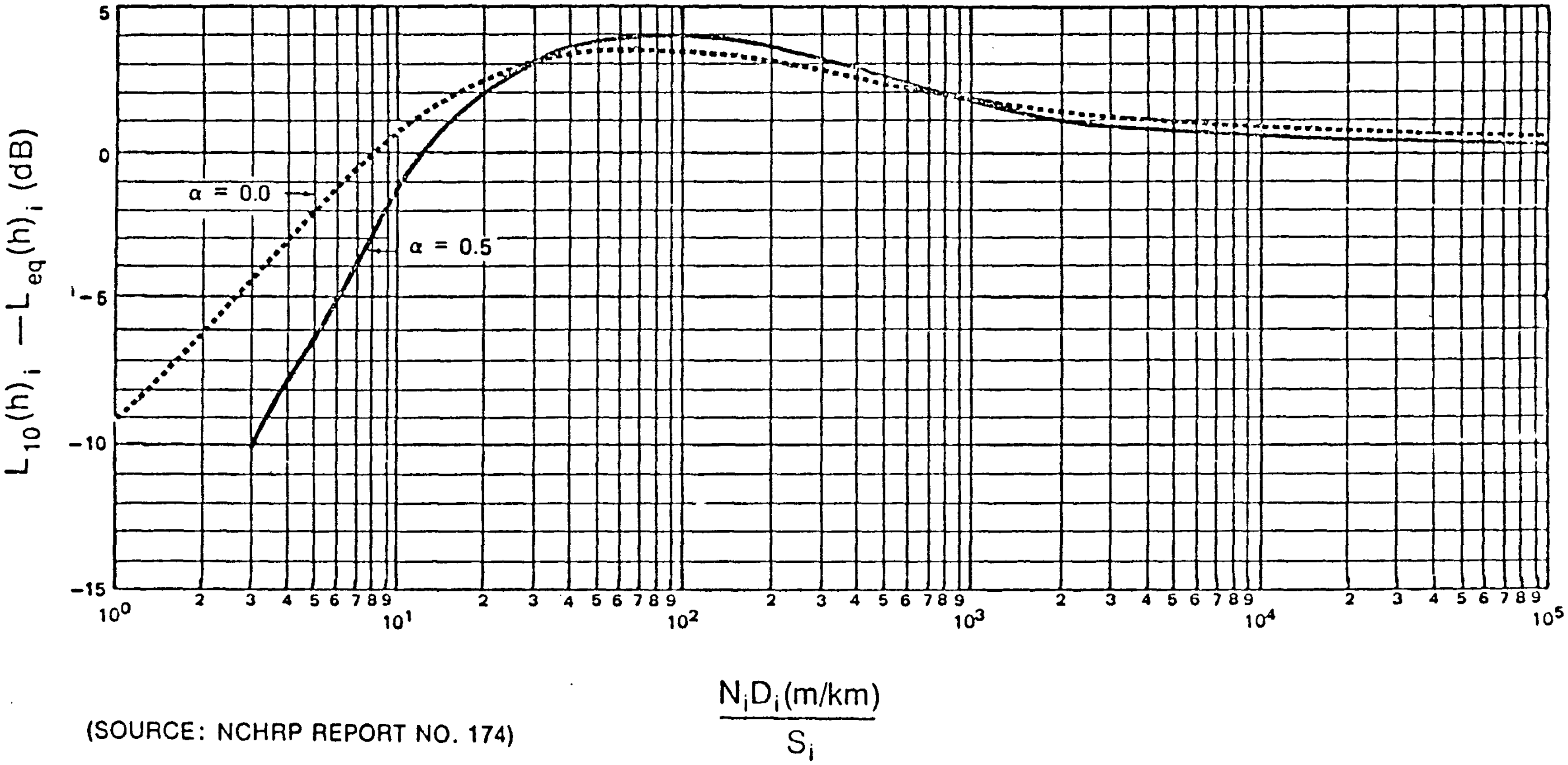
Enter chart with $\Delta\phi/180^\circ$ (see page 5 for $\Delta\phi$) and read Hard Site adjustment value. Enter this value on Line 11 of work sheet. Do not use this chart for infinite sections. (Infinite section = $180^\circ/180^\circ = 1$; enter chart with 1; adjustment = 0.)



Φ_1	Φ_2	$\Psi_{1/2}$
-90°	+90°	-1.2
-80°	+80°	-1.4
-70°	+70°	-1.7
-60°	+60°	-2.2
-50°	+50°	-2.8
-40°	+40°	-3.7
-30°	+30°	-4.9
-20°	+20°	-6.6
-10°	+10°	-9.6

