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HIGHWAY NOISE

A DESIGN GUIDE FOR HIGHWAY ENGINEERS

by

B. Andrew Kugler
Colin G. Gordon
William J. Galloway

January 1970

Submitted to:
William L. Williams
Projects Engineer
Highway Research Board
2101 Constitution Avenue N. W.
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INTRODUCTION

How will the introduction of a new highway influence the noise environment? How acceptable will this new environment be to people living or working in the vicinity of the highway? What methods might be pursued to remove or reduce any adverse influence caused by the highway noise? The purpose of this design guide is to provide the highway designer with tools necessary to answer these questions.

The province of noise and the physics of acoustics lies somewhat outside the range of the highway engineers normal training and experience. For this reason, rather than provide an acoustical text book--which might confuse rather than help the engineer--we have attempted to develop a design "cookbook", hopefully in the best sense of the term. Our intention throughout this preparation has been to provide a tool which the designer with no experience in acoustics can use and use quickly and effectively. We hope that this intention has been achieved.

The format used in the guide is as follows:

Chapter 1 gives a glossary of definitions and symbols.

Chapter 2 introduces the reader to the basic concepts on which the noise prediction method used in this design guide is based. An understanding of these concepts is important if the design guide user is to make adequate decisions in using the guide. The chapter, first of all, introduces the basic parameters of environmental noise since these parameters are the ones which the design guide must set out to calculate. Then the analytical model which forms the heart of the calculation procedure is discussed. Finally some comments are presented concerning the response of people to noise environments.

Chapter 3 presents an overview of the methodology used. The parameters considered in a traffic situation are defined and the procedure involved in calculating an estimated noise level from a proposed highway discussed. Two methods of predicting noise levels are introduced: 1) Complete Method, and 2) Short Method.

Chapter 4 gives detailed step-by-step instructions for the complete method calculations. These instructions are paralleled by complete work sheets, figures and tables through which the user progresses to obtain finally estimated outside noise level for a particular roadway. These are presented in Appendices A and B.

Chapter 5 gives step-by-step instructions for the short method calculations.

Chapter 6 shows the procedure through which the estimated outside noise levels are interpreted in terms of design criteria. The criteria is based on both environmental utility, such as speech and sleep requirements, and environmental conservation. This is done for a variety of observer situations for both outside and inside conditions. In addition, the chapter presents a brief discussion of the expected impact on the community when the estimated levels exceed the design criteria.

CHAPTER 1 - GLOSSARY OF TERMINOLOGY

This chapter contains a glossary of the terminology used throughout the design guide. This glossary is divided in three main groups:

- Acoustical Terminology: Contains the definition of all terms that are acoustical in nature.

- Roadway Terminology: Contains the definitions associated with the roadway design and evaluation. These definitions, where possible, are consistent with the user in the Highway Capacity Manual 1965, Highway Research Board Special Report No. 87.

- Definition of Symbols: Contains the definition of all symbols used in the design guide.

ACOUSTICAL TERMINOLOGY

Ambient Noise Level - the noise level existing in an area before the proposed roadway. This quantity is measured in dBA and expressed as L_{10} or L_{50} ambient noise level depending on the time averaging used.

Audible Spectrum - the frequency range normally associated with human hearing. For noise control purposes, this range is usually taken to include frequencies between 20 Hz and 10,000 Hz.

Decibel (dB) - a logarithmic "unit" which indicates the ratio between two powers. A ratio of 10 in power corresponds to a difference in 10 decibels. The abbreviation for decibel is dB.

dBA* - the sound pressure levels in decibels measured with a frequency weighting network corresponding to the "A-scale" on a standard sound level meter. The A-scale tends to suppress lower frequencies, e.g., below 1000 Hz.

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* In interpreting traffic noise levels in dBA, one may note that a change of 10 dBA corresponds to a subjective judgment of the halving or doubling of the noisiness of the sound. In other words, a sound judged to be twice as noisy as another sound would have a sound pressure level rating approximately 10 dBA greater than the first sound. A sound 20 dBA greater than the first sound would generally be rated as four times as noisy as the first sound. On the other hand, a difference of 1 or 2 dBA between sounds, although detectable if heard within a short time interval, would not be judged as a very significant difference by most observers.

Frequency - the frequency of a sine wave of sound is the number of times it repeats itself in each second. The unit of frequency is called the hertz, abbreviated as "Hz", or the cycle per second.

Frequency Band - an interval of the frequency spectrum defined between an upper and lower "cut-off" frequency. The band may be described in terms of these two frequencies, or, preferably, by the width of the band and by the geometric mean frequency of the upper and lower cut-off frequencies, e.g., "an octave band centered at 500 Hz".

Hz - the abbreviation for frequency in Hertz.

Level - an adjective used to indicate that the quantity referred to is in the logarithmic notation of decibels, with a standardized reference quantity used as the denominator in the decibel ratio expression.

Reference Median Level - the L_{50} level measured 100 feet from the single lane equivalent roadway element with the element assumed infinitely long and located at grade on a flat level terrain.

Single Lane Equivalent - of a roadway is that single lane represent of the roadway which to the observer is acoustically similar to the real roadway.

Sound Level - a corruption of the term "sound pressure level".

L_{10} - sound level which is exceeded 10% of the time.

L_{50} - sound level which is exceeded 50% of the time.

Sound Pressure Level - the root-mean-square sound pressure, p, related in decibels to a reference pressure.

$$\text{sound pressure level} = 10 \log \frac{P^2}{P^2_{ref}}$$

where $P_{ref} = 0.0002$ microbar

Abbreviation: SPL. The value reads directly from a sound level meter.

ROADWAY TERMINOLOGY

At-Grade Roadway: When Roadway Element is level with the immediate surrounding terrain.

Automobiles: Defined as passenger vehicles other than motorcycles, trucks of less than 10,000 pounds gross vehicle weight, busses having capacity for 15 or less passengers.

Average Annual Daily Traffic (AADT): The total yearly volume divided by the number of days in the year.

Average Roadway Speed: The weighted average of the design speeds within a roadway section.

Barrier: Infinite or finite walls located near the roadway and parallel to it. Such walls must be solid and not undercut.

Capacity: Is the maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane during a given time period under prevailing traffic conditions.

Depressed Roadway: When Roadway Element is depressed below the immediate surrounding terrain.

Elevated Roadway: When Roadway Element is elevated above the immediate terrain.

Interrupted Flow: A condition in which a vehicle transversing a section of a lane or a roadway is required to stop by a cause outside of the traffic stream, such as signs or signals at an intersection or a junction. Stopage of vehicles by causes internal to the traffic stream does not constitute interrupted flow.

Normal Roadway: When Roadway Element surface is moderately rough asphalt or concrete surface.

Pavement: That part of the roadway having a constructed surface for the facilitation of vehicular movement.

Percent Gradient: Change in roadway elevation per 100 feet of roadway.

Roadway Element: A section of roadway with constant characteristics of geometry and vehicular operating conditions.

Finite Roadway Element: When roadway element starts and finishes within the 8 D_N limits of the roadway, where D_N is the observer-near lane distance (see Figure B.1).

Infinite Roadway Element: When roadway element length is larger than 8 D_N where D_N is the observer-near lane distance (see Figure B.1).

Semi-Infinite Roadway Element: When roadway element extends across 4 D_N in one direction but which terminates within the 8 D_N roadway length where D_N is the observer-near lane distance (see Figure B.1).

Roadway Surface: Determines the Roadway Surface characteristics (see Smooth, Normal or Rough Roadway).

Rough Roadway: When roadway element is rough, asphalt pavement with large voids 1/2" or larger in diameter or grooved concrete.

Shoulder: That portion of the roadway between the outer edge of the through traffic pavement or the curb or the point of intersection or the slope lines at the outer edge of the roadway and the fill, or median slope.

Smooth Roadway: When roadway element surface is very smooth, seal coated asphalt pavement.

Speed: The rate of movement of vehicular traffic expressed in miles per hour.

Traffic Lane: A strip of roadway intended to accommodate a single line of moving vehicles.

Trucks: Defined as trucks of over 10,000 pounds gross vehicle weight, busses having a capacity for more than 15 passengers.

Volume: The number of vehicles that pass over a given section of a lane or roadway during a time period of one hour or more. Volume can be expressed in terms of daily traffic or annual traffic as well as on an hourly basis.

DEFINITION OF SYMBOLS

A General Parameter

B General Parameter

C General Parameter

D Distance Parameter, measured between observer and nearest point to centerline of roadway (in feet).

D_B Distance Parameter measured between observer position and barrier - in feet (see Table A.7).

D_C Distance Parameter, measured between observer and cut of roadway - in feet (see Table A.6).

D_E Distance Parameter measured between observer and equivalent lane of roadway - in feet (see Figure B.1).

D_N Distance Parameter, measured between observer and center of near lane of roadway - in feet (see Figure B.1).

D_S Distance Parameter, measured between observer and shoulder of roadway - in feet (see Table A.6).

dB See acoustical terminology.

dBA See acoustical terminology.

H Height Parameter in feet.

L Length Parameter, measured along a roadway element (finite) - in feet.

L_{10} See acoustical terminology.

L_{50} See acoustical terminology

N Number of traffic lanes on Roadway.

P Width Parameter, measured from outside to outside lane on roadway in feet.

R_B Distance Parameter measured between equivalent lane and barrier - in feet (see Table A.7).

S Speed Parameter, measured as the average speed of vehicular flow in miles per hour.

S_A Speed Parameter, measured as above for automobiles.

S_T Speed Parameter measured as above for trucks.

V Vehicle Volume Parameter (in vehicles per hour), this represents the total volume of automobiles and trucks mixed.

V_A Vehicle Volume Parameter (in vehicles per hour) for automobiles only.

V_T Vehicle Volume Parameter (in vehicles per hour) for trucks only.

α Angle Parameter, measured as included angle between observer and barrier in degrees.

θ Angle Parameter, measured as included angle between observer and roadway element (finite) and complementary angle (semi infinite roadway) - in degrees.

CHAPTER 2 - BASIC CONCEPTS

In the following paragraphs some of the basic concepts and findings of the studies that have led to the development of this Design Guide are briefly discussed. It is felt that an appreciation of these will help the reader to use the guide more effectively and to bring good judgment to bear where judgment is necessary.

THE PARAMETERS OF ENVIRONMENTAL NOISE

The three dimensions of environmental noise which are of particular concern in determining subjective response are:

- The intensity or level of the sound.
- The frequency spectrum of the sound.
- The time varying character of the sound.

The first two of these dimensions are adequately handled in the case of traffic noise by measuring or calculating the sound in terms of the "A-Weighted" sound level. The A-Scale reading of a standard sound level meter provides a single number measure of the noise stimulus which "weights" the frequency spectrum of the signal in accordance with subjective sensitivity to sounds of different frequency. The A-Scale reading therefore (in dBA units, meaning decibels, A-scale) provides a measure of the level and spectrum of the stimulus which correlates well with subjective response to the stimulus.

The third dimension reflects the fact that environmental noise is rarely constant; it is changing from second to second, from minute to minute and from hour to hour. Road traffic is by far the most common source of environmental noise and environmental noise levels tend to follow closely traffic activity.

On the macroscopic time scale, therefore, environmental noise is highest during the day and especially during the morning and afternoon traffic peaks. Levels reach their lowest values during the night when local traffic activity all but ceases and arterial activity becomes small.

On the microscopic time scale, environmental noise follows the moment-to-moment details of traffic patterns. Such patterns are effectively random in time and thus the corresponding short term noise fluctuations are also randomly occuring.

Environmental noise level variations on the macroscopic time scale can be handled by analyzing the traffic flow situation at different time intervals during the 24 hour day. Such a procedure is convenient since the requirements that a person places upon his environment also changes from one time interval to another

Short term variations are most sensibly accounted for statistically. The "statistical time distribution" identifies each level within the environmental range with the percentage of time which that level, over the short term, is exceeded. The 50% level (or median level) is that level which is exceeded for 50% of the time. The 10% level is that level which is exceeded for 10% of the time.

These two descriptors of the "statistical time distribution", symbolised by L_{50} and L_{10} respectively, play an important role in this design guide.

PREDICTION OF TRAFFIC NOISE

SINGLE

The maximum noise emitted by an automobile as it passes an observer increases, approximately, with the third power of road speed. The noise output of a diesel truck, on the other hand, shows little dependence upon road speed. A truck, of course, is also very much noisier than an automobile. It is assumed in this design guide that the bulk of highway traffic can be classified into one or other of these two vehicle classifications. Appropriate definitions are given in the glossary.

Consider now a single lane pavement which is straight and infinitely long, and which lies at-grade with respect to a flat level terrain. The members of each vehicle classification are considered uniformly distributed along the lane and each vehicle classification is categorised by volume flow (vehicles/hour) and average (group) speed (miles/hour).

Analysis of this rather idealised system shows, when the density of vehicles per unit length is sufficiently high, that the sideline noise for the automobile population increases linearly with the volume flow and increases with the second power of average speed. Under the same conditions, on the other hand, the noise of the truck population increases linearly with the volume flow but decreases linearly with increase in average speed*.

* This apparent paradox is explained by the fact that the noise of an array of trucks is dependent only upon the density (in vehicles per mile) of the vehicles. For constant volume flow the density is inversely proportional to speed.

A further finding of the analysis is that sections of roadway which subtend equal angles at a fixed observer location, contribute equally to the observer's noise environment. Furthermore, the contribution is directly and linearly proportional to the angle subtended. Thus, the noise contribution of any finite element of roadway can be derived from the infinite roadway model.

Further, non-ideal, attributes of real roadway systems can be accommodated by adjustments to the finite roadway model.

- Any realistic number of lanes, with or without median separator, can be collectively grouped as an "equivalent" single lane provided that the lanes lie in the same horizontal plane and that they are not obstructed acoustically from each other. The appropriate adjustment is determined by the relation of the near-and-far-lane to the observer.

- Vertical translation of the roadway to an elevated or depressed position, with respect to the terrain, can also be accommodated if an adjustment is made to the predicted noise levels to account for the shielding effect imposed by the vertical displacement. The extent of shielding depends upon the extent to which the roadway configuration blocks the sightline between the observer and the equivalent single lane representative of the roadway.

A real roadway system, therefore, having the real attributes of curves, gradient changes, cross section changes, flow changes, etc. can be synthesised as a number of finite (or semi-infinite) discrete roadway elements. The noise of each element can be derived from the infinite roadway model with adjustments to account for each of these real attributes as will be shown in the following chapters.

REACTION TO ENVIRONMENTAL NOISE

The effects of noise on people can be listed in three general categories:

- Subjective effects of annoyance, nusiance, dissatisfaction.
- Interference with activities such as speech, sleep, learning.
- Physiological effects such as startle, hearing loss.

The noise levels associated with traffic noise are, in almost every case, of concern only in the first two categories. Unfortunately, there is no satisfactory objective measure of the subjective effects of noise. In laboratory evaluations it is possible to quantify the comparative subjective reactions between different sounds. However, no experiments yet provide an adequate absolute measure for subjective reaction. This result stems primarily from the wide variation in individual differences in thresholds of annoyance, habituation to noise over differing past experiences with noise, the semantic content conveyed by specific sounds, and the meaning of the source of noise itself.