ADJUSTMENT FACTOR FOR <u>FINITE</u> LENGTH ROADWAYS FOR <u>SOFT</u> <u>SITES</u>

Figure 7



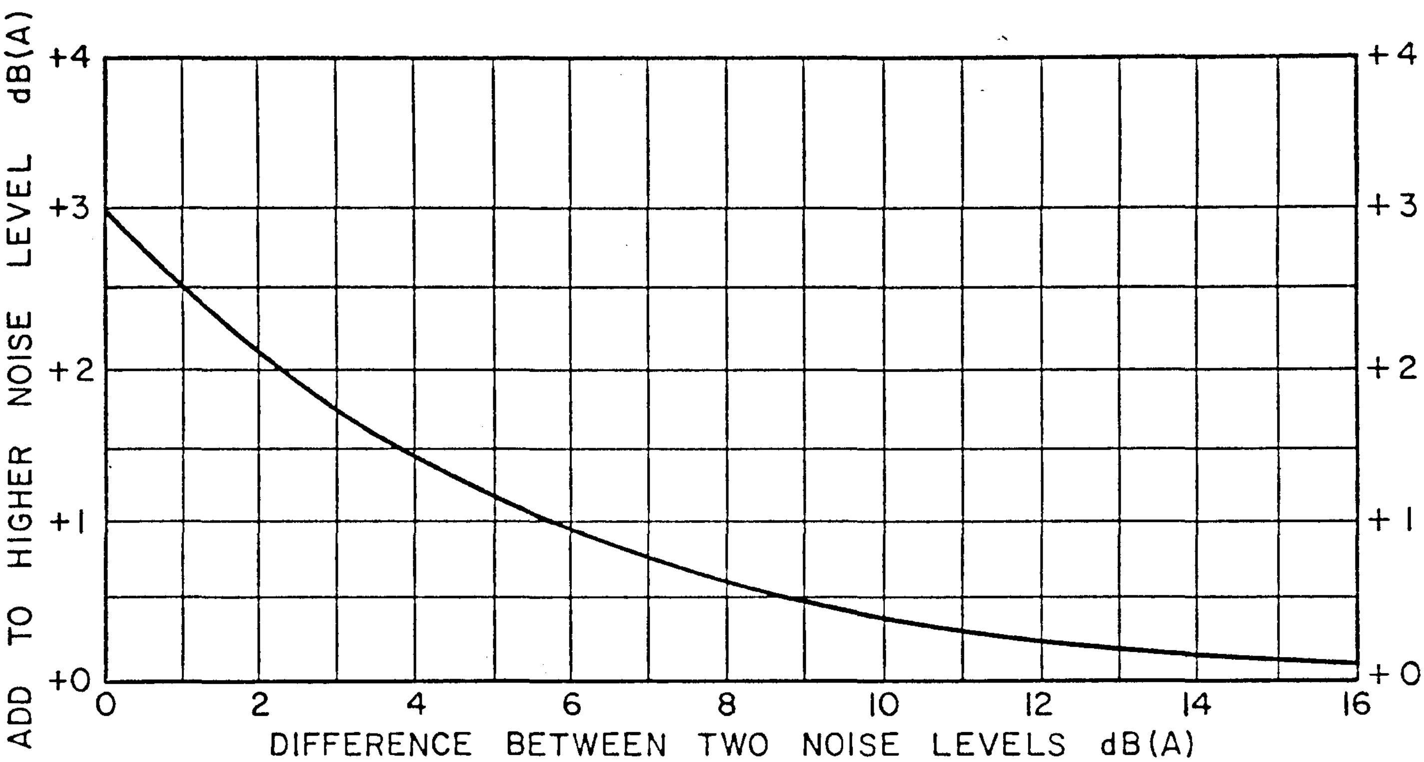
(SOURCE: NCHRP REPORT NO. 174)

Figure 15: Adjustment Factor for Converting $L_{eq}(h)_i$ to $L_{10}(h)_i$

Enter chart with N D/S (N=VPH; D=distance(m) Source to observer; S=Speed in KPH) and read L_{10}-LEQ for Autos, Medium Trucks and Heavy Trucks. Enter these values on line 24 of work sheet.

Rev. 8/29/79

PROCEDURE FOR COMBINING NOISE LEVELS EITHER LEQ OR L10 VALUES



Use this chart to combine LEQ's or L10's on lines 20 and 25, respectively.

Example: Combine 68dBA, 70dBA and 65dBA. Select the lesser two of the three dBA values (68 and 65); obtain the difference (3dBA); enter chart with 3, move vertically upward to the curve then horizonally to the left and read +1.7. Add 1.7 to the larger (68dBA) to obtain a sum of 69.7dBA. Repeat the process using 69.7dBA and 70dBA.

TRAFFIC NOISE PREDICTION SHEET

EXAMPLE A - INFINITE SECTION

ONE DISTANCE

SITE NO. (S)______

1	~~LANE (S) IDENTIFICATION~~	Soft site			Hard site														
2	VEHICLE CLAS.	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT
3	N (vph)	598	36	47	598	36	47												
4	S~~(k/h)~~(mph)~~x 1.609)~~	55	55	55	55	55	55												
5	D~~(m)~~(feet)~~x 0.305)~~	100	100	100	100	100	100												
6	ϕ_1 (DEGREES) (+ or −) FIG. 5	-90°	-90°	-90°	-90°	-90°	-90°												
7	ϕ_2 (DEGREES) (+ or −) FIG. 5	+90°	+90°	+90°	+90°	+90°	+90°												
8	$(L_0)E_i$ FIG. 2	71.8	82.4	86.4	71.8	82.4	86.4												
9	10 LOG (N_iD_0/S_i) FIG. 3	20.1	7.9	9.0	20.1	7.9	9.0												
10	10 LOG (D_0/D) FIG. 4				-3.1	-3.1	-3.1												
11	10 LOG (Ψ_0) HARDSITE ____ FIG. 6				0	0	0												
12	15 LOG (D_0/D) FIG. 4	-4.6	-4.6	-4.6															
13	10 LOG $(\Psi_{1/2})$ SOFTSITE ____ FIG. 7	-1.2	-1.2	-1.2															
14	ϕ_L (DEGREES) (+ or −) FIG. 10																		
15	ϕ_R (DEGREES) (+ or −) FIG. 10																		
16	δ (METRES)																		
17	N_0																		
18	Δ_B																		
19	CONSTANT	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25
20	$L_{eq}(h)_i$	61.1	59.5	64.6	63.8	62.2	67.3												
21	$L_{eq}(h)$	67.0			69.7														
22	$L_{eq}(h)$																		
23	ND/S	206	12	16	206	12	16												
24	$(L_{10}(h)_i - L_{eq}(h)_i)$ FIG. 15	+3.0	-0.5	+1.0	+3.5	+1.0	+2.0												
25	$L_{10}(h)_i$	64.6	59.0	65.6	67.3	63.2	67.3												
26	$L_{10}(h)$	68.6			72.0														
27	$L_{10}(h)$																		
28	COLUMN IDENTIFICATION	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29	SITE. NO.																		