In terms of task interference with speech or sleep, quantitive evaluations of criteria, while difficult, are more easily obtained. For example, much data exist concerning the effects of a steady masking noise on the intelligibility of speech in different environments or speech conditions. Data also exist on what noise levels are considered desirable in different speech environments. For example, continuous noise levels which should not be exceeded if adequate telephone use is to be expected or what levels of noise permit acceptable TV listening for most people. The effect on speech interference of noises which are intermittently higher than the average to which the listener is exposed is not yet well understood.

The effect of noise on sleep interference is more difficult to assess than the effect on speech interference. Study of sleep interference is difficult because of the different physiological states of sleep and the fact that sleep interference can exist without a person being consciously awakened. Recent experiments do provida guidelines, however, in considering sleep interference effects in the selection of design criteria for traffic noise.

Moving from laboratory data to the results of social surveys of traffic noise adds some insight in the development of criteria. These surveys help determine percentages of people having different responses to various noise sources. When examined against physical descriptions of the noise environment, information can be developed on at least the significant physical measures of noise which contribute to the variance in the general response of a community to noise. It is worth observing that physical descriptions alone generally account for less than half the components of variance in response to noise, with the other non-physical factors mentioned earlier often dominating.

Certain general factors may be deduced from the present body of laboratory and social survey studies:

- Interference with speech or TV listening is the predominant complaint against traffic noise.

- Interference with sleep is often cited as a complaint.

- Both a measure of the time-average noise level and measures of the magnitude and rate of occurences of peak noise levels are important in describing people's response to traffic noise.

On the basis of the above considerations, we have derived suggested design criteria for traffic noise indicated in Table B.5. These criteria specify maximum noise levels which would be considered by the average individual to be acceptable with respect to speech, radio and TV interference, sleep interference, and annoyance.

There are numerous existing situations where people are now living with traffic noise levels which are in excess of those specified in Table B.5. This is not to say that these noisy environments are entirely satisfactory, rather that people will either accept an unsatisfactory noise environment, move away from it, or attempt to bring legal action to reduce the noise. The design criteria presented are, on the other hand, higher in some instances then considered desirable by some public authorities. They are presented as realistic goals which people will find acceptable, even though lower levels might often be desired. We believe that exceeding these criteria by more than 5 dB will provide environments in which the majority of people would express a major dissatisfaction.

CHAPTER 3 - THE METHODOLOGY OF TRAFFIC NOISE PREDICTION

In the previous chapter some of the basic concepts involved in defining and analyzing the highway noise environment have been discussed. The intention in this present chapter is to describe in general terms the methodology used in the Design Guide.

The general traffic situation is composed of an infinity of variables; different cars driving at different speeds in other than plane surroundings. Obviously, to make the problem practicable, certain assumptions and simplifications must be made. This is done through a model of the traffic situation which defines the most important parameters involved and thus permits the prediction of the true situation with a certain degree of accuracy. The flow diagram illustrating the methodology is shown in Table 1 and is discussed below.

DEFINITION OF PARAMETERS

Consider a highway transversing a populated area. The simplest case would be to assume a perfectly flat and straight road of constant cross section, carrying a constant vehicle volume. Thus, observers at different positions along the highway, each at a distance of 400 feet would be subjected to the same, unchanging noise level. In this simple case, we

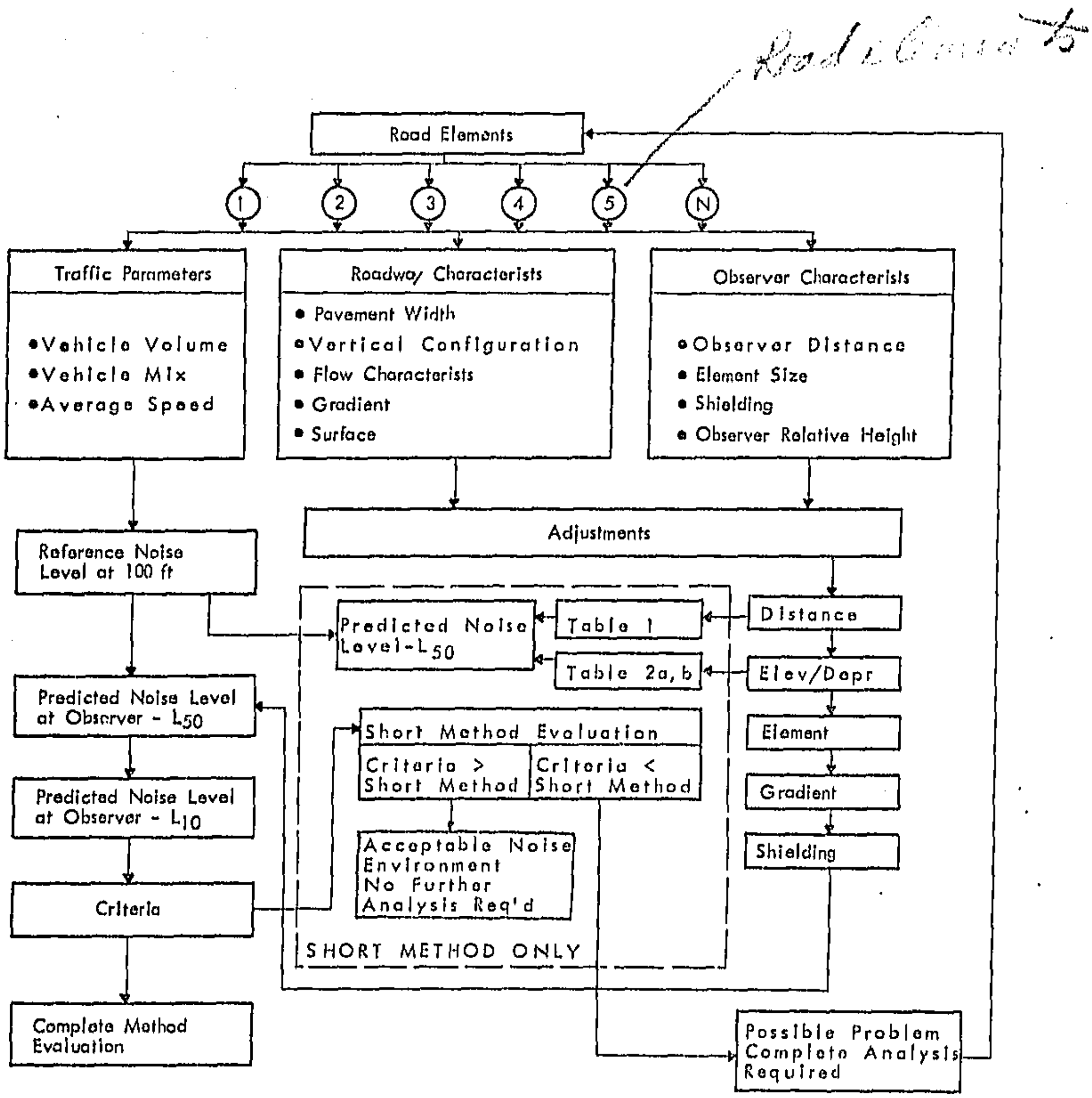


TABLE 1. FLOW DIAGRAM OF TRAFFIC NOISE METHODOLOGY

can define the highway as a constant infinite noise source. On the other hand, if the road geometry is not constant with respect to the observer (elevated or depressed sections, four lanes changing to two lanes, curves etc.) the infinite noise source model no longer is true and the geometry must be discretized into elements of constant characteristics. In reality, since we are dealing with a practical model, these constant characteristics are allowed to vary within certain practical limits; for example, continuous change in elevation of 5 feet over 1000 feet span can be neglected.

For the purposes of this present discussion, a road element is defined as that section of the road whose geometrical configuration (straight, level, constant cross section etc.) with respect to the observer and whose traffic density and speed over the element length can be considered constant. Table 1 shows that for a general case, N different road elements are possible.

Each road element identified can be described by a series of parameters that must be known or measured. These parameters can be grouped under three headings:

- Traffic Parameters

- Roadway Characteristics

- Observer Characteristics

The step-by-step method of obtaining these parameters is treated in detail in Chapter 4. Their role in the methodology of the Design Guide may be summarized as follows:

Traffic Parameters describe the "idealized" traffic situation on the road element. Vehicle Volume defines total number of vehicles that pass a point on the road element during one hour. Vehicle Mix describes the proportion of heavy trucks in the population. As discussed in Chapter 2, truck noise has different characteristics from automobile noise and must be treated separately. Average Speed describes the average speed of vehicles on the road element. Note that this parameter is especially important for automobiles since the noise emitted increases with the third power of speed, while it remains constant for trucks.

Roadway Characteristics are described by five parameters which define the geometry of the road element with respect to the immediate surroundings. Pavement Width defines the distance across the roadway. This distance does not include outside emergency lanes. Vertical Configuration describes the roadway elevation or depression with respect to the surrounding terrain. Flow Characteristics relate to flow interruption imposed by roadway design. Gradient defines the percent gradient of the roadway. Surface Characteristic describes the "roughness" of the pavement.

Observer Characteristics describe the location of the roadway element with respect to the observer and take account of the attenuating influence of the intervening terrain. Observer Distance defines the perpendicular distance between the observer and the roadway element. Element Size is defined by the angle subtended by the element at the observer. Shielding describes all acoustical shielding present between observer and road element. Observer Relative Height describes the observer vertical position with respect to the roadway.

PROCEDURE

These three groups of parameters must be known for each roadway element to predict the noise level for a single observer location. Consider again the example given earlier of a single roadway element, infinitely long and of constant characteristics located at-grade on a flat level terrain. Furthermore, let us locate the observer 100 feet from the road with no shielding present. This, for practical considerations is considered the "worst case" or the noisiest condition (obviously points closer to the road will be subjected to higher noise levels, but such points are seldom of interest). The noise level at 100 feet is called the Reference Noise Level. This reference noise level is measured as a median level, called L_{50} (the 50% level is that level which is exceeded for 50% of the time). Under the assumptions of our model, Reference Noise Levels can be obtained by knowing the Traffic Parameters only and will yield two numbers, one for automobiles and one for trucks, measured in dBA.

Deviations from this simple model will introduce parameters from the Roadway Characteristics and Observer Characteristics groups and will result in Adjustments to the Reference Noise Level. In most cases, these adjustments will be negative, thus providing attenuation to the Reference Noise Level. For instance, consider that the roadway of the example is now elevated above the surrounding terrain by a height H. The observer, standing below the level of the roadway is wholly or partially shielded from the vehicular noise sources depending upon the extent of elevation. Some attenuation of the radiated traffic noise is, therefore, imposed. A further adjustment will occur if the observer location with respect to the roadway is moved from 100 feet to 200 feet. Traffic noise levels, in general, decrease at a rate of between 3 and 6 dB for doubling of observer distance.

The model considered in this study, through the use of the defined parameters, allows for five types of adjustments for each road element as shown in Table 1. The Distance and Vertical Configuration adjustment are the most important of these in terms of frequency of occurance and model sensitivity.

For the general case then, each roadway element gives two reference noise levels (one for autos, one for trucks) based on the infinite element length assumption and using the traffic parameters. These reference noise levels for each element are then modified by the applicable adjustments and finally, the sum of all corrected noise levels (adding contributions from all road elements) yields the desired final noise level at the observer position.

CRITERIA AND RESPONSE

Once the expected noise level is computed at the observer location, its meaning must be evaluated in terms of some predetermined noise criteria. The criteria used in this guide are presented and discussed in Chapter 6. If on the basis of these criteria it appears that the proposed highway design will be undesirably noisy or cause significant community opposition, the highway engineer can reenter the Design Guide with highway modifications and reevaluate the situation.

COMPLETE AND SHORT METHODS

Chapters 4 and 5 present the complete and short noise prediction methods respectively. They are both presented schematically in Table 1.

The complete method uses all the parameters discussed in this chapter and applies them to compute a complete set of adjustments. Thus, under the restrictions of the model used in this study, this method represents the more exact solution. It precedes the short method in the guide because it is felt that an understanding of the complete method is necessary before the short method can be used.

The short method, shown green in Table 1, allows the designer to obtain a quick, first approximation to the expected noise levels. In general, this procedure will result in higher noise levels than the complete method.

If a potential high noise level is discovered, the complete solution should then be used to assess properly the magnitude of the problem, however, the method allows the designer to discard observer positions unaffected by the roadway resulting in considerable time savings. These savings result because only a limited amount of data is required and the calculations necessary to obtain the predicted noise levels are simplified by the use of tables.

CHAPTER 4 - COMPLETE METHOD

The complete method for estimating the noise generated by a roadway at a selected observer location is given in this chapter. A typical example is presented following the instructions to more fully illustrate the method. The method is divided in four main sections:

Section 1 - Roadway Element Identification: The roadway is separated into elements with constant characteristics, thus simplifying the analysis.

Section 2 - Traffic Parameters Identification: Parameters of speed and volume are computed thus describing the dynamics of the Roadway Elements.

Section 3 - Roadway Characteristics and Observer Characteristic Identification: The geometrical characteristics of each roadway element and the relationship of the observer and each roadway element are established.

Section 4 - Noise Levels Estimation: Given the descriptions from Sections 2 and 3 for each roadway element, this procedure shows how to calculate the desired Predicted Noise Levels for each element and finally how to combine them to obtain an overall noise level at the observer due to the entire roadway.

All Work Sheets used in this procedure are shown in Appendix A. All Figures and Tables used in this procedure are shown in Appendix B unless otherwise noted.

SECTION 1 - ROADWAY ELEMENT IDENTIFICATION

A roadway element is defined as that section of the roadway whose cross section and traffic flow characteristics can be considered constant and that can be analyzed directly by means of a straight infinite roadway noise model with a simple correction to allow for the angle subtended by the element at the observer.

In many real cases the highway engineer will be able to identify the roadway with a single, effectively infinite and straight, element. In other cases, however, analysis into two, three, or more elements will be required. The following rules and procedures are set forth to help the process of element identification.

In order to be defined as a roadway element a section of roadway must satisfy the following requirements:

- Firstly, all lanes within the element must meet the requirements for grouping together as a single equivalent traffic lane.

- In addition, over the length of the element the conditions of unchanging cross section, straightness, unchanging gradient and constant traffic operating conditions must be met.

1.0 WORK SHEET NO. 1 (See Table A.4): The conditions and requirements necessary to define the Roadway Elements are presented here in detail. The procedure is as follows:

1.1 On a route map of convenient scale select the observer location for which analysis is required.

1.2 Draw a line from this location to intersect the roadway at its nearest point, i.e. right angle intersect.

1.3 On either side of this intersect point mark off a length of roadway equal to four times the length of the observer-roadway intersect.

Note: The length of road just defined to all intents and purposes can be considered as infinitely long. Sections of road further removed from the intersect point can be neglected unless their configuration is such as to render them particularly noisy.

1.4 Examine the cross-section of the roadway at the intersect point to determine the number of different lane groupings required (in accordance with the rules in Work Sheet No. 1). Denote these A, B, C, etc., starting with the lane grouping nearest the observer.

Note: This lane grouping test simply allows for highway configurations having different pavement elevations in each direction of flow, or having an acoustically opaque median barrier or berm. The designer is <u>not</u> advised to take frontage roads into account at this time since it will unduly complicate the process of element identification.

1.5 Study each lane grouping along its length with regard to significant changes in alinement (curves), section, gradient or flow as defined in the work sheet. Identify by checking the appropriate box in the table.

1.6 Following the conditions set forth in the work sheet identify and number those elements pertinent to each lane grouping. Enter and describe these in the second table on the work sheet.

Note: Elements which run the total length (8D) of the roadway section are termed Infinite Elements. Elements which extend across the 4D limit in one direction but which terminate within the 8D roadway length are termed Semi-Infinite Elements. Elements which start and finish within the 8D limits of the roadway are termed Finite Elements. These three element classifications are numbered I, II, III respectively.

1.7 On the same table note the position parameters that each element bears to the observer, as illustrated in Figure B.1. Note also the total pavement width (P) and the number of lanes appropriate to each.

- Observer-Near Lane Distance (D_N). Measured along the right angle intercept between the observer and the center of the near lane.

- Element Length (L). This distance represents the length of the Roadway Element and must be measured in the Finite Element Case only.

- Angle θ. This angle represents the included angle between observer and element in the Finite Element Case and the included angle between observer and the Semi-Infinite

Element as shown in figure B.1. (This angle can be positive or negative.) Note that both angles are measured to the middle of the roadway.

1.8 Identify and describe any other roadway elements that you may wish to include at this time--parts of access ramps for instance. Identify each of these as a further lane grouping (D, E, etc.) and follow the general procedure of Steps 1.6 and 1.7.

RULES FOR ELEMENT IDENTIFICATION

LANE GROUPINGS: In order to permit lane grouping within a single element the following conditions must apply:

- All lanes must lie at the same elevation with respect to the terrain.

- Lane and median separators must not shield lanes acoustically from each other.

- Vehicle operating conditions must be broadly similar for each lane.

(Most roadways satisfy these conditions and consequently all roadway lanes can be accommodated within a single element.

In general, however, these conditions do not permit frontage roads and ramps to be included with the main highway configuration.)

ALINEMENT (CURVES): In order to satisfy the requirements of a single element definition the element must be effectively straight. The following rules apply:

- Stretches of road separated by curves must in general be regarded as separate elements.
- When the ratio of curve radius to observer distance exceeds ten and when the observer lies within the triangle formed by the normal intersects of the roadway at the curve tangency points, the curve itself should be represented by a straight element to provide a "best fit" representation of the curve.
- A roadway having double or multiple curves can be represented a "best fit" straight roadway as long as deviations from this representation do not exceed ±20% of the mean observer-roadway distance.

GRADIENTS: In order to satisfy the requirements of a single element definition the element must not contain a change in roadway gradient of greater than 2%

CROSS SECTION: In order to satisfy the requirements of a single element definition the cross section along the length of the element must be effectively unchanging. Significant changes are defined as follows:

- A change in the differential in roadway elevation with respect to the terrain (parameter H for elevated and depressed) of more than ±10% about the mid-point value.

- A change in total roadway width (including median strip) of more than ±25% about the mid-point value.

- A change, on the observer side of the roadway cut distance or the roadway shoulder distance, for depressed and elevated configurations respectively, of more than ±25% about the mid-point value.

An exception to this requirement is the transition length of roadway between different roadway elevations e.g.; between elevated and at-grade configurations. For such transitions the following rules apply:

- A transition section of roadway between an elevated and at-grade configuration or between a depressed and at-grade configuration is defined as having constant cross-section with a geometry corresponding to that of the mid-point of the transition.

- A transition section of roadway between an elevated and depressed configuration, i.e. a transition which passes through at-grade, is considered as two transitions each of them going to grade. Each of these transitions is analysed as above.

TRAFFIC FLOW: In order to satisfy the requirements of a single element definition the traffic flow conditions along the length of the element must be effectively constant. Significant changes are defined as follows:

- A flow volume change of ±10%.

- An average speed change of ±10%.

A change from uninterrupted to interrupted flow conditions.

With regard to the last item, interrupted flow imposed by a traffic control signal is assumed to have an influence on the operating noise of a vehicle over a distance of 1000 feet centered at the center of the signal area. This length would therefore define the element length.

Note: In principle at least the highway engineer may thus develop noise estimates for complex roadway systems involving interchange and access ramps, intersections, frontage roads etc. If too many elements are identified at one time, however, the procedure may become very laborious. It is suggested that the user use judgement in determining those sections of road and groupings of lanes which will influence the noise environment.

2.0 Enter Roadway Elements defined on Work Sheet No. 1 on "Parameter Work Sheet" (see Table A.1) in the columns provided, one element per column, by noting:

- The Road Element Number
- The Roadway Element Type
- The applicable Time Interval of interest

Note: The "Parameter Work Sheet" can be used to handle several Roadway Elements at one Time Interval, or one Roadway Element at several different Time Intervals.

SECTION 2 - TRAFFIC PARAMETER IDENTIFICATION

This section describes the procedure for Traffic Parameter Identification. It covers Lines 1 and 2 on "Parameter Work Sheet". The procedure is as follows:

1.0 VEHICLE OPERATING CONDITIONS: Determine the Vehicle Operating Conditions for each Roadway Element at the required Time Interval and enter in Lines 1 and 2 on "Parameter Work Sheet". The Vehicle Operating Conditions are:

- The Hourly Volume (V) in vehicles per hour.

- The Average Speed (S) in miles per hour.

These parameters are required separately for two categories of motor vehicles; automobiles and trucks as defined in Chapter I.

In the event that these parameters must be computed from estimates of AADT and of percentage flow and mix variations during the day, Work Sheet No. 2 (see Table A.5) is provided.

2.0 WORK SHEET NO. 2: For each Roadway Element identified and defined in Work Sheet No. 1:

2.1 Enter Estimated AADT in Line 1.

2.2 Enter the Hourly Volume, for the required Time Interval as a percentage of AADT, in Line 2. (In the event that this is unknown, illustrative data from the Highway Capacity Manual is given in Appendix C Figure C.1.)

2.3 Enter the Vehicle volume (V) in vehicles per hour in Line 3. This is obtained by multiplying Line 1 by Line 2 and dividing by 100.

2.4 Enter Truck to Auto Mix in percentage of vehicle volume in Line 4. (In the event that this is unknown, illustrative data from the Highway Capacity Manual is given in Appendix C Figure C.2.)

2.5 Enter Truck Volume (in vehicles per hour) in Line 5. This is obtained by multiplying Line 3 by Line 4 and dividing by 100.

2.6 Enter Auto Vŏlume in vehicles per hour in Line 6. This is obtained by subtracting Line 5 from Line 3.

2.7 Enter expected Average Truck Speed (in miles per hour) in Line 7 and the Average Auto Speed in Line 8.

Note: The noisiest flow condition will occur under the condition of the highest stable volume flow at the highest expected average speed. The capacity chart of Figure C.3, (Appendix C) for instance, would suggest that the highest noise condition on a highway designed for an Average Highway Speed of 70 mph, would occur with a lane volume close to 2000 vph at an average speed of 45 mph.

2.8 Enter Lines 5 and 6 from Work Sheet No. 2 in Line 1b and 1a in "Parameter Work Sheet", respectively.

Enter Lines 7 and 8 from Work Sheet No. 2 on Line 2b and 2a in "Parameter Work Sheet", respectively.

SECTION 3 - ROADWAY AND OBSERVER CHARACTERISTICS IDENTIFICATION

This section describes the procedure for Roadway and Observer Characteristics Identification and it covers lines 3 through 10 on the "Parameter Work Sheet".

1.0 FLOW CHARACTERISTICS: Note the Flow Characteristics of each Roadway Element by checking either the 3a or 3b Line on "Parameter Work Sheet".

- Interrupted Flow is defined as the vehicle flow interrupted by an outside source such as stop signs, traffic light, etc. Slowdown or stop due to heavy traffic, accident, etc. is not an outside source.

2.0 PAVEMENT CHARACTERISTICS: Measure the Pavement Characteristics for each Roadway Element and enter in Lines 4a and 4b on "Parameter Work Sheet". This data may be transferred from Work Sheet No. 1.

3.0 PERCENTAGE GRADIENT: Establish the Percentage Gradient for each Roadway Element and enter in Line 5 on "Parameter Work Sheet".

- Percentage Gradient is defined as the change in roadway elevation measured in feet per 100 feet of roadway. Note that a Percentage Gradient <2% is considered insignificant and noted as 0%.

4.0 VERTICAL CONFIGURATION: Determine the form of Vertical Configuration for each Roadway Element and check the appropriate line on "Parameter Work Sheet".

- Elevated: When Roadway Element is elevated above the immediate surrounding terrain.

- Depressed: When Roadway Element is depressed below the immediate surrounding terrain (cut).

- At-Grade: When Roadway Element is level with the immediate surrounding terrain.

5.0 ROADWAY SURFACE: Determine the Roadway Surface characteristics for each Roadway Element and check the appropriate line on the "Parameter Work Sheet".

- Smooth: Very smooth, seal coated asphalt pavement.

- Normal: Moderately rough asphalt and concrete surface.

- Rough: Rough asphalt pavement with large voids 1/2" or larger in diameter, grooved concrete.

6.0 POSITION PARAMETERS: Enter the Position Parameters from Work Sheet No. 1 for each Roadway Element. Evaluate and note the Observer-Equivalent Lane Distance D_E, using Figure B.2.

7.0 SHIELDING CHARACTERISTICS: Determine the Shielding Characteristics between the observer and each Roadway Element and check the appropriate line as follows:

- Barriers: Defined as infinite or finite barriers and walls generally located near the roadway and parallel to it.

- Buildings: This category includes residential, commercial and industrial buildings that may wholly or partially shield the roadway from the observer.

- Others: This category includes all other shielding effects such as trees, vegetation, etc. Terrain effects are not included.

- None: When no shielding is present.

8.0 TERRAIN CHARACTERISTICS: Determine the Terrain Characteristics at the Observer by noting the observer elevation relative to the ground elevation at the roadway and enter in Line 10 on "Parameter Work Sheet".

SECTION 4 - NOISE LEVEL ESTIMATION

This section describes the procedure to obtain the Estimated Noise Levels at the observer due to the proposed highway using the data from the above sections.

1.0 REFERENCE L_{50} AT 100 FEET: Determine the Reference L_{50} Levels at 100 feet for both autos and trucks using Figures B.3 and B.4 and enter on Line 1 on "Noise Prediction Work Sheet" (see Table A.2). These levels are obtained as follows:

- Automobiles: Using Vehicle Volume, V_A (Line 1a on "Parameter Work Sheet") enter Figure B.3 and read the corresponding Sound Level in dBA.

- Trucks: Using Vehicle Volume, V_T, and Average Speed, S_T, enter Figure B.4 and read the corresponding sound level in dBA.

2.0 DISTANCE ADJUSTMENT (Δ_1): The distance adjustment to account for Observer - Near Lane Distance and the Width of Roadway Element must be determined for each Roadway Element and entered in Line 2. This adjustment is the <u>same</u> for autos and trucks and is obtained as follows:

- Using Near Lane Distance, D_N (Line 8a on "Parameter Work Sheet") and Roadway Element Width, P (Line 4a on "Parameter Work Sheet") enter Figure B.5 and read the Adjustment in dB.

3.0 ELEMENT ADJUSTMENT (Δ_2): Determine the Element Adjustment for each Roadway Element and enter in Line 3 on "Noise Prediction Work Sheet". This adjustment is applicable to the Semi-Infinite Roadway Element and Finite Roadway Element only. For the Infinite Roadway Element enter zero on Line 3.

- Semi-Infinite Element: Using the angle θ (Line 8d on "Parameter Work Sheet") enter Figure B.6 and read the appropriate adjustment in dB. The same adjustment applies for autos and trucks.

- Finite Element: Using the angle θ (Line 8d on "Parameter Work Sheet") enter Figure B.7 and read the appropriate adjustment in dB. The same adjustment applies for autos and trucks.

4.0 GRADIENT ADJUSTMENT (Δ_3): The Gradient Adjustment applies only for trucks and should be determined whenever the gradient is greater than 2% (see Line 5 on "Parameter Work Sheet"). The appropriate adjustment is obtained from Table B.1. Enter adjustment on Line 4 on "Noise Prediction Work Sheet" under Truck.

5.0 VERTICAL ADJUSTMENT (Δ_4): Determine the Vertical Adjustment for each Roadway Element and enter in Line 5 of "Noise Prediction Work Sheet". This adjustment is zero for an <u>at-grade</u> road configuration, otherwise go to procedure on Work Sheet No. 3 (see Table A.6).

6.0 WORK SHEET NO. 3: The procedure for estimating the Adjustment due to Vertical Configuration is as follows for each element:

6.1 Enter Roadway Elements defined on Work Sheet No. 1.

6.2 For an elevated road configuration, proceed through steps 6.4 through 6.10.

6.3 For a depressed road configuration proceed through steps 6.11 through 6.17.

6.4 Enter height of Elevated Roadway, H_1, in feet in Line 1.

Note: For an elevated roadway, H_1, is defined as the height of the roadway element above the observer. If the observer is above the roadway elevation, then this is considered an at-grade situation and no vertical adjustment is necessary.

6.5 Enter Observer-Equivalent Lane Distance, D_E, in Line 2 (see Line 8b of "Parameter Work Sheet").

6.6 Enter Observer-Shoulder Distance, D_S, in Line 3.

6.7 Compute parameter $A = H_1^2/D_S$ and enter in Line 4.

6.8 Compute parameter $B = H_1^2/(D_E - D_S)$ and enter in Line 5.

6.9 Using Parameters A and B, enter Figure B.8 and read the appropriate adjustment for Elevated Roadway. Enter on Line 11a.

6.10 To obtain the adjustment for trucks, add +5 dB to Line 11a and enter on Line 11b. (Note: the numerical value of the truck adjustment is <u>smaller</u> than that for autos but it can never be positive.)

6.11 Enter Depth of Depressed Roadway, H_2 in feet on Line 6.

6.12 Same as 6.5. Enter on Line 7.

6.13 Enter Observer - Cut Distance D_C on Line 8.

6.14 Compute Parameter $A = H_2^2/(D_E - D_C)$ and enter on Line 9.

6.15 Compute Parameter $B = H_2^2/D_C$ and enter on Line 10.

6.16 Using Parameters A and B enter Figure B.8 and read appropriate adjustment for Depressed Roadway. Enter in Line 12a.

6.17 Same as 6.10 and enter in Line 12b.

7.0 SURFACE ADJUSTMENT (Δ_S): Determine the Surface Adjustment for each Roadway Element and enter in Line 6 in "Noise Prediction Work Sheet". This adjustment is obtained from Table B.2 using the Road Surface classification from Line 7 of "Parameter Work Sheet".