DISTRICT ______ PREPAIRED BY ____________ ____________ TEX-AN ____________ SHEET ______ OF ______

Rev. 4/2/80

TRAFFIC NOISE PREDICTION SHEET

EXAMPLE B - INFINITE SECTION

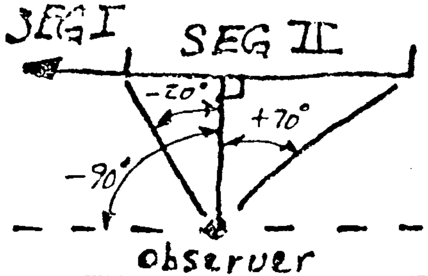
TWO DISTANCES

SITE NO. (S)______

Soft Site Hard site

1	LANE (S) IDENTIFICATION		Eastbound lanes			Westbound Lanes			Eastbound Lanes			Westbound Lanes								
2	VEHICLE CLAS.		A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT
3	N(vph)		317	24	22	281	12	25	317	24	22	281	12	25						
4	S(~~k/h~~)(mph)~~x 1.609)~~		← 55 →						← 55 →											
5	D(~~m~~)(feet)~~x 0.305)~~		← 100 →			← 150 →			← 100 →			← 150 →								
6	ϕ_1 (DEGREES) (+ or −)	FIG. 5	← -90° →						← -90° →											
7	ϕ_2 (DEGREES) (+ or −)	FIG. 5	← +90° →						← +90° →											
8	$(L_o)E_i$	FIG. 2	71.8	82.4	86.4	71.8	82.4	86.4	71.8	82.4	86.4	71.8	82.4	86.4						
9	10 LOG (N_iD_o/S_i)	FIG. 3	17.3	6.1	5.7	16.8	3.1	6.3	17.3	6.1	5.7	16.8	3.1	6.3						
10	10 LOG (D_o/D)	FIG. 4							← -3.1 →			← -4.8 →								
11	10 LOG (ψ_o) HARDSITE ____	FIG. 6								0			0							
12	15 LOG (D_o/D)	FIG. 4	← -4.6 →			← -7.3 →														
13	10 LOG $(\psi_{1/2})$ SOFTSITE ____	FIG. 7	← -1.2 →																	
14	ϕ_L (DEGREES)(+ or −)	FIG. 10																		
15	ϕ_R (DEGREES)(+ or −)	FIG. 10																		
16	δ (METRES)																			
17	N_o																			
18	Δ_B																			
19	CONSTANT		−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25
20	$L_{eq}(h)_i$		58.3	57.7	61.3	55.1	52.0	59.2	61.0	60.4	64.0	58.8	55.7	62.9						
21	$L_{eq}(h)$		64.2			61.2			66.9			64.9								
22	$L_{eq}(h)$																			
23	ND/S		109	8	8	145	6	13	109	8	8	145	6	13						
24	$(L_{10}(h)_i - L_{eq}(h)_i)$	FIG. 15	+4.0	-3.0	-3.0	+3.8	-5.0	0.0	3.4 ~~+4.0~~	0.0	0.0	+3.2	-1.1	+1.3						
25	$L_{10}(h)_i$		61.7	54.7	58.3	58.9	47.0	59.2	64.4	60.4	64.0	62.0	54.6	64.2						
26	$L_{10}(h)$		63.9			62.2			68.0			66.5								
27	$L_{10}(h)$		66.1						70.3											
28	COLUMN IDENTIFICATION		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29	SITE NO.																			

DISTRICT ______ PREPAIRED BY ____________ TEX-AN ______ SHEET ______ OF ______



TRAFFIC NOISE PREDICTION SHEET

EXAMPLE C - INFINITE SECTION TWO DISTANCES

SITE NO. (S)______

Soft Site - SEG. I   Hard Site - SEG II

1	LANE (S) IDENTIFICATION		E.B.			W.B.			E.B.			W.B.								
2	VEHICLE CLAS.		A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT
3	N(vph)		281	12	25	317	24	22	281	12	25	317	24	22						
4	S(~~K/h~~)(mph)~~x 1.609~~		55						55											
5	D(~~m~~)(feet)~~x 0.305~~		100			150			100			150								
6	ϕ_1 (DEGREES) (+ or −)	FIG. 5	-90°						-20°											
7	ϕ_2 (DEGREES) (+ or −)	FIG. 5	-20°						+70°											
8	$(L_o)E_i$	FIG. 2	71.8	82.4	86.9	71.8	82.4	86.4	71.8	82.4	86.9	71.8	82.4	86.4						
9	10 LOG (N_iD_o/S_i)	FIG. 3	16.8	3.1	6.3	17.3	6.1	5.7	16.8	3.1	6.3	17.3	6.1	5.7						
10	10 LOG (D_o/D)	FIG. 4							-3.1			-4.8								
11	10 LOG (ψ_o) HARDSITE _____	FIG. 6							-3.0											
12	15 LOG (D_o/D)	FIG. 4	-9.6			-7.3														
13	10 LOG $(\psi_{1/2})$ SOFTSITE _____	FIG. 7	-5.7																	
14	ϕ_L (DEGREES)(+ or −)	FIG. 10																		
15	ϕ_R (DEGREES)(+ or −)	FIG. 10																		
16	δ (METRES)																			
17	N_o																			
18	Δ_B																			
19	CONSTANT		-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25
20	$L_{eq}(h)_i$		53.3	50.2	57.4	51.1	50.5	54.1	57.5	54.4	61.6	56.3	55.7	59.3						
21	$L_{eq}(h)$		59.4			57.0			63.6			62.2								
22	$L_{eq}(h)$																			
23	ND/S		97	4	9	164	12	11	97	4	9	164	12	11						
24	$(L_{10}(h)_i - L_{eq}(h)_i)$	FIG. 15	+4.0	-7.7	-1.8	+3.2	0.0	-1.0	+3.4	-3.0	+0.3	+3.1	+1.0	+1.0						
25	$L_{10}(h)_i$		57.3	42.5	55.6	54.3	50.5	53.1	60.9	51.4	61.9	59.4	56.7	60.3						
26	$L_{10}(h)$		59.6			57.7			64.7			63.8								
27	$L_{10}(h)$		61.8						67.3											
28	COLUMN IDENTIFICATION		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29	SITE NO.																			