8.0 SHIELDING ADJUSTMENT (Δ_6 AND Δ_7): Determine the Shielding Adjustments for each Roadway Element and enter in Line 7a or 7b of "Noise Prediction Work Sheet" as follows:

- If Line 9d on "Parameter Work Sheet" is checked, then the shielding adjustment is zero. Proceed to section 10.0.

- Otherwise go to procedure on Work Sheet No. 4.

9.0 WORK SHEET NO. 4: The procedure for estimating Shielding Adjustments due to barriers, buildings and other effects is as follows for each element:

9.1 Enter Roadway Elements defined on Work Sheet No. 1.

9.2 If Line 9a on "Parameter Work Sheet" is checked, then proceed to section 9.4 through 9.10.

9.3 If Line 9b or/and 9c on the "Parameter Work Sheet" is checked, then proceed to section 9.11 through 9.13.

9.4 Enter Height of Barrier (H), in feet, in Line 1.

9.5 Enter Observer-Barrier Distance (D_B) in feet, in Line 2.

9.6 Enter Equivalent Lane-Barrier Distance (R_B), in feet, in Line 3, where $R_B = (D_E - D_B)$.

9.7 Compute the ratios H^2/D_B and H^2/R_B and enter in Lines 4 and 5 respectively.

9.8 Using these ratios, enter Figure B.9 and read the appropriate adjustment for an Infinite Barrier and enter in Line 6.

9.9 Depending on the Roadway Element type considered, do one of the following:

- For a Finite Roadway Element proceed to section 9.9.1 through 9.9.4.

- For Semi-Infinite Roadway Element proceed to Section 9.9.5 through 9.9.8.

- For Infinite Roadway Element proceed to Section 9.9.9 through 9.9.11.

9.9.1 Enter Included Element Angle θ on Line 7. This is obtained from Line 8d on "Parameter Work Sheet".

9.9.2 Enter Included Barrier Angle α on Line 8. This angle represents the included angle between observer and barrier.

9.9.3 Compute the Parameter $A= \frac{\alpha}{\theta}$ and enter in Line 9.

9.9.4 Using Parameter A and the Infinite Barrier Adjustment (Line 6) enter Figure B.9 and read the appropriate adjustment for a finite barrier. Note that the adjustments are given for only three values of Infinite Barrier. Select the closest value to the one calculated in Line 6. Enter this adjustment on Line 10. Go to Section 9.10.

9.9.5 Enter Included Element angle θ on Line 11. This is obtained from Line 8d on "Parameter Work Sheet".

9.9.6 Enter Included Barrier Angle α on Line 12. This angle represents the included angle between the observer and barrier.

9.9.7 Compute the Parameter $A= \frac{\alpha}{90-\theta}$ and enter in Line 13.

9.9.8 Using Parameter A and the Infinite Barrier Adjustment (Line 6) enter Figure B.9 and read the appropriate adjustment for a finite barrier. Note that the adjustments are given for only three values of the Infinite Barrier. Select the closest value to the one calculated in Line 6. Enter this adjustment in Line 14. Go to Section 9.10.

9.9.9 Enter Included Barrier Angle α on Line 15. This angle represents the included angle between observer and barrier.

9.9.10 Compute the Parameter $A = \alpha/180$ and enter in Line 16.

9.9.11 Using Parameter A and the Infinite Barrier Adjustment (Line 6) enter Figure B.9 and read the appropriate adjustment for a finite barrier. Note that the adjustments are given for only three values of Infinite Barrier. Select the closest value to the one calculated in Line 6. Enter this adjustment in Line 17.

9.10 Enter the Finite Barrier Adjustment in Line 7a of the "Noise Prediction Work Sheet". Note that the algebraic addition of the Vertical Adjustment (Δ_4) Line 5 and the

Barrier Adjustment (Δ_6) Line 7a should <u>not</u> exceed -15 dB. ($\Delta_4+\Delta_6$>-15 dB)

9.11 Multiple rows of intervening buildings and structures, such as houses, apartments, etc. will reduce levels by up to 10 dB depending upon the degree of shielding provided. A single row of houses between the roadway element and the observer will generally reduce levels by approximately 5 dB. Enter the assumed adjustment in Line 18 on Work Sheet No. 4. Note that this adjustment is always negative.

9.12 A design value of 5 dB noise reduction for every 100 feet of foliage between observer and roadway element may be used if the trees are at least 15 feet tall and sufficiently dense so that no visual path between them and the roadway exists. The total adjustment should not exceed 10 dB. Enter the assumed adjustment in Line 19 on Work Sheet No. 4. Note that this adjustment is always negative.

9.13 Add the adjustments of Line 18 and 19 and enter in Line 20. Enter this adjustment on Line 7b on "Noise Prediction Work Sheet".

10.0 L_{50} AT OBSERVER: Determine the L_{50} Level at the observer for each Roadway Element and enter on Line 9 on "Noise Prediction Work Sheet". This is obtained by algebraic addition of Lines 1 and 7.

11.0 L_{10}-L_{50} ADJUSTMENT: Determine the L_{10} adjustment for each Roadway Element and enter in Line 10 on "Noise Prediction Work Sheet". This is obtained by using Work Sheet No. 5 (see Table A.8) and the following procedure.

12.0 WORK SHEET NO. 5: The procedure for estimating the L_{10} Adjustment is as follows for each element.

12.1 Enter Roadway Elements defined on Work Sheet No. 1.

12.2 Enter Hourly Volume (V) in Line 1. This is obtained from Lines 1a and 1b on "Parameter Work Sheet" for autos and trucks respectively.

12.3 Enter Average Speed (S) in Line 2. This is obtained from Lines 2a and 2b on "Parameter Work Sheet" for autos and trucks respectively.

12.4 Enter Observer-Equivalent Lane Distance D_E in Line 3. This is obtained from Line 8b on "Parameter Work Sheet".

12.5 Calculate Parameter $A = V D_E/S$, and enter in Line 4.

12.6 Using Parameter A, enter Figure B.10 and read appropriate Adjustment in dB. Enter on Line 5.

13.0 INTERRUPTED FLOW ADJUSTMENT: Determine the interrupted flow adjustment for each Roadway Element and enter in Line 11 on "Noise Prediction Work Sheet". This adjustment applies <u>only</u> if Line 3b on "Parameter Work Sheet" is checked. The adjustment is obtained from Table B.3.

14.0 L_{10} AT OBSERVER: Determine the L_{10} Levels for each Roadway Element and enter in Line 12 on "Noise Prediction Work Sheet". This is obtained by algebraic addition of Lines 9, 10 and 11.

15.0 ELEMENT TOTAL: Determine the Element Total for each Roadway Element and enter in Line 13. This is obtained for both the L_{50} and L_{10} Levels by adding the levels for automobiles and trucks. The procedure for adding decibel levels is presented in Work Sheet No. 6. (A sample calculation is shown in Table B.4.)

16.0 GRAND TOTAL: Determine the Grand Total L_{50} Predicted Noise Levels by adding the contributions from all roadway elements and enter in Line 14. Do same for L_{10} Predicted Noise Levels. Again follow the procedure in Work Sheet No. 6.

17.0 L_{10}-L_{50}: Determine the L_{10}-L_{50} Predicted Noise Level and enter in Line 15 of Noise Prediction Work Sheet. This is obtained by algebraic difference of the grand total L_{10} and L_{50} Levels.

ILLUSTRATIVE EXAMPLE

To more fully illustrate the above procedure, a typical example is presented and solved in full. This same example is later solved using the short method in Chapter 5. Consider a roadway configuration as shown below in Figure 1. The observer is located in a classroom, 400 feet from the nearest lane of the roadway. At the time of interest, 8-10 a.m., the average speed of traffic flow is estimated to be 55 mph with a truck/auto mix of 5%. In addition, it is estimated that the Average Annual Daily Traffic (AADT) is 49,000 vehicles per day of which 7% per hour will pass between 8-10 a.m. The problem is to calculate both the L_{50} and the L_{10} Predicted Noise Levels using the complete method. The first task in the procedure is the roadway element identification. Using Work Sheet No. 1 (see Table 2) we note that according to the rules,

AADT

there is only one lane grouping, in this case, eight lanes of traffic with a 20 foot median strip, but that a single infinite roadway element cannot be assumed since there is both alignment and cross sectional changes. Using the procedure of Section 1, three roadway elements are identified as shown in Figure 2 and Table 2. They are:

- Element 1 is a Semi-Infinite type, and is represented by the ag-grade crossection No. 1.

- Element 2 is a Finite Element type and is represented by depressed crossection 2.

- Element 3 is a Semi-Infinite type and is represented by depressed cross section 3.

With the road elements identified, the procedure for Traffic Parameters, Roadway Characteristics and Observer Characteristics Identification is used to obtain all the necessary parameters and complete the "Parameter Work Sheet" Table 4. The Reference Noise Levels and the necessary adjustments are found by following the Noise Level Estimation procedure. The results are shown on the "Noise Prediction Work Sheet" Table 4. Note that the vertical adjustment for roadway element No.1

is zero since we have an at-grade condition, however, roadway element No. 2 is depressed and the vertical adjustment for trucks is also zero. This result is easily explained by following the procedure for Work Sheet No. 3 (see Table 6). Note that the depression depth is only 5 feet, thus in reality the trucks whose noise source (mainly the exhaust stack and engine) is elevated are not shielded from the observer. Table 8 shows the L_{10} adjustment.

The final L_{50} and L_{10} Noise Levels are shown to be 60 dBA and 62 dBA respectively. This is shown on Tables 9 and 10 respectively. The meaning of these levels as compared against the N ise Criterion is discussed in Chapter 6.

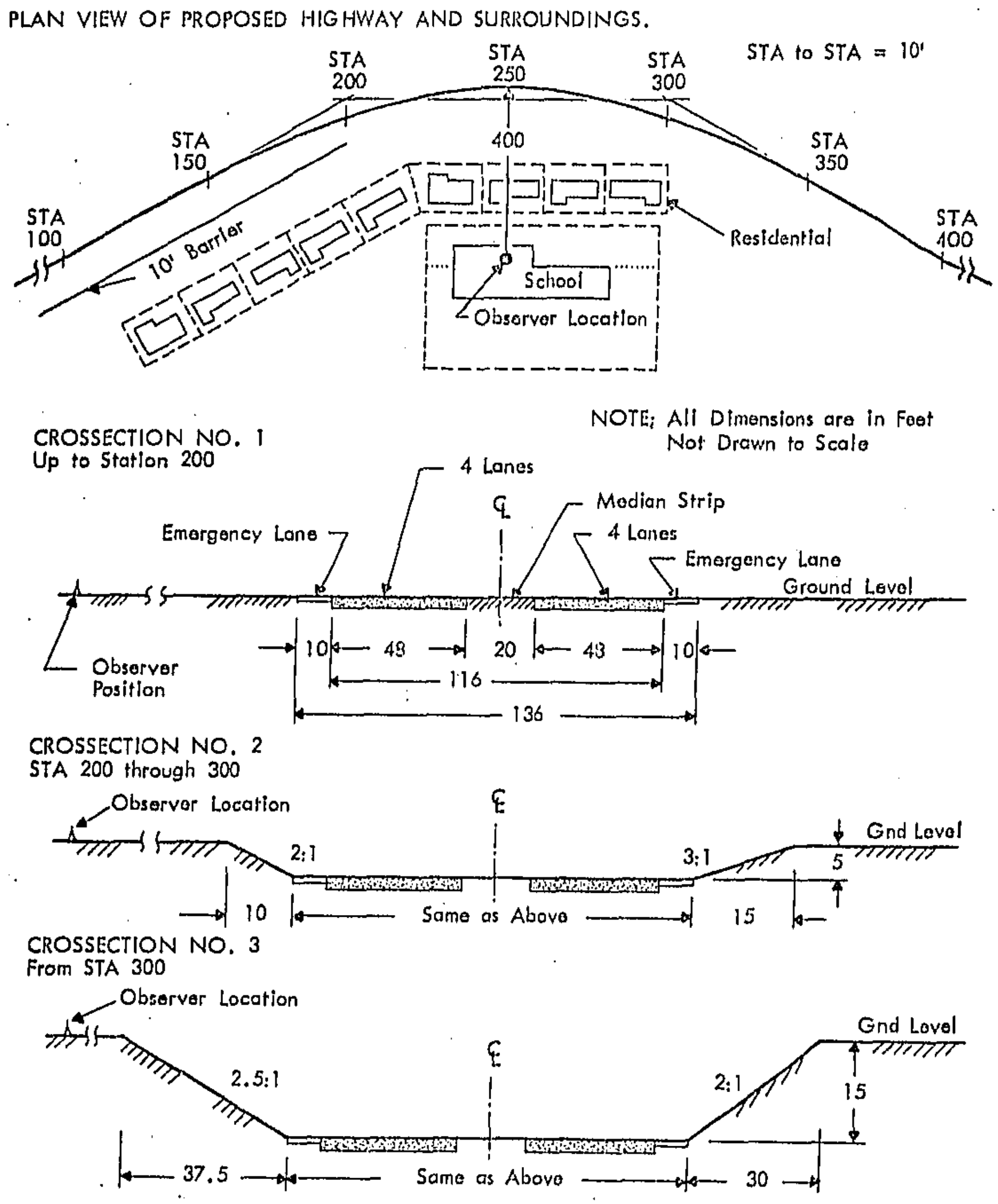


FIGURE 1. TYPICAL EXAMPLE OF A PROPOSED HIGHWAY

WORK SHEET NO. 1

ROAD ELEMENT IDENTIFICATION

Lane Grouping

Group	DESCRIPTION	Change In Alinement	Change In Section	Change In Gradient	Change In Flow
A	8 lane roadway with a 20 foot median strip	✓	✓		

Lane Group Element No.	Type *	DESCRIPTION	Position Parameters D	L	θ	Pavement P	N
1	II	STA 100 through 200 on level roadway	590'	-	19°	116'	8
2	III	STA 200 through 300 on depressed roadway	395'	1000'	102.5°	116'	8
3	II	STA 300 through 400 on depressed roadway	590'	-	19°	116'	8
4							
5							
6							
7							
8							

* Element Type Classification: Type I Infinite Element
  II Semi-Infinite
  III Finite

TABLE 2. WORK SHEET NO. 1 FOR ILLUSTRATIVE EXAMPLE (COMPLETE METHOD)

WORK SHEET NO.2

TRAFFIC FLOW PARAMETERS

Line	Symbol	Ref.	ROAD ELEMENT Number	1	2	3	
			Type	II	III	II	
			TIME INTERVAL	8-10 a.m.	8-10 a.m.	8-10 a.m.	
1			Estimated AADT, Vehicles per Day	49000	49000	49000	
2		Fig C1	Vehicle Volume, % AADT	7%	7%	7%	
3	V		Vehicle Volume, vph	7000	7000	7000	
4		Fig C2	Truck / Vehicle Mix, %	5%	5%	5%	
5	V_T		Truck Volume, vph	350	350	350	
6	V_A		Auto Volume, vph	6650	6650	6650	
7	S_T	Fig C3	Average Truck Speed, mph	55	55	55	
8	S_A	Fig C3	Average Auto Speed, mph	55	55	55	

TABLE 3. WORK SHEET NO. 2 FOR ILLUSTRATIVE EXAMPLE (COMPLETE METHOD)

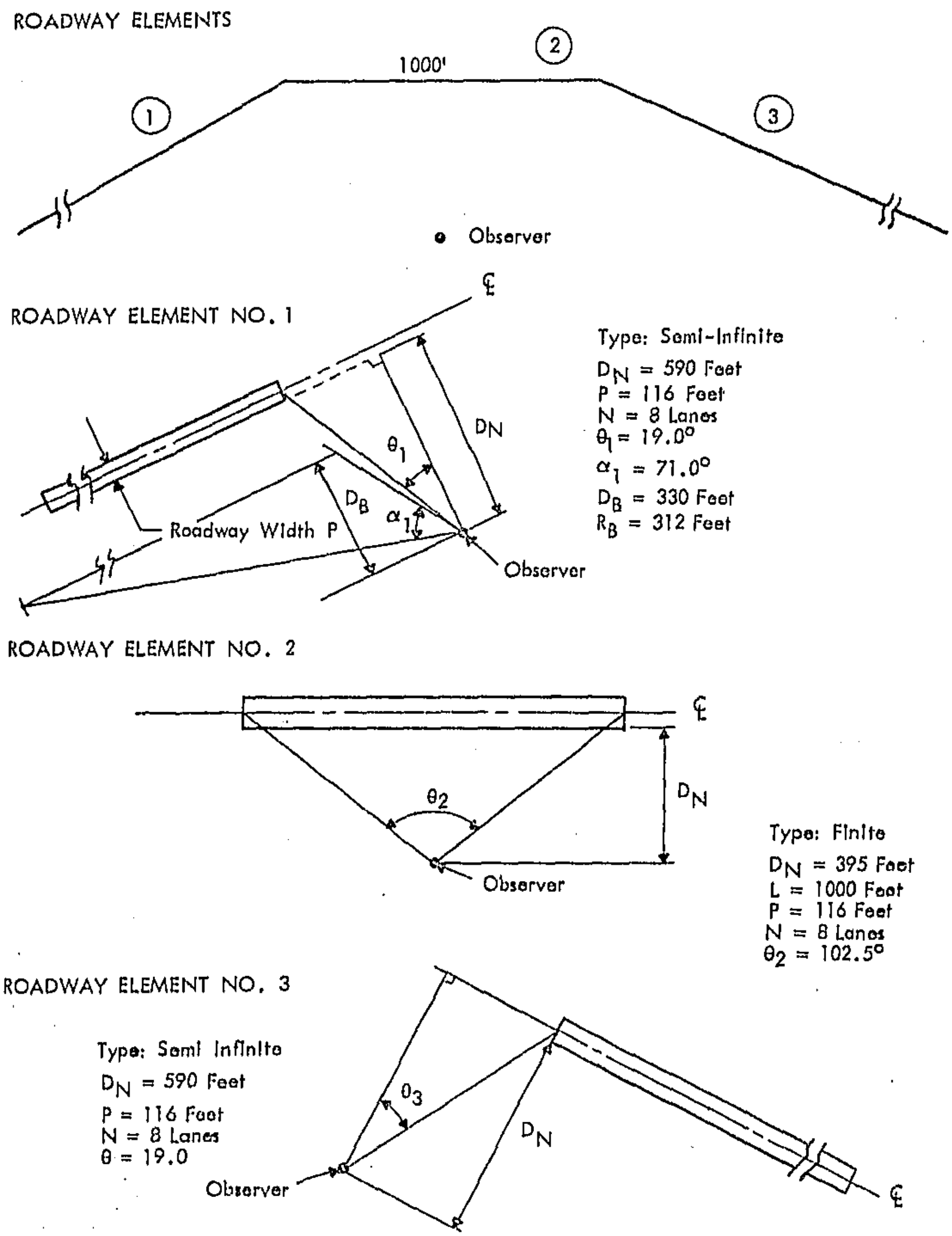


FIGURE 2. IDENTIFIED ROADWAY ELEMENTS SHOWING APPLICABLE PARAMETERS (COMPLETE METHOD)

PARAMETER WORK SHEET

	Line	Symbol	Ref.	ROAD ELEMENT		1	2	3	
					Number	1	2	3	
					Type	II	III	II	
				TIME INTERVAL		6-10 a.m.	8-10 a.m.	6-10 a.m.	
TRAFFIC PARAMETERS	1	V_A	W.S. 2	VEHICLE VOLUME (vph)	(a) Automobiles	6650	6650	6650	
		V_T			(b) Trucks	350	350	350	
	2	S_A	W.S. 2	AVERAGE SPEED (mph)	(a) Automobiles	55	55	55	
		S_T			(b) Trucks	55	55	55	
ROADWAY CHARACTERISTICS	3			FLOW CHARACTERISTIC	(a) Uninterrupted *	✓	✓	✓	
					(b) Interrupted *				
	4		W.S. 1	PAVEMENT	(a) Width (P)	116	116	116	
					(b) No. of Lanes (N)	8	8	8	
	5			PERCENTAGE GRADIENT (if greater than 2%) *		0	0	0	
	6			VERTICAL CONFIGURATION	(a) Elevated *				
					(b) Depressed *		✓	✓	
					(c) At Grade *	✓			
	7			ROAD SURFACE	(a) Smooth *				
					(b) Normal *	✓	✓	✓	
					(c) Rough *				
OBSERVER CHARACTERISTICS	8		W.S. 1	POSITIONS PARAMETERS	(a) D (ft.)	590	395	590	
					(b) D_E (ft.)	642	450	642	
					(c) L (ft.)	-	1000	-	
					(d) θ (deg.)	19.0	102.5	19.0	
	9			SHIELDING EFFECTS	(a) Barriers *	✓			
					(b) Buildings *	✓	✓		
					(c) Others *				
					(d) None *			✓	
	10			TERRAIN EFFECTS		0	0	0	

* Check Where Applicable

TABLE 4. PARAMETER WORK SHEET FOR ILLUSTRATIVE EXAMPLE (COMPLETE METHOD)

NOISE PREDICTION WORK SHEET

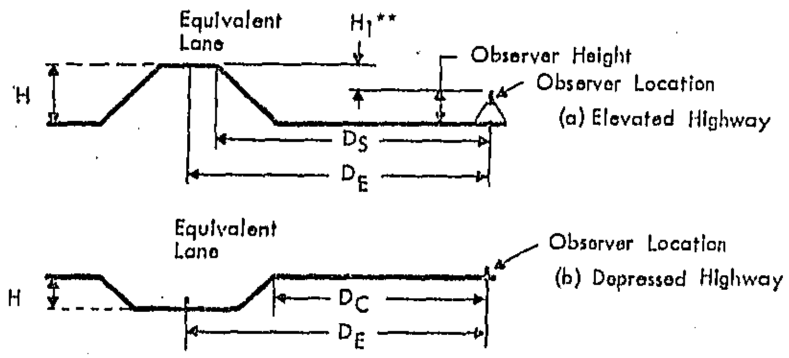
Line	Symbol	Ref.	ROAD ELEMENT		Number: 1		Number: 2		Number: 3			
				Type	II		III		II			
			TIME INTERVAL		8-10 a.m.		8-10 a.m.		8-10 a.m.			
			VEHICLE TYPE		Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck
ACOUSTIC CHARACTERISTICS												
1			Reference L_{50} at 100 ft		72	69	72	69	72	69		
2	Δ_1		ADJUSTMENT	Distance	-11	-11	- 9	- 9	-11	-11		
3	Δ_2			Element	- 4	- 4	- 2	- 2	- 4	- 4		
4	Δ_3			Gradient	0	0	0	0	0	0		
5	Δ_4	W.S. 3		Vertical	0	0	- 5	0	-14	- 9		
6	Δ_5			Surface	0	0	0	0	0	0		
7	Δ_6	W.S. 4		Shielding (a) Barriers	- 4	- 4	0	0	0	0		
	Δ_7			Shielding (b) Structures & Plant.	- 5	- 5	- 5	- 5	0	0		
8			TOTAL ADJUSTMENT (add rows 2 through 7)		-19	-19	-21	-16	-29	-25		
9			L_{50} AT OBSERVER (add row 1 to row 8)		53	50	51	53	43	44		
10		W.S. 5	L_{10} - L_{50} ADJUSTMENT		+ 1	+ 2	+ 1	+ 2	+ 1	+ 2		
11			INTERRUPTED ADJUSTMENT									
12			L_{10} AT OBSERVER (add row 10 & 11 to row 9)		54	52	52	55	44	46		
13		W.S. 6	ELEMENT TOTAL	L_{50}	55		55		47			
				L_{10}	56		57		48			
14		W.S. 6	GRAND TOTAL		L_{50} = 58 dBA				L_{10} = 60 dBA			
15					L_{10} - L_{50} = 2 dBA							

TABLE 5. NOISE PREDICTION WORK SHEET FOR ILLUSTRATIVE EXAMPLE (COMPLETE METHOD)

WORKSHEET NO. 3

ELEVATED AND DEPRESSED HIGHWAY ADJUSTMENT

Line	Symbol	Ref.		ROAD ELEMENT				
					Number	2	3		
					Type	III	II		
				TIME INTERVAL		8-10 a.m.	8-10 a.m.		
1	H_1**		ELEVATED FREEWAY	Height of Elevated Freeway **			-		
2	D_E	P.W.S.	ELEVATED FREEWAY	Observer - Equivalent Lane Dist.					
3	D_S		ELEVATED FREEWAY	Observer - Shoulder Distance					
4	A		ELEVATED FREEWAY	$A = H_1^2 / D_S$					
5	B		ELEVATED FREEWAY	$B = H_1^2 / (D_E - D_S)$					
6	H_2		DEPRESSED FREEWAY	Depth of Depressed Freeway		5	15		
7	D_E	P.W.S.	DEPRESSED FREEWAY	Observer - Equivalent Lane Dist.		450	642		
8	D_C		DEPRESSED FREEWAY	Observer - Cut Distance		375	555.5		
9	A		DEPRESSED FREEWAY	$A = H_2^2 / (D_E - D_C)$		.333	2.40		
10	B		DEPRESSED FREEWAY	$B = H_2^2 / D_C$		.067	.405		
11		Fig B8	ELEVATED FREEWAY ADJUSTMENT		(a) Auto				
					(b) Trucks*				
12		Fig B8	DEPRESSED FREEWAY ADJUSTMENT		(a) Auto	-5	-14		
					(b) Trucks*	0	-9		



* For trucks add +5 dB to value given by Figure

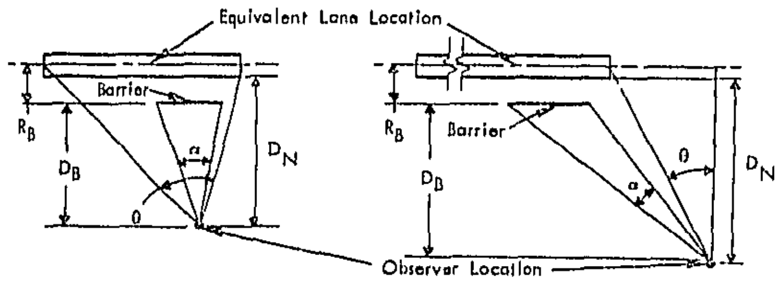
** Height of elevated freeway above observer (H_1)

TABLE 6. WORK SHEET NO. 3 FOR ILLUSTRATIVE EXAMPLE (COMPLETE METHOD)

WORK SHEET NO. 4

SHIELDING ADJUSTMENT

	Line	Symbol	Ref.		ROADWAY ELEMENT	Number	1	2		
						Type	II	III		
					TIME INTERVAL		8-10a.	a.8-10		
BARRIERS	1	H			Height of Barrier		10			
BARRIERS	2	D_B			Observer - Barrier Distance					
BARRIERS	3	R_B			Equivalent Lane - Barrier Distance					
BARRIERS	4				H^2/D_B		0.3			
BARRIERS	5				H^2/R_B		0.32			
BARRIERS	6		Fig B9		Adjustment for Infinite Barrier		-6.0			
BARRIERS	7	θ		ADJUSTMENT FOR FINITE BARRIER — Finite Element	Included Element Angle					
BARRIERS	8	α		ADJUSTMENT FOR FINITE BARRIER — Finite Element	Included Barrier Angle					
BARRIERS	9			ADJUSTMENT FOR FINITE BARRIER — Finite Element	$A = \alpha/\theta$					
BARRIERS	10		Fig B9	ADJUSTMENT FOR FINITE BARRIER — Finite Element	Adjustment in dB					
BARRIERS	11	θ		ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	Comp. Element Angle		19.0			
BARRIERS	12	α		ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	Included Barrier Angle		71.0			
BARRIERS	13			ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	$A = \alpha/90-\theta$		0.9			
BARRIERS	14		Fig B9	ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	Adjustment in dB		-4			
BARRIERS	15	α		ADJUSTMENT FOR FINITE BARRIER — Infinite Element	Included Barrier Angle					
BARRIERS	16			ADJUSTMENT FOR FINITE BARRIER — Infinite Element	$A = \alpha/180$					
BARRIERS	17		Fig B9	ADJUSTMENT FOR FINITE BARRIER — Infinite Element	Adjustment in dB					
STRUCTURES	18				Multiple Rows of Intervening Bldgs and Structures, Such As Houses, Apartments, etc. Will Reduce Levels By Up To 10 dB Assumed Adjustment in dB		-5	-5		
PLANTING	19				A Design Value of .5 dB Noise Reduction For Every 100 ft of Planting (Depth) May Be Used If These Trees Are At Least 15 ft Tall and Sufficiently Dense So That No Visual Path Between Them and The Highway Exists Assumed Adjustment in dB					
	20				Total Adjustment for Structure and Planting (Add Lines 18 and 19)		-5	-5		



Finite Roadway Element

Semi Infinite Roadway Element

TABLE 7. WORK SHEET NO. 4 FOR ILLUSTRATIVE EXAMPLE (COMPLETE METHOD)

WORK SHEET NO. 5

L_{10} ADJUSTMENT

Line	Symbol	Ref.	ROAD ELEMENT								
			Number	1		2		3			
			Type	II		III		II			
			TIME INTERVAL	8-10 a.m.		8-10 a.m.		8-10 a.m.			
			VEHICLE TYPE	Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck
1	V	P.W.S.	Vehicle Volume, vph	6650	350	6650	350	6650	350		
2	S	P.W.S.	Average Speed, mph	55	55	55	55	55	55		
3	D_E	P.W.S.	Observer - Equiv. Lane Distance, ft.	642	642	450	450	642	642		
4	A		Parameter $A = VD_E/S$, Vehicles ft/m	77500	4070	54500	2860	77500	4070		
		Fig. B10	L_{10} Adjustment, dB	+1	+2	+1	+2	+1	+2		

TABLE 8. WORK SHEET NO. 5 FOR ILLUSTRATIVE EXAMPLE (COMPLETE METHOD)

WORK SHEET NO. 6

DECIBEL ADDITION

Source or Element No.	Sound Level - dB	Antilog Columns - Left Digit of Sound Level								Antilog Table	
		9	8	7	6	5	4	3	2	Right Digit of Sound Level	Antilog
1 L_{50}	55					3	1	6	1	0	1000
2 L_{50}	55					3	1	6	2	1	1259
3 L_{50}	47						5	0	1	2	1585
										3	1995
										4	2512
										5	3162
										6	3981
										7	5013
										8	6311
Total	58					6	8	2	4	9	7944

List sound levels by source or Roadway Elements.