DISTRICT ______ PREPAIRED BY ______________________ TEX-AN __________ SHEET ______ OF ______

TRAFFIC NOISE PREDICTION SHEET

SITE NO. (S)______

1	LANE (S) IDENTIFICATION																			
2	VEHICLE CLAS.		A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT
3	N(vph)																			
4	S(k/h)(mph x 1.609)																			
5	D(m)(feet x 0.305)																			
6	ϕ_1 (DEGREES) (+ or −)	FIG. 5																		
7	ϕ_2 (DEGREES) (+ or −)	FIG. 5																		
8	$(L_o)E_i$	FIG. 2																		
9	10 LOG $(N_i D_o/S_i)$	FIG. 3																		
10	10 LOG (D_o/D)	FIG. 4																		
11	10 LOG (ψ_o) HARDSITE ____	FIG. 6																		
12	15 LOG (D_o/D)	FIG. 4																		
13	10 LOG $(\psi_{1/2})$ SOFTSITE ____	FIG. 7																		
14	ϕ_L (DEGREES)(+ or −)	FIG. 10																		
15	ϕ_R (DEGREES)(+ or −)	FIG. 10																		
16	δ (METRES)																			
17	N_o																			
18	Δ_B																			
19	CONSTANT		−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25	−25
20	$L_{eq}(h)_i$																			
21	$L_{eq}(h)$																			
22	$L_{eq}(h)$																			
23	ND/S																			
24	$(L_{10}(h)_i - L_{eq}(h)_i)$	FIG. 15																		
25	$L_{10}(h)_i$																			
26	$L_{10}(h)$																			
27	$L_{10}(h)$																			
28	COLUMN IDENTIFICATION		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29	SITE NO.																			

DISTRICT ______ PREPAIRED BY ____________________ TEX-AN __________ SHEET _____ OF _____

Appendix B

Manual Method to Solve the Condensed Form, FHWA Traffic Noise Prediction Model

MANUAL METHOD
TO SOLVE THE
FHWA NOISE PREDICTION MODEL

Using a calculator with "Log" and "y^x" functions, the attached form allows the FHWA NOISE MODEL to be solved (except for barrier evaluations) for a hard or soft site and for a infinite or finite highway section. The formulas are arranged in the same order used to enter the functions into a calculator. For infinite sections, Item 4. is omitted except for the adjustment of -1.2 dB(A) for a soft site, infinite section. $\emptyset$ is the sum of $\emptyset_1$ and $\emptyset_2$ regardless of the sign of the angles. $\emptyset_1$ and $\emptyset_2$ (observing signs) are also used to obtain the soft site, infinite section adjustment from Graph A on the reverse side of the form. ND/S (Item 6) is used to obtain the L_{eq} and L_{10} adjustment from Graph B.