Enter antilog table with right digit of sound level to obtain antilog value.

Enter antilog on work sheet under antilog Columns. Position by entering left digit of antilog under the column numbered the same as the left digit of the sound level.

Add the antilog values of the individual sources to obtain the antilog of the total sound level.

Enter antilog table with antilog of total sound level. Obtain right digit of total sound level by selecting digit from table whose antilog is closest numerically to the antilog obtained in Step 4.

Indentify column number containing left most digit of the antilog derived from Step 4. This is the numerical value of the left digit of the total sound level.

TABLE 9. WORK SHEET NO. 6 FOR ILLUSTRATIVE EXAMPLE

WORK SHEET NO. 6

DECIBEL ADDITION

Source or Element No.	Sound Level - dB	Antilog Columns - Left Digit of Sound Level							
		9	8	7	6	5	4	3	2
1 L_{10}	56					3	9	8	1
2 L_{10}	57					5	0	1	3
3 L_{10}	48						6	3	1
Total	60					9	6	2	5

Antilog Table	
Right Digit of Sound Level	Antilog
0	1000
1	1259
2	1585
3	1995
4	2512
5	3162
6	3981
7	5013
8	6311
9	7944

List sound levels by source or Roadway Elements.

Enter antilog table with right digit of sound level to obtain antilog value.

Enter antilog on work sheet under antilog Columns. Position by entering left digit of antilog under the column numbered the same as the left digit of the sound level.

Add the antilog values of the individual sources to obtain the antilog of the total sound level.

Enter antilog table with antilog of total sound level. Obtain right digit of total sound level by selecting digit from table whose antilog is closest numerically to the antilog obtained in Step 4.

Indentify column number containing left most digit of the antilog derived from Step 4. This is the numerical value of the left digit of the total sound level.

TABLE 10. WORK SHEET NO. 6 FOR ILLUSTRATIVE EXAMPLE

CHAPTER 5 - THE SHORT METHOD

In the previous chapter, the step-by-step procedure of predicting noise levels from a roadway was presented. However, when approaching the problem of noise prediction from an existing or proposed roadway, it is desirable to first obtain a "rough" idea of the magnitude of noise levels expected and compare those with design criteria. To this purpose, the short method presented in this chapter was developed. This method will use some of the procedures from Chapter 4.

It should be noted at this point, that the short method should not be used in lieu of the complete method analysis and that it is restricted to fairly simple roadway configurations. Properly used, however, it allows the designer to pin-point trouble areas quickly and in many cases reduce the analysis time by discarding unaffected observer positions.

PROCEDURE

Basically, the method assumes that the roadway can be approximated by one infinite element with constant traffic parameters and roadway characteristics, the assumed roadway geometry is shown below in Figure 3. The work sheets used in this procedure are shown in Appendix A. All figures and tables used in this procedure are shown in Appendix B unless otherwise specified. The procedure is as follows:

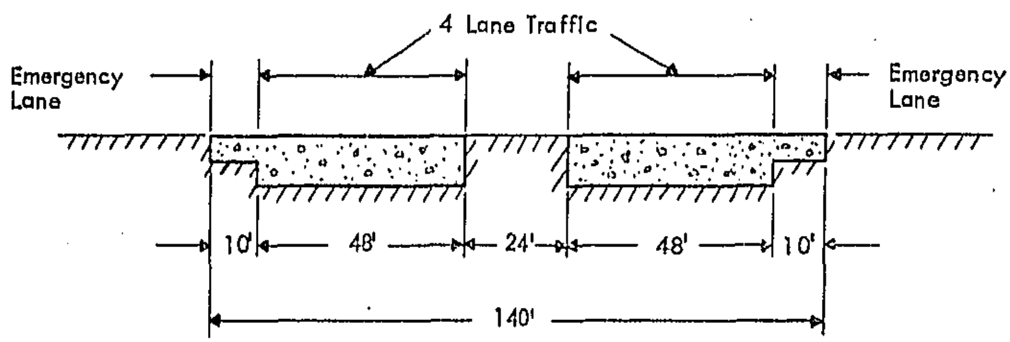


FIGURE 3. ASSUMED ROADWAY CROSSECTION (SHORT METHOD)

1.0 ROAD ELEMENT: Draw a line from the observer location to intersect the roadway at its nearest point, i.e. right angle intersect. This defines the position of the assumed infinite roadway element.

2.0 VEHICLE OPERATING CONDITIONS: Determine the Vehicle Operating Conditions for the infinite road element by using the Traffic Parameters at the roadway nearest point (if these parameters vary along the roadway) and follow the procedure for Work Sheet No. 1 (see Chapter 4). Enter this data of the "Parameter Work Sheet" (Table A.1) on lines 1 and 2.

3.0 VERTICAL CONFIGURATION: Determine the form of vertical Configuration at the roadway nearest point and check appropriate line on "Parameter Work Sheet".

4.0 POSITION PARAMETER: Determine the Distance to the nearest lane (D_N) by measuring the distance between observer and infinite roadway element at the nearest point. Enter in Line 8a of "Parameter Work Sheet".

5.0 REFERENCE L_{50} AT 100 FEET: Determine the Reference L_{50} Levels at 100 feet for both autos and trucks using

Figures B.3 and B.4 and enter on Line 1 on "Noise Prediction Work Sheet" (see Table A.2). These levels are obtained as follows:

- Automobiles: Using Vehicle Volume, V_A (Line 1a on "Parameter Work Sheet") and Average Speed S_A enter Figure B.3 and read the corresponding Sound Level in dBA.

- Trucks: Using Vehicle Volume, V_T, and Average Speed, S_T, enter Figure B.4 and read the corresponding sound level in dBA.

6.0 DISTANCE ADJUSTMENT: Determine the Distance Adjustment to account for Observer Near Lane Distance and the Width of the Roadway and enter in Line 2 of "Noise Prediction Work Sheet". This adjustment is the same for autos and trucks and is obtained using the Near Lane Distance, D_N (Line 8a on "Parameter Work Sheet") and entering Table B.6. Find the closest D_N listed and read corresponding adjustment.

7.0 VERTICAL ADJUSTMENT: Determine the Vertical Adjustment and enter in Line 5 of "Noise Prediction Work Sheet". This adjustment is zero for an at-grade configuration (if Line 6c on "Parameter Work Sheet" is checked), otherwise do one of the following:

- For elevated roadway configuration, take height H and enter in Table B.7 for appropriate adjustment.

- For depressed roadway configuration, take depth H and enter in Table B.8 for appropriate adjustment.

8.0 L_{50} AT OBSERVER: Determine the L_{50} level at the observer by algebraic sum of lines 1, 2 and 5 on "Noise Prediction Work Sheet". Enter on Line 10.

9.0 INFINITE ELEMENT TOTAL: Determine the infinite element total noise level at the observer and enter in Line 15 on "Noise Prediction Work Sheet". This is obtained by adding the L_{50} noise levels for autos and trucks using "Work Sheet No. 6" (see Table A.9).

ILLUSTRATIVE EXAMPLE

Let us apply the short method described above to the illustrative example of Chapter 4. In this case, the nearest lane from the observer location is found at 400 feet. Through this point we pass an infinite roadway element as illustrated below in Figure 4. The roadway cross section at the nearest lane location corresponds to cross section 2 (a 5 foot depressed roadway). This cross section is assumed valid for the entire element. Following the procedure for the short method, a final Predicted Noise Level L_{50} of 61 dBA is found. This is shown on Tables 10 and 11. Note that the L_{50} noise level obtained by this method is 3 dB higher than the Complete Method solution. In general, unless the roadway geometry is very complicated the short method will result in a higher value. The interpretation of both the Chapter 4 and the above results will be discussed in Chapter 6.

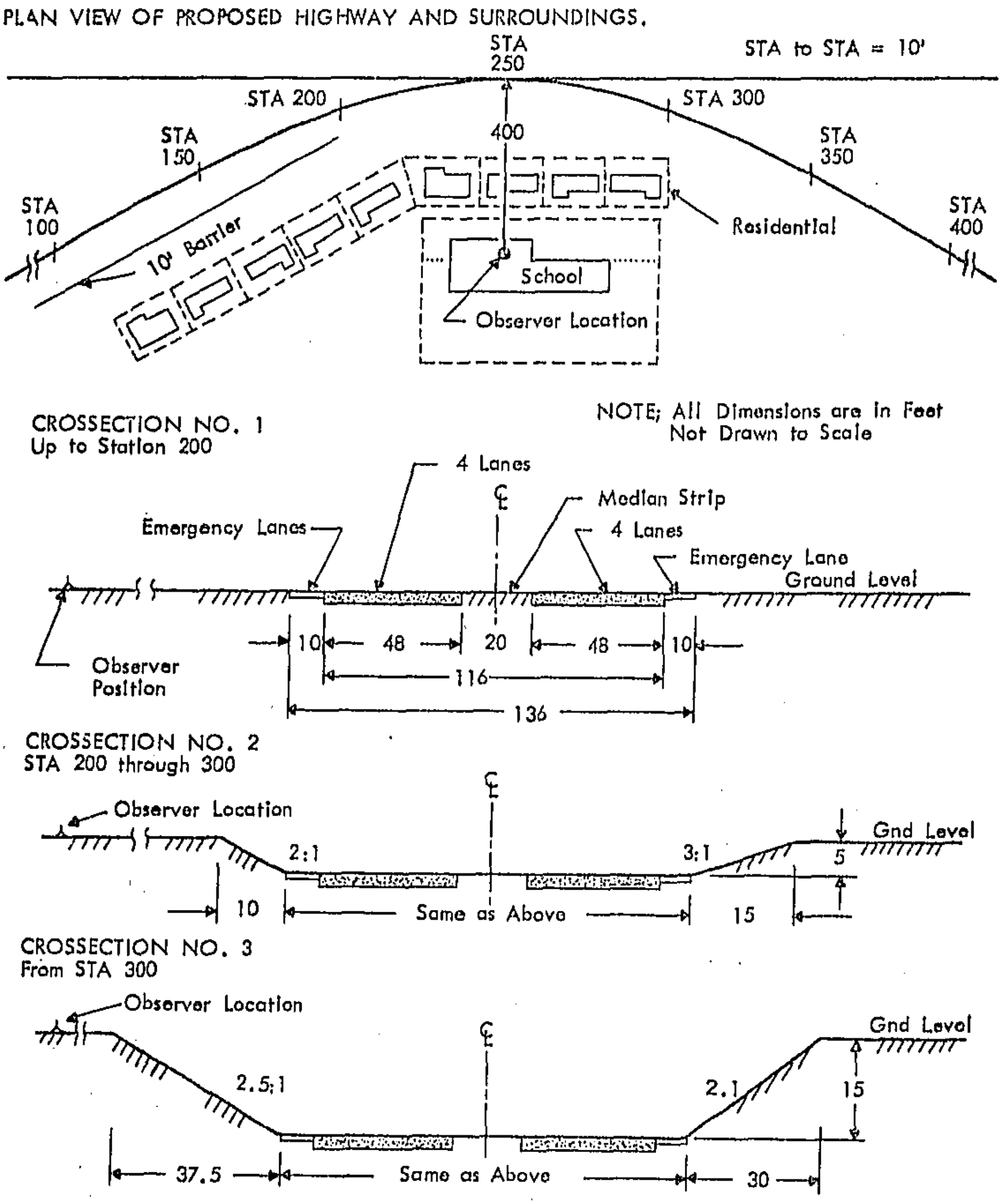


FIGURE 4. TYPICAL EXAMPLE OF A PROPOSED HIGHWAY SHOWING SHORT METHOD APPROXIMATION

PARAMETER WORK SHEET

	Line	Symbol	Ref.						
				ROAD ELEMENT	Number	1			
					Type	I			
				TIME INTERVAL		8-10			
TRAFFIC PARAMETERS	1	V_A	W.S. 2	VEHICLE VOLUME (vph)	(a) Automobiles	6650			
		V_T			(b) Trucks	350			
	2	S_A	W.S. 2	AVERAGE SPEED (mph)	(a) Automobiles	55			
		S_T			(b) Trucks	55			
ROADWAY CHARACTERISTICS	3			FLOW CHARACTERISTIC	(a) Uninterrupted *				
					(b) Interrupted *				
	4		W.S. 1	PAVEMENT	(a) Width (P)	116			
					(b) No. of Lanes (N)	8			
	5			PERCENTAGE GRADIENT (If greater than 2%) *		-			
	6			VERTICAL CONFIGURATION	(a) Elevated *				
					(b) Depressed *	✓			
					(c) At Grade *				
	7			ROAD SURFACE	(a) Smooth *				
					(b) Normal *				
					(c) Rough *				
OBSERVER CHARACTERISTICS	8		W.S. 1	POSITIONS PARAMETERS	(a) D (ft.)	400			
					(b) D_E (ft.)	455			
					(c) L (ft.)	-			
					(d) θ (deg.)	-			
	9			SHIELDING EFFECTS	(a) Barriers *				
					(b) Buildings *				
					(c) Others *				
					(d) None *				
	10			TERRAIN EFFECTS					

* Check Where Applicable

TABLE 11. PARAMETER WORK SHEET FOR ILLUSTRATIVE EXAMPLE (SHORT METHOD)

NOISE PREDICTION WORK SHEET

ACOUSTIC CHARACTERISTICS Line	Symbol	Ref.	ROAD ELEMENT			Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck
			ROAD ELEMENT		Number	1							
					Type	I							
			TIME INTERVAL			8-10 a.m.							
			VEHICLE TYPE			Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck
1			Reference L_{50} at 100 ft			72	69						
2	Δ_1		ADJUSTMENT	Distance		-10	-10						
3	Δ_2			Element									
4	Δ_3			Gradient		-		-		-		-	
5	Δ_4	W.S. 3		Vertical		- 5	0						
6	Δ_5			Surface									
7	Δ_6	W.S. 4		Shielding	(a) Barriers								
	Δ_7				(b) Structures & Plant.								
8			TOTAL ADJUSTMENT (add rows 2 through 7)			-15	-10						
9			L_{50} AT OBSERVER (add row 1 to row 8)			57	59						
10		W.S. 5	$L_{10} - L_{50}$ ADJUSTMENT										
11			INTERRUPTED ADJUSTMENT										
12			L_{10} AT OBSERVER (add row 10 & 11 to row 9)										
13		W.S. 6	ELEMENT TOTAL		L_{50}	61							
					L_{10}								
14		W.S. 6	GRAND TOTAL			L_{50} = 61 dBA				L_{10} = dBA			
15						L_{10} - L_{50} = dBA							

TABLE 12. NOISE PREDICTION WORK SHEET FOR ILLUSTRATIVE EXAMPLE (SHORT METHOD)

CHAPTER 6 - COMPARISON WITH CRITERIA AND INTERPRETATION

This chapter takes the estimated outside traffic levels calculated in Chapters 4 and 5 and tests their compatibility with the Design Criteria shown in Table B.5.

PROCEDURE

The following is a step-by-step procedure:

1.0 CRITERIA WORK SHEET: Identify the observer category considered from Table B.9 (i.e.: Residences, inside; churches, etc.) by number and enter in a column on "Criteria Work Sheet". Note the appropriate time interval applicable.

1.1 DESIGN CRITERIA LEVEL: Determine the Design Criterion Level (L_{50} or L_{10}) applicable by the following:

- If $L_{10} - L_{50} \leq 6$ dB, then L_{50} Design Criterion applies.
- If $L_{10} - L_{50} \geq 6$ dB, then L_{10} Design Criterion applies.
- $L_{10} - L_{50}$ is obtained from Line 15 on "Noise Prediction Work Sheet" in Chapter 4.

This determines the Design Criteria levels to be used throughout the compatibility tests for that one observer position and time interval only.

1.2 ESTIMATED OUTSIDE TRAFFIC NOISE: Determine the estimated outside traffic noise and enter in Line 1 on "Criteria Work Sheet". This is obtained from Line 9 or 12 on "Noise Prediction Work Sheet" in Chapter 4 depending on the applicable design criteria.

1.3 AMBIENT NOISE LEVEL: Determine the L_{50} or L_{10} ambient noise level in dBA at the observer location and enter in Line 2 on "Criteria Work Sheet". Note that these levels are outside levels, independent of the observer category.

Depending on the observer category, do one of the following:

- If observer category is 2, 4 or 7 do section 1.4 through 1.6.

- If observer category is 1, 3, 5, 6, 8, 9 or 10 do section 1.7 through 1.10.

1.4 OUTSIDE CRITERION: Determine the L_{50} or L_{10} outside criterion in dBA and enter in Line 3 on "Criteria Work Work Sheet". This is obtained from Table B.5.

1.5 AMBIENT DIFFERENCE. Determine the Ambient difference in dB and enter in Line 4 on "Criteria Work Sheet". This is obtained by subtracting Line 2 from Line 1.

1.6 CRITERION DIFFERENCE OUTSIDE: Determine the criterion difference outside and enter in Line 5 on "Criteria Work Sheet". This is obtained by subtracting Line 3 from Line 1.

1.7 BUILDING NOISE REDUCTION: Determine the building noise reduction and enter in Line 6 on "Criteria Work Sheet". This is obtained from Table B.9. Note that these noise reductions vary with geographic location and open or closed window conditions.

1.8 ESTIMATED TRAFFIC LEVEL INSIDE: Determine the Estimated Traffic Level inside and enter in Line 7 on "Criteria Work Sheet". This is obtained by subtracting Line 6 from Line 1.

1.9 INSIDE CRITERION: Determine the L_{50} or L_{10} Inside

Criterion in dBA and enter in Line 8 on "Criteria Work Sheet". This is obtained from Table B.5.

1.11 CRITERION DIFFERENCE INSIDE: Determine the Criterion difference inside and enter in Line 9 on "Criteria Work Sheet". This is obtained by subtracting Line 8 from Line 7.

1.11 COMPATIBILITY: Determine the compatibility with criteria and enter in Line 10 on "Criteria Work Sheet" as follows:

- If Line 4 or 5 is ≤ 0 dB then enter YES

- If either Line 4 or 5 is > 0 dB then enter NO

- If Line 9 is ≤ 0 dB then enter YES

- If Line 9 is > 0 dB then enter NO

Thus, based on the Design Criteria, the noise levels estimated for the roadway are judged as compatible or not compatible with the environment.

NOISE IMPACT & CRITERIA INTERPRETATION

The idea of "acceptable noise level" implies no community reaction to an intruding noise source. In developing the impact criteria for this "Design Guide", both the environmental conservation and environmental utility were considered.

1) The community in general, will react if the existing noise environment is increased. As individuals, we have a natural urge to conserve what we already have. Thus an increase in the existing noise levels due to a proposed highway can be expected to produce some type of impact on the community.

2) Irrespective of the increase in existing noise environment, the utility of an area depends on the ability to perform certain tasks. The tasks considered in this study are the ability to communicate (speech intelligibility) and sleep. Table B.5 represents the "maximum acceptable noise levels" that are compatible with speech requirements for a range of different land-uses.

The compatibility of an environment thus is based on these two considerations as indicated in the "Criteria Work Sheet". In order to assess the impact that can be expected when one or both of these considerations are exceeded ("NO" on Line 10 on "Criteria Work Sheet"), three basic "noise impact" categories are defined:

NO IMPACT: under this category, very little comment or individual reaction is expected.

SOME IMPACT: under this category, some individual comment and reaction is expected but no group action is likely.

GREAT IMPACT: under this category, strong individual comment and group action may be expected.

Table B.10 relates these three categories to the amount by which the criteria are exceeded.

ILLUSTRATIVE EXAMPLE

Using the criteria developed in this chapter, consider the example discussed in Chapters 4 and 5. The results of the short method gave a noise level of 61 dBA and the complete method resulted in a noise level of 58 dBA. Let us now describe the utility of the area by locating the observer inside the classroom. Assume the school in question is airconditioned and located in Los Angeles. The ambient noise level outside the building was measured to be 55 dBA. Find Impact of proposed highway in the classroom only.

Table B.5 indicates that the criterion for a classroom is 40 dBA. For the geographic area under consideration Table B.9 gives a 20 dB attenuation between outside and inside for closed windows.

Looking at the short method first we note that the Estimated traffic level inside will be 41 dBA (see Table 13). Thus, we exceed the Criterion by 1 dB. Table 11 indicates that when the criterion is exceeded using the short method, a possible noise problem is present, thus, the complete method should be used.

The Estimated Traffic Noise Level Inside for the complete method results in a noise level of 38 dBA. Thus, the projected environment is compatible with criteria.

Note that if the impact of the outside noise level was also required, the complete method shows that both Criterion Difference Outside and Ambient Difference are exceeded by 3 dB. In that case, the highway noise levels would not be compatible and checking Table B.10 we find that Some Impact would be expected.

CRITERIA WORK SHEET

Line	Reference			SHORT METHOD		COMPLETE METHOD	
			OBSERVER CATEGORY	3		3	
			TIME INTERVAL	8-10 a.m.		8-10 a.m.	
1	NPWS	OUTSIDE	Estimated Outside Traffic Level (dBA)	61		58	
2		OUTSIDE	Ambient (dB)			55	
3	T B5	OUTSIDE	Outside Criterion (dBA)	55		55	
4		OUTSIDE	Ambient Difference (dB) (Subtract Line 2 from Line 1)	-		3	
5		OUTSIDE	Criterion Difference Outside (dB) (Subtract Line 3 from Line 1)	6		3	
6	T B8	INSIDE	Building Noise Reduction (dB)	20		20	
7		INSIDE	Estimated Traffic Level Inside (dBA)	41		38	
8		INSIDE	Inside Criterion (dBA)	40		40	
9		INSIDE	Criterion Difference Inside (dB) (Subtract Line 8 from Line 7)	1.0		-2.0	
10			Compatability	No		Yes	

TABLE 13. CRITERIA WORK SHEET FOR ILLUSTRATIVE EXAMPLE (COMPLETE AND SHORT METHOD)

APPENDIX A

WORK SHEETS

PARAMETER WORK SHEET

	Line	Symbol	Ref.	ROAD ELEMENT	Number				
					Type				
				TIME INTERVAL					
TRAFFIC PARAMETERS	1	V_A	W.S. 2	VEHICLE VOLUME (vph)	(a) Automobiles				
		V_T			(b) Trucks				
	2	S_A	W.S. 2	AVERAGE SPEED (mph)	(a) Automobiles				
		S_T			(b) Trucks				
ROADWAY CHARACTERISTICS	3			FLOW CHARACTERISTIC	(a) Uninterrupted *				
					(b) Interrupted *				
	4		W.S. 1	PAVEMENT	(a) Width (P)				
					(b) No. of Lanes (N)				
	5			PERCENTAGE GRADIENT (If greater than 2%) *					
	6			VERTICAL CONFIGURATION	(a) Elevated *				
					(b) Depressed *				
					(c) At Grade *				
	7			ROAD SURFACE	(a) Smooth *				
					(b) Normal *				
					(c) Rough *				
OBSERVER CHARACTERISTICS	8		W.S. 1	POSITIONS PARAMETERS	(a) D (ft.)				
					(b) D_E (ft.)				
					(c) L (ft.)				
					(d) θ (deg.)				
	9			SHIELDING EFFECTS	(a) Barriers *				
					(b) Buildings *				
					(c) Others *				
					(d) None *				
	10			TERRAIN EFFECTS					

* Check Where Applicable

TABLE A.1 PARAMETER WORK SHEET

NOISE PREDICTION WORK SHEET

ACOUSTIC CHARACTERISTICS

Line	Symbol	Ref.										
			ROAD ELEMENT	Number								
				Type								
			TIME INTERVAL									
			VEHICLE TYPE		Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck
1			Reference L_{50} at 100 ft									
2	Δ_1		ADJUSTMENT	Distance								
3	Δ_2			Element								
4	Δ_3			Gradient	-		-		-		-	
5	Δ_4	W.S.3		Vertical								
6	Δ_5			Surface								
7	Δ_6	W.S. 4		Shielding (a) Barriers								
	Δ_7			Shielding (b) Structures & Plant.								
8			TOTAL ADJUSTMENT (add rows 2 through 7)									
9			L_{50} AT OBSERVER (add row 1 to row 8)									
10		W.S.5	L_{10} - L_{50} ADJUSTMENT									
11			INTERRUPTED ADJUSTMENT									
12			L_{10} AT OBSERVER (add row 10 & 11 to row 9)									
13		W.S.6	ELEMENT TOTAL	L_{50}								
				L_{10}								
14		W.S.6	GRAND TOTAL		L_{50} =		dBA		L_{10} =		dBA	
15					L_{10} - L_{50} =		dBA					

TABLE A.2 NOISE PREDICTION WORK SHEET

CRITERIA WORK SHEET

Line	Reference		OBSERVER CATEGORY				
			TIME INTERVAL				
1	NPWS	OUTSIDE	Estimated Outside Traffic Level (dBA)				
2		OUTSIDE	Ambient (dB)				
3	T B5	OUTSIDE	Outside Criterion (dBA)				
4		OUTSIDE	Ambient Difference (dB) (Subtract Line 3 from Line 1)				
5		OUTSIDE	Criterion Difference Outside (dB) (Subtract Line 3 from Line 1)				
6	T B8	INSIDE	Building Noise Reduction (dB)				
7		INSIDE	Estimated Traffic Level Inside (dBA)				
8		INSIDE	Inside Criterion (dBA)				
9		INSIDE	Criterion Difference Inside (dB) (Subtract Line 8 from Line 7)				
10			Compatability				

TABLE A.3 CRITERIA WORK SHEET

WORK SHEET NO. 1

ROAD ELEMENT IDENTIFICATION

Lane Grouping

Group	DESCRIPTION	Change in Alinement	Change in Section	Change in Gradient	Change in Flow

Lane Group	Element No.	Type *	DESCRIPTION	Position Parameters D	Position Parameters L	Position Parameters θ	Pavement P	Pavement N
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							

* Element Type Classification: Type I Infinite Element
II Semi-Infinite
III Finite

TABLE A.4 WORK SHEET NO. 1 - ROAD ELEMENT IDENTIFICATION

WORK SHEET NO. 2

TRAFFIC FLOW PARAMETERS

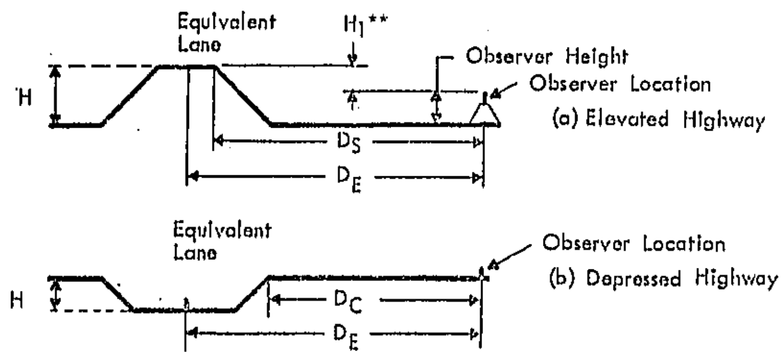
Line	Symbol	Ref.	ROAD ELEMENT / TIME INTERVAL	Number / Type			
1			Estimated AADT, Vehicles per Day				
2		Fig C1	Vehicle Volume, % AADT				
3	V		Vehicle Volume, vph				
4		Fig C2	Truck / Vehicle Mix, %				
5	V_T		Truck Volume, vph				
6	V_A		Auto Volume, vph				
7	S_T	Fig C3	Average Truck Speed, mph				
8	S_A	Fig C3	Average Auto Speed, mph				

TABLE A.5 WORK SHEET NO. 2 - TRAFFIC FLOW PARAMETERS

WORKSHEET NO.3

ELEVATED AND DEPRESSED HIGHWAY ADJUSTMENT

Line	Symbol	Ref.		ROAD ELEMENT	Number / Type				
				TIME INTERVAL					
1	H_1^{**}		ELEVATED FREEWAY	Height of Elevated Freeway **					
2	D_E	P.W.S.		Observer - Equivalent Lane Dist.					
3	D_S			Observer - Shoulder Distance					
4	A			$A = H_1^2 / D_S$					
5	B			$B = H_1^2 / (D_E - D_S)$					
6	H_2		DEPRESSED FREEWAY	Depth of Depressed Freeway					
7	D_E	P.W.S.		Observer - Equivalent Lane Dist.					
8	D_C			Observer - Cut Distance					
9	A			$A = H_2^2 / (D_E - D_C)$					
10	B			$B = H_2^2 / D_C$					
11		Fig B8	ELEVATED FREEWAY ADJUSTMENT		(a) Auto				
					(b) Trucks*				
12		Fig B8	DEPRESSED FREEWAY ADJUSTMENT		(a) Auto				
					(b) Trucks*				



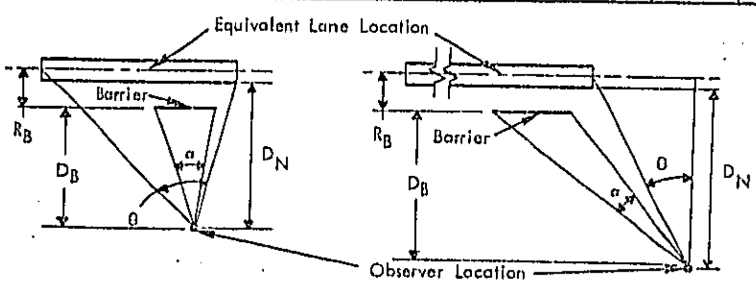
* For trucks add +5 dB to value given by Figure
** Height of elevated freeway above observer (H_1)