FHWA NOISE PREDICTION MODEL

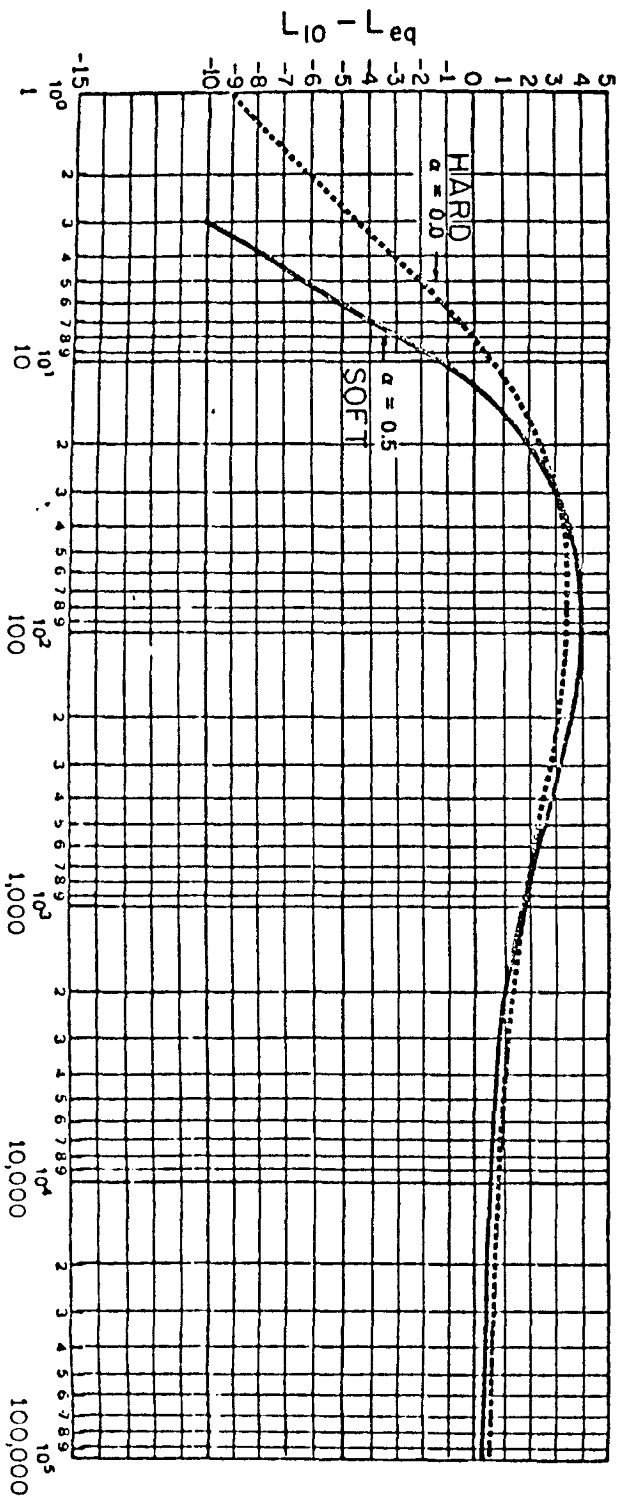
(MPH X 1.609 = KPH) USE METRIC UNITS (FEET X 0.305 = METRES)

HARD SITE	BOTH	SOFT SITE
1. A = +______ M = +______ H = +______	Emission Levels A = S Log x 38.1 - 2.4 M = S Log x 33.9 + 16.4 H = S Log x 24.6 + 38.5	A = +______ M = +______ H = +______
2. A = ______ M = ______ H = ______	Real Traffic Flows (add) 15xN÷S=Logx10-25=	A = ______ M = ______ H = ______
3. Distance Adjustment (Subtract) 15÷D=Logx10=-______	DATA Autos_____ Speed______ M.T.______ Dist.______ H.T.______	Distance Adjustment (Subtract) 15÷D=Logx15=-______
4. Finite Section (Substract) $\Delta\phi$÷180=Logx10=-_____ (Infinite Section = -0.0)	ϕ_1 = ______ ϕ_2 = ______ $\Delta\phi$ = ______	Finite Section (Substract) See Graph A = -_____ (Infinite Section = -1.2)

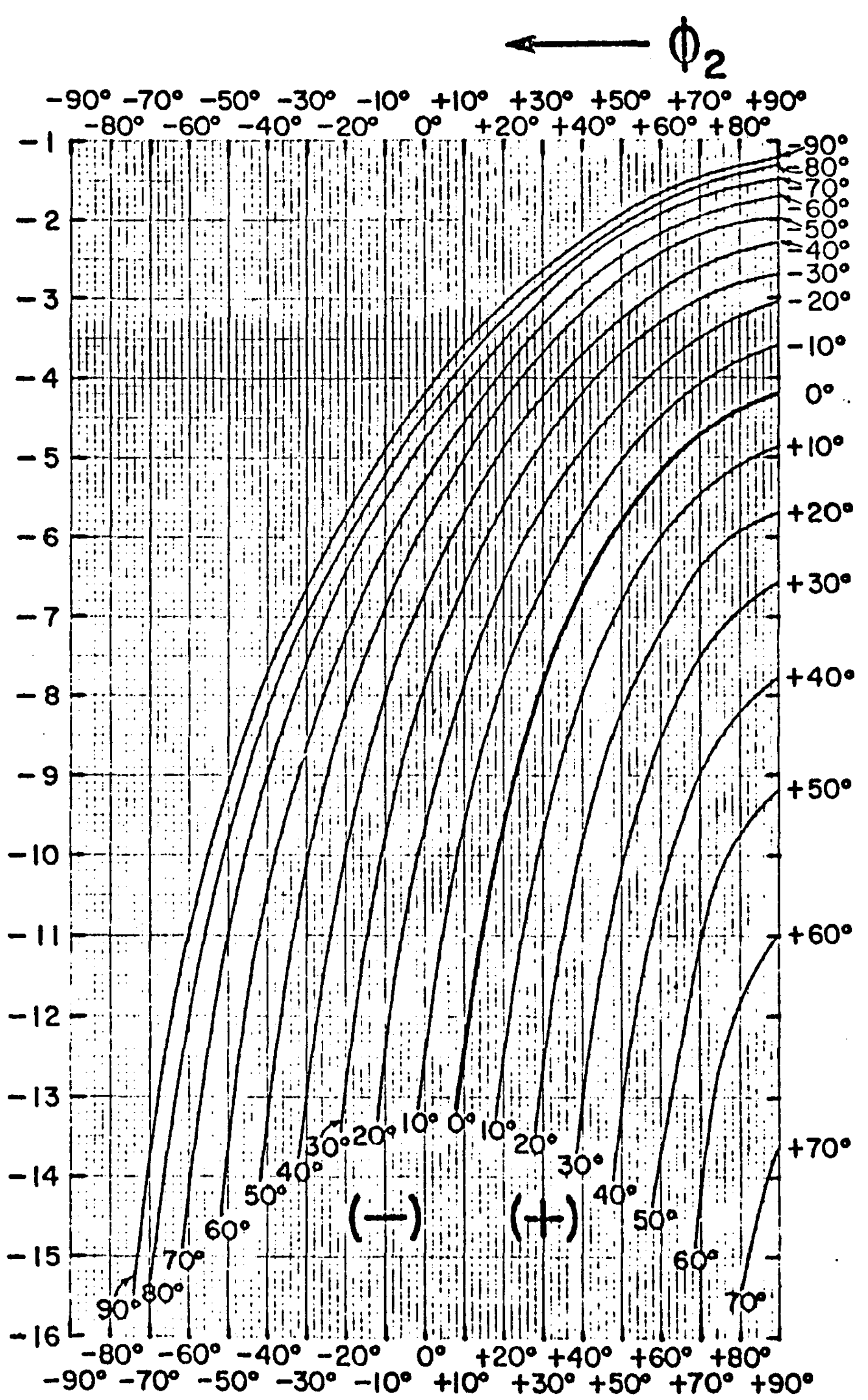
5. (Observe Sign) LEQ (Observe Sign)
1A +2A+ 3 + 4 = A = ______________ dBA = 1A +2A+ 3 + 4
1M +2M+ 3 + 4 = M = ______________ dBA = 1M +2M+ 3 + 4
1H +2H+ 3 + 4 = H = ______________ dBA = 1H +2H+ 3 + 4
* SUM = ______________ dBA (See 6. under "BOTH")

6. N X D ÷ S A = ______ M = ______ H = ______	*Sum=10Y^x $\left(\frac{dBA^A}{10}\right)$+10Y^x $\left(\frac{dBA^M}{10}\right)$ +10Y^x $\left(\frac{dBA^H}{10}\right)$= Log x 10 = __________dBA	N X D ÷ S A = ______ M = ______ H = ______
7. LEQ To L10 (add) See Graph B, dotted line (A) L10 - LEQ = ______ (M) L10 - LEQ = ______ (H) L10 - LEQ = ______		LEQ To L10 (add) See Graph B, solid line (A) L10 - LEQ = ______ (M) L10 - LEQ = ______ (H) L10 - LEQ = ______

8. (Observe Sign) L10 (Observe Sign)
5A + 7A = A = ______________ dBA = 5A + 7A
5M + 7M = M = ______________ dBA = 5M + 7M
5H + 7H = H = ______________ dBA = 5H + 7H
Answer *Sum = ______________ dBA (see 6. under "BOTH")



GRAPH B



ϕ_1	ϕ_2	$\psi_{1/2}$
-90°	+90°	-1.2
-80°	+80°	-1.4
-70°	+70°	-1.7
-60°	+60°	-2.2
-50°	+50°	-2.8
-40°	+40°	-3.7
-30°	+30°	-4.9
-20°	+20°	-6.6
-10°	+10°	-9.6

GRAPH A

FEDERAL-AID HIGHWAY PROGRAM MANUAL

VOLUME 7; CHAPTER 7; SECTION 3

[FHPM 7-7-3]

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

FEDERAL-AID HIGHWAY PROGRAM MANUAL

VOLUME	7	RIGHT-OF-WAY AND ENVIRONMENT
CHAPTER	7	ENVIRONMENT
SECTION	3	PROCEDURES FOR ABATEMENT OF HIGHWAY TRAFFIC NOISE AND CONSTRUCTION NOISE

Transmittal 348
August 9, 1982
HEV-30

1. PURPOSE. **To provide procedures for noise studies and noise abatement measures to help protect the public health and welfare, to supply noise abatement criteria, and to establish requirements for information to be given to local officials for use in the planning and design of highways approved pursuant to Title 23, United States Code (U.S.C.).*

2. AUTHORITY. *23 U.S.C. 109(h), 109(i); 42 U.S.C. 4331, 4332; and 49 CFR 1.48(b).*

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*Regulatory material is italicized and appears in the Federal Register under 23 CFR Part 772.

3. NOISE STANDARDS. *The highway traffic noise prediction requirements, noise analyses, noise abatement criteria, and requirements for informing local officials in this directive constitute the noise standards mandated by 23 U.S.C. 109(i). All highway projects which are developed in conformance with this directive shall be deemed to be in conformance with the Federal Highway Administration (FHWA) noise standards.*

4. DEFINITIONS

   a. *Design Year - the future year used to estimate the probable traffic volume for which a highway is designed. A time, 10 to 20 years, from the start of construction is usually used.*

   b. *Existing Noise Levels - the noise, resulting from the natural and mechanical sources and human activity, considered to be usually present in a particular area.*

   c. L_{10} *- the sound level that is exceeded 10 percent of the time (the 90th percentile) for the period under consideration.*

   d. $L_{10}(h)$ *- the hourly value of* L_{10}.

   e. *Leq - the equivalent steady-state sound level which in a stated period of time contains the same acoustic energy as the time-varying sound level during the same period.*

   f. *Leq(h) - the hourly value of Leq.*

   g. *Traffic Noise Impacts - impacts which occur when the predicted traffic noise levels approach or exceed the noise abatement criteria (Table 1), or when the predicted traffic noise levels substantially exceed the existing noise levels.*

   h. *Type I Projects - a proposed Federal or Federal-aid highway project for the construction of a highway on new location or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignment or increases the number of through-traffic lanes.*

   i. *Type II Projects - a proposed Federal or Federal-aid highway for noise abatement on an existing highway.*

5. APPLICABILITY

a. *Type I Projects. This directive applies to all Type I projects unless it is specifically indicated that a section applies only to Type II projects.*

b. *Type II Projects. The development and implementation of Type II projects are not mandatory requirements of 23 U.S.C. 109(i) and are, therefore, not required by this directive. When Type II projects are proposed for Federal-aid highway participation at the option of the highway agency, the provisions of paragraphs 6, 8, and 11 of this directive shall apply.*

6. ANALYSIS OF TRAFFIC NOISE IMPACTS AND ABATEMENT MEASURES

a. *The highway agency shall determine and analyze expected traffic noise impacts and alternative noise abatement measures to mitigate these impacts, giving weight to the benefits and cost of abatement, and to the overall social, economic and environmental effects.*

b. *The traffic noise analysis shall include the following for each alternative under detailed study:*

   (1) *identification of existing activities, developed lands, and undeveloped lands for which development is planned, designed and programmed, which may be affected by noise from the highway;*

   (2) *prediction of traffic noise levels;*

   (3) *determination of existing noise levels;*

   (4) *determination of traffic noise impacts; and*

   (5) *examination and evaluation of alternative noise abatement measures for reducing or eliminating the noise impacts.*

c. *Highway agencies proposing to use Federal-aid highway funds for Type II projects shall perform a noise analysis of sufficient scope to provide information needed to make the determination required by paragraph 8a of this directive.*

7. NOISE ABATEMENT

a. *In determining and abating traffic noise impacts, primary consideration is to be given to exterior areas. Abatement will usually be necessary only where frequent human use occurs and a lowered noise level would be of benefit.*

b. *In those situations where there are no exterior activities to be affected by the traffic noise, or where the exterior activities are far from or physically shielded from the roadway in a manner that prevents an impact on exterior activities, the interior criterion shall be used as the basis of determining noise impacts.*

c. *If a noise impact is identified, the abatement measures listed in paragraph 8c of this directive must be considered.*

d. *When noise abatement measures are being considered, every reasonable effort shall be made to obtain substantial noise reductions.*

e. *Before adoption of a final environmental impact statement or finding of no significant impact, the highway agency shall identify:*

   (1) *noise abatement measures which are reasonable and feasible and which are likely to be incorporated in the project, and*

   (2) *noise impacts for which no apparent solution is available.*

f. *The views of the impacted residents will be a major consideration in reaching a decision on the abatement measures to be provided.*

g. *The plans and specifications will not be approved by FHWA unless those noise abatement measures which are reasonable and feasible are incorporated into the plans and specifications to reduce or eliminate the noise impact on existing activities, developed lands, or undeveloped lands for which development is planned, designed, and programmed.*

8. FEDERAL PARTICIPATION

a. *Federal funds may be used for noise abatement measures where:*

(1) *a traffic noise impact has been identified,*

(2) *the noise abatement measures will reduce the traffic noise impact, and*

(3) *the overall noise abatement benefits are determined to outweigh the overall adverse social, economic, and environmental effects and the costs of the noise abatement measures.*

b. *For Type II projects, noise abatement measures will not normally be approved for those activities and land uses which come into existence after May 14, 1976. However, noise abatement measures may be approved for activities and land uses which come into existence after May 14, 1976, provided local authorities have taken measures to exercise land use control over the remaining undeveloped lands adjacent to highways in the local jurisdiction to prevent further development of incompatible activities.*

c. *The noise abatement measures listed below may be incorporated in Type I and Type II projects to reduce traffic noise impacts. The costs of such measures may be included in Federal-aid participating project costs with the Federal share being the same as that for the system on which the project is located, except that Interstate construction funds may only participate in Type I projects:*

(1) *traffic management measures (e.g., traffic control devices and signing for prohibition of certain vehicle types, time-use restrictions for certain vehicle types, modified speed limits, and exclusive land designations),*

(2) *alteration of horizontal and vertical alignments,*

(3) *acquisition of property rights (either in fee or lesser interest) for construction of noise barriers,*

(4) construction of noise barriers (including landscaping for esthetic purposes) whether within or outside the highway right-of-way. Interstate construction funds may not participate in landscaping,

(5) acquisition of real property or interests therein (predominately unimproved property) to serve as a buffer zone to preempt development which would be adversely impacted by traffic noise. This measure may be included in Type I projects only, and

(6) noise insulation of public use or nonprofit institutional structures.

d. There may be situations where (1) severe traffic noise impacts exist or are expected, and (2) the abatement measures listed above are physically infeasible or economically unreasonable. In these instances, noise abatement measures other than those listed in paragraph 8c of this directive may be proposed for Types I and II projects by the highway agency and approved by the Regional Federal Highway Administrator on a case-by-case basis when the conditions of paragraph 8a of this directive have been met.

9. INFORMATION FOR LOCAL OFFICIALS. *In an effort to prevent future traffic noise impacts on currently undeveloped lands, highway agencies shall inform local officials within whose jurisdiction the highway project is located of the following:*

a. The best estimation of future noise levels (for various distances from the highway improvement) for both developed and undeveloped lands or properties in the immediate vicinity of the project,

b. Information that may be useful to local communities to protect future land development from becoming incompatible with anticipated highway noise levels, and

c. eligibility for Federal-aid participation for Type II projects as described in paragraph 8b of this directive.

10. TRAFFIC NOISE PREDICTION

a. *Any traffic noise prediction method is approved for use in any noise analysis required by this directive if it generally meets the following two conditions:*

(1) *The methodology is consistent with the methodology in the FHWA Highway Traffic Noise Prediction Model (Report No. FHWA-RD-77-108).*

(2) *The prediction method uses noise emission levels obtained from one of the following:*

(a) *National Reference Energy Mean Emission Levels as a Function of Speed (Appendix A).*

(b) *Determination of reference energy mean emission levels in "Sound Procedures for Measuring Highway Noise: Final Report," Report No. DP-45-1R.*

b. *In predicting noise levels and assessing noise impacts, traffic characteristics which will yield the worst hourly traffic noise impact on a regular basis for the design year shall be used.*

11. CONSTRUCTION NOISE. *The following general steps are to be performed for all Types I and II projects:*

a. *Identify land uses or activities which may be affected by noise from construction of the project. The identification is to be performed during the project development studies.*

b. *Determine the measures which are needed in the plans and specifications to minimize or eliminate adverse construction noise impacts to the community. This determination shall include a weighing of the benefits achieved and the overall adverse social, economic, and environmental effects and the costs of the abatement measures.*

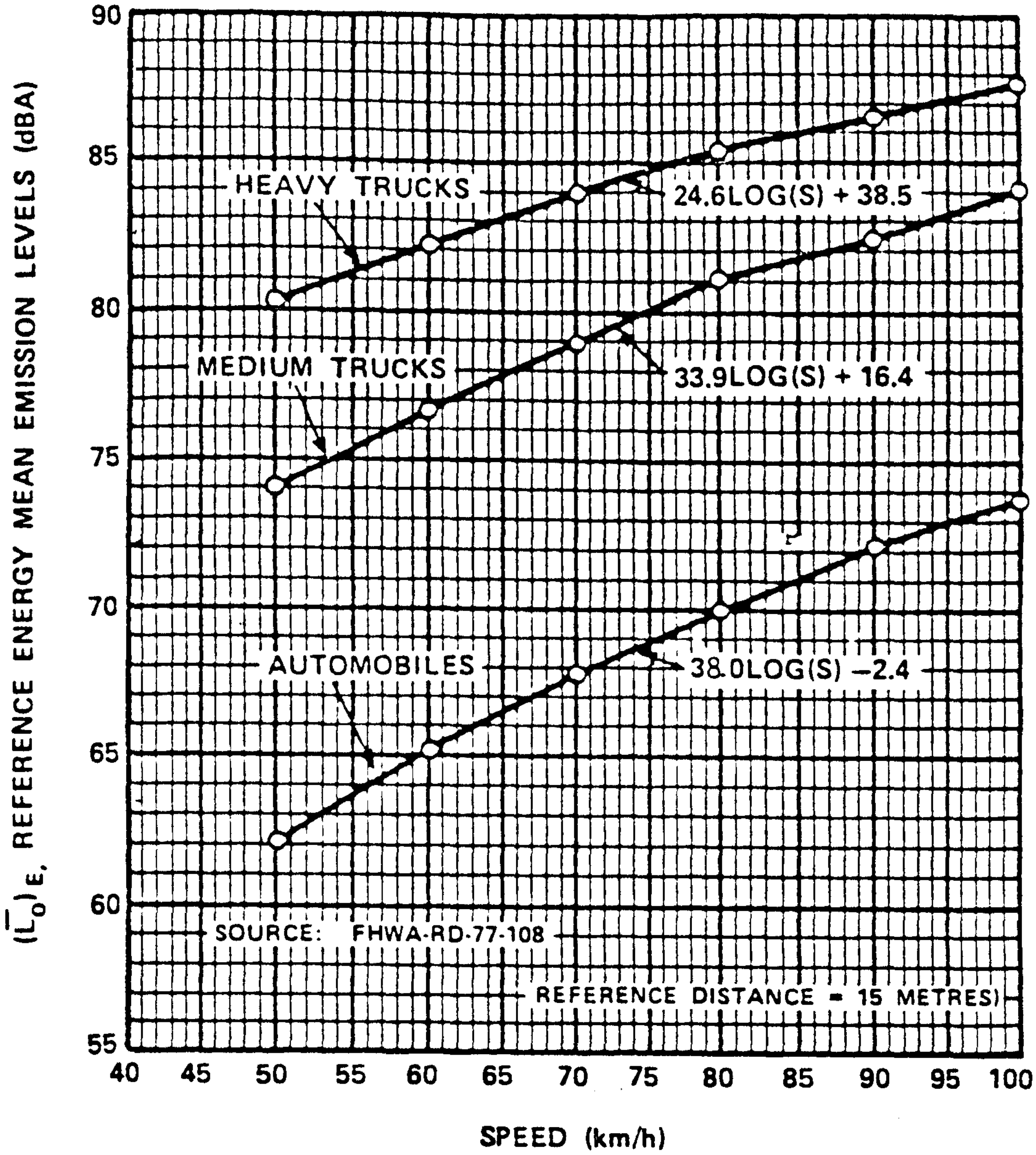
c. *Incorporate the needed abatement measures in the plans and specifications.*

TABLE 1 - Noise Abatement Criteria

Hourly A-Weighted Sound Level - decibels (dBA) 1/

Activity Category	Leq(h)	$L_{10}(h)$	Description of Activity Category
A	57 (Exterior)	60 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (Exterior)	70 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C	72 (Exterior)	75 (Exterior)	Developed lands, properties, or activities not included in Categories A or B above.
D	--	--	Undeveloped lands.
E	52 (Interior)	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

1/Either $L_{10}(h)$ or Leq(h) (but not both) may be used on a project.



LEGEND:

1. AUTOMOBILES: ALL VEHICLES WITH TWO AXLES AND FOUR WHEELS.
2. MEDIUM TRUCKS: ALL VEHICLES WITH TWO AXLES AND SIX WHEELS.
3. HEAVY TRUCKS: ALL VEHICLES WITH THREE OR MORE AXLES.

National Reference Energy Mean Emission Levels as a Function of Speed