TABLE A.6 WORK SHEET NO. 3
ELEVATED & DEPRESSED HIGHWAY ADJUSTMENT

WORK SHEET NO. 4

SHIELDING ADJUSTMENT

	Line	Symbol	Ref.						
				ROADWAY ELEMENT	Number				
					Type				
				TIME INTERVAL					
BARRIERS	1	H		Height of Barrier					
BARRIERS	2	D_B		Observer - Barrier Distance					
BARRIERS	3	R_B		Equivalent Lane - Barrier Distance					
BARRIERS	4			H^2/D_B					
BARRIERS	5			H^2/R_B					
BARRIERS	6		Fig B9	Adjustment for Infinite Barrier					
BARRIERS	7	θ		ADJUSTMENT FOR FINITE BARRIER — Finite Element	Included Element Angle				
BARRIERS	8	α		ADJUSTMENT FOR FINITE BARRIER — Finite Element	Included Barrier Angle				
BARRIERS	9			ADJUSTMENT FOR FINITE BARRIER — Finite Element	$A = \alpha/\theta$				
BARRIERS	10		Fig B9	ADJUSTMENT FOR FINITE BARRIER — Finite Element	Adjustment in dB				
BARRIERS	11	θ		ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	Comp. Barrier Angle				
BARRIERS	12	α		ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	Included Barrier Angle				
BARRIERS	13			ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	$A = \alpha/90 - \theta$				
BARRIERS	14		Fig B9	ADJUSTMENT FOR FINITE BARRIER — Semi-Infinite Element	Adjustment in dB				
BARRIERS	15	α		ADJUSTMENT FOR FINITE BARRIER — Infinite Element	Included Barrier Angle				
BARRIERS	16			ADJUSTMENT FOR FINITE BARRIER — Infinite Element	$A = \alpha/180$				
BARRIERS	17		Fig B9	ADJUSTMENT FOR FINITE BARRIER — Infinite Element	Adjustment in dB				
STRUCTURES	18			Multiple Rows of Intervening Bldgs and Structures, Such As Houses, Apartments, etc. Will Reduce Levels By Up To 10 dB	Assumed Adjustment in dB				
PLANTING	19			A Design Value of 5 dB Noise Reduction For Every 100 ft of Planting (Depth) May Be Used If These Trees Are At Least 15 ft Tall and Sufficiently Dense So That No Visual Path Between Them and The Highway Exists	Assumed Adjustment in dB				
	20				Total Adjustment for Structure and Planting (Add Lines 18 and 19)				



Finite Roadway Element

Semi Infinite Roadway Element

TABLE A.7 WORK SHEET NO. 4 - SHIELDING ADJUSTMENT

WORK SHEET NO. 5

L_{10} ADJUSTMENT

Line	Symbol	Ref.	ROAD ELEMENT: Number								
			ROAD ELEMENT: Type								
			TIME INTERVAL								
			VEHICLE TYPE	Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck
1	V	P.W.S.	Vehicle Volume, vph								
2	S	P.W.S.	Average Speed, mph								
3	D_E	P.W.S.	Observer - Equiv. Lane Distance, ft.								
4	A		Parameter $A = VD_E/S$, Vehicles ft/m								
		Fig. B10	L_{10} Adjustment, dB								

TABLE A.8 WORK SHEET NO. 5 - L_{10} ADJUSTMENT

WORK SHEET NO. 6

DECIBEL ADDITION

Source or Element No.	Sound Level – dB	Antilog Columns – Left Digit of Sound Level								Antilog Table	
		9	8	7	6	5	4	3	2	Right Digit of Sound Level	Antilog
										0	1000
										1	1259
										2	1585
										3	1995
										4	2512
										5	3162
										6	3981
										7	5013
										8	6311
Total										9	7944

List sound levels by source or Roadway Elements.

Enter antilog table with right digit of sound level to obtain antilog value.

Enter antilog on work sheet under antilog Columns. Position by entering left digit of antilog under the column numbered the same as the left digit of the sound level.

Add the antilog values of the individual sources to obtain the antilog of the total sound level.

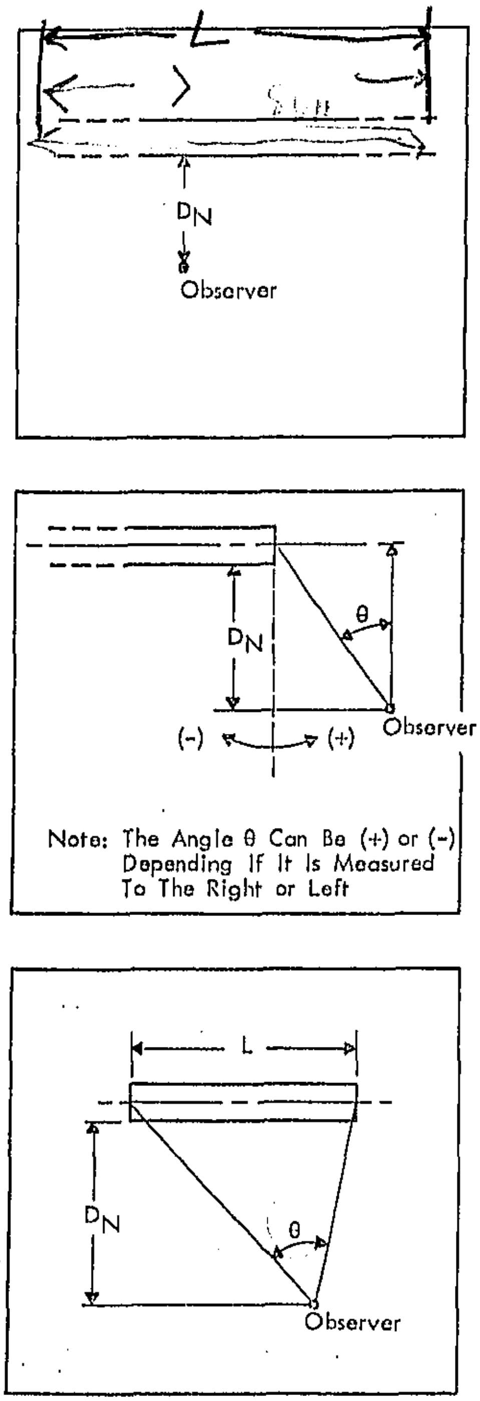
Enter antilog table with antilog of total sound level. Obtain right digit of total sound level by selecting digit from table whose antilog is closest numerically to the antilog obtained in Step 4.

Indentify column number containing left most digit of the antilog derived from Step 4. This is the numerical value of the left digit of the total sound level.

TABLE A.9 WORK SHEET NO. 6 – DECIBEL ADDITION

APPENDIX B

FIGURES AND TABLES



$L > 8D_N$

(a) INFINITE ELEMENT

(b) SEMI-INFINITE ELEMENT

$L = < 8D_N$

(c) FINITE ELEMENT

FIGURE B.1 DIFINITION OF POSITION PARAMETERS FOR ROADWAY ELEMENTS

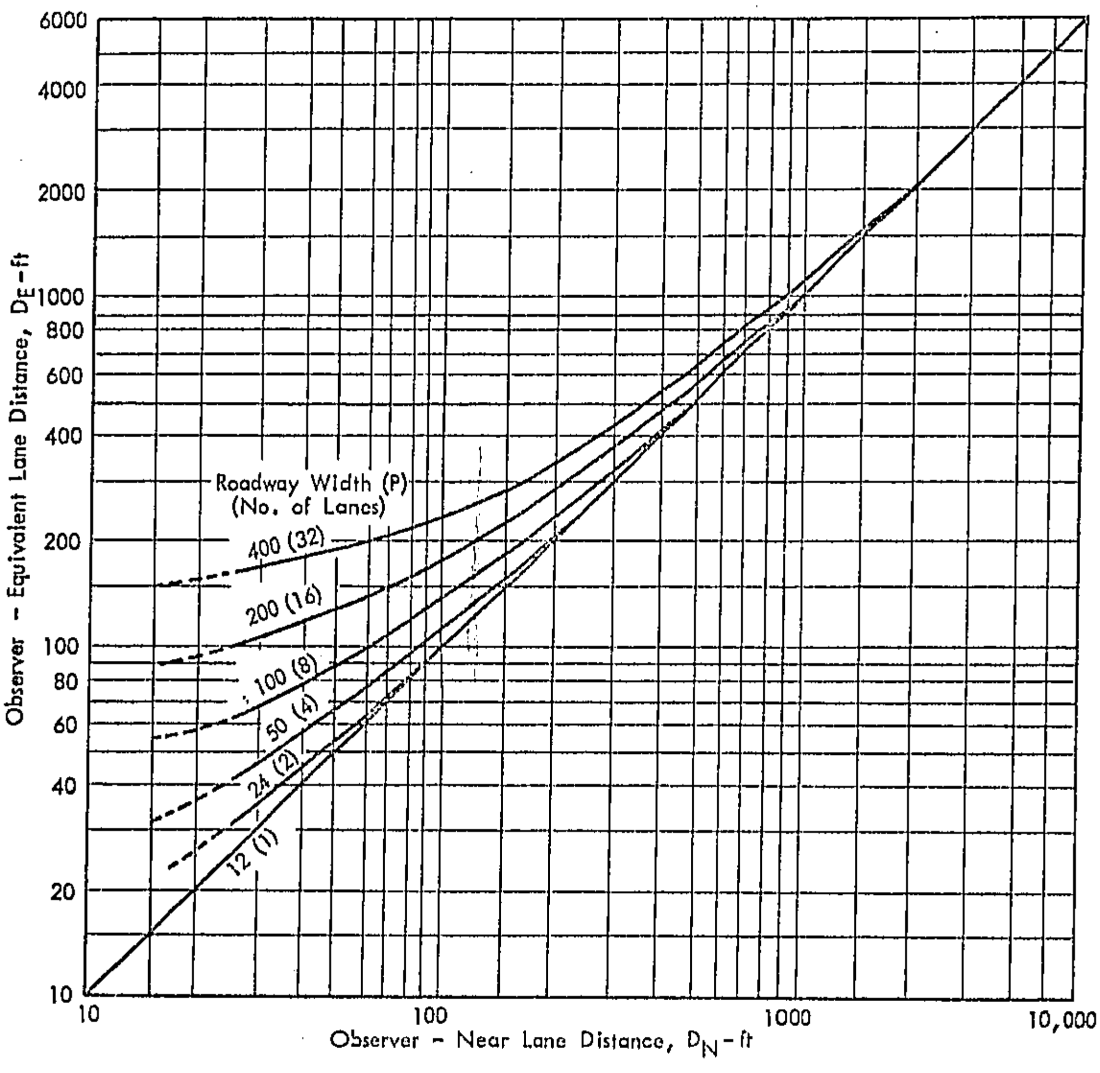


FIGURE B.2 OBSERVER - EQUIVALENT LANE DISTANCE AS FUNCTION OF NEAR LANE DISTANCE AND WIDTH OF ROADWAY

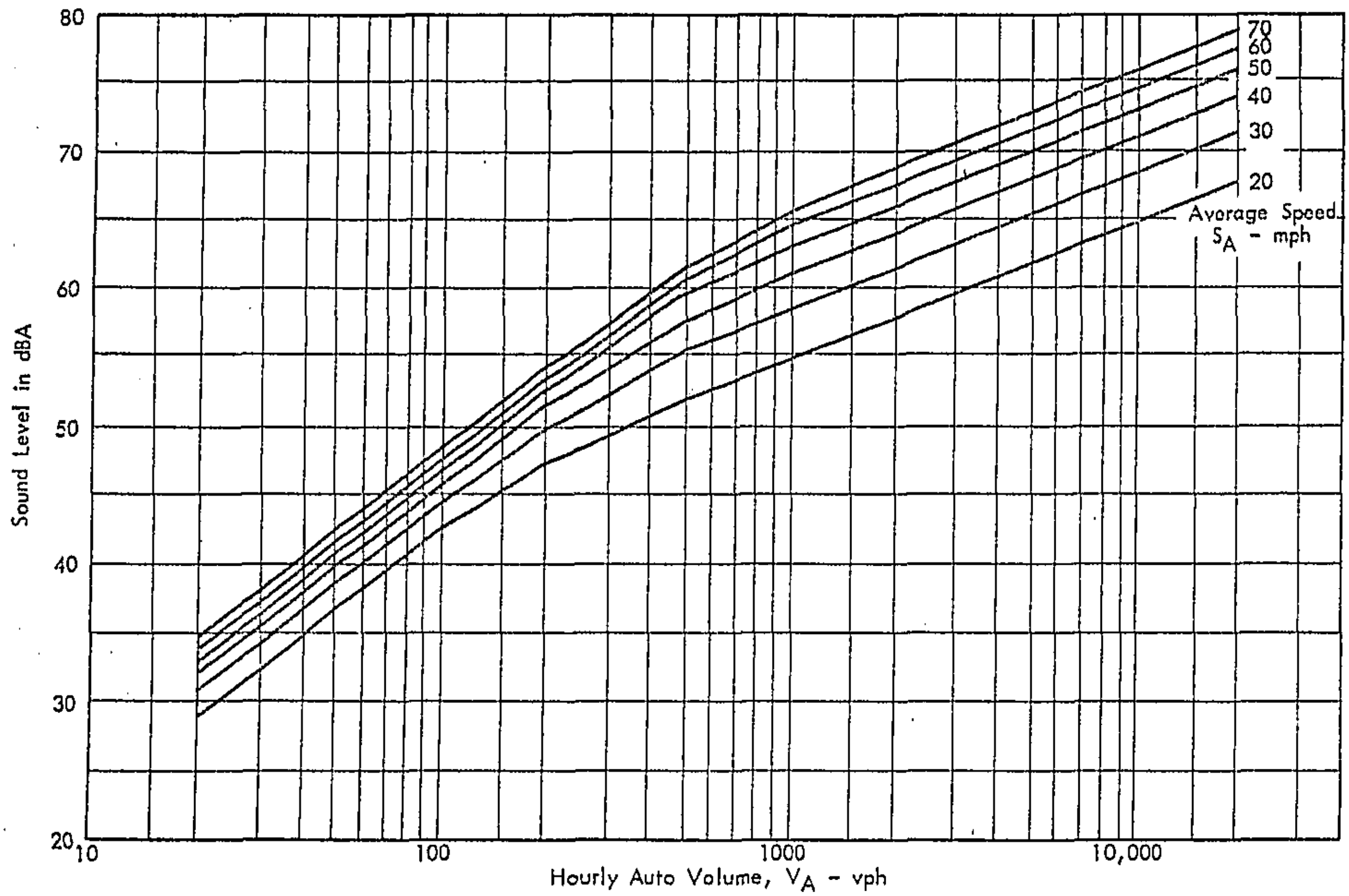


FIGURE B.3 PLOT OF L_{50} FOR AUTOMOBILES AS FUNCTION OF VOLUME FLOW AND AVERAGE SPEED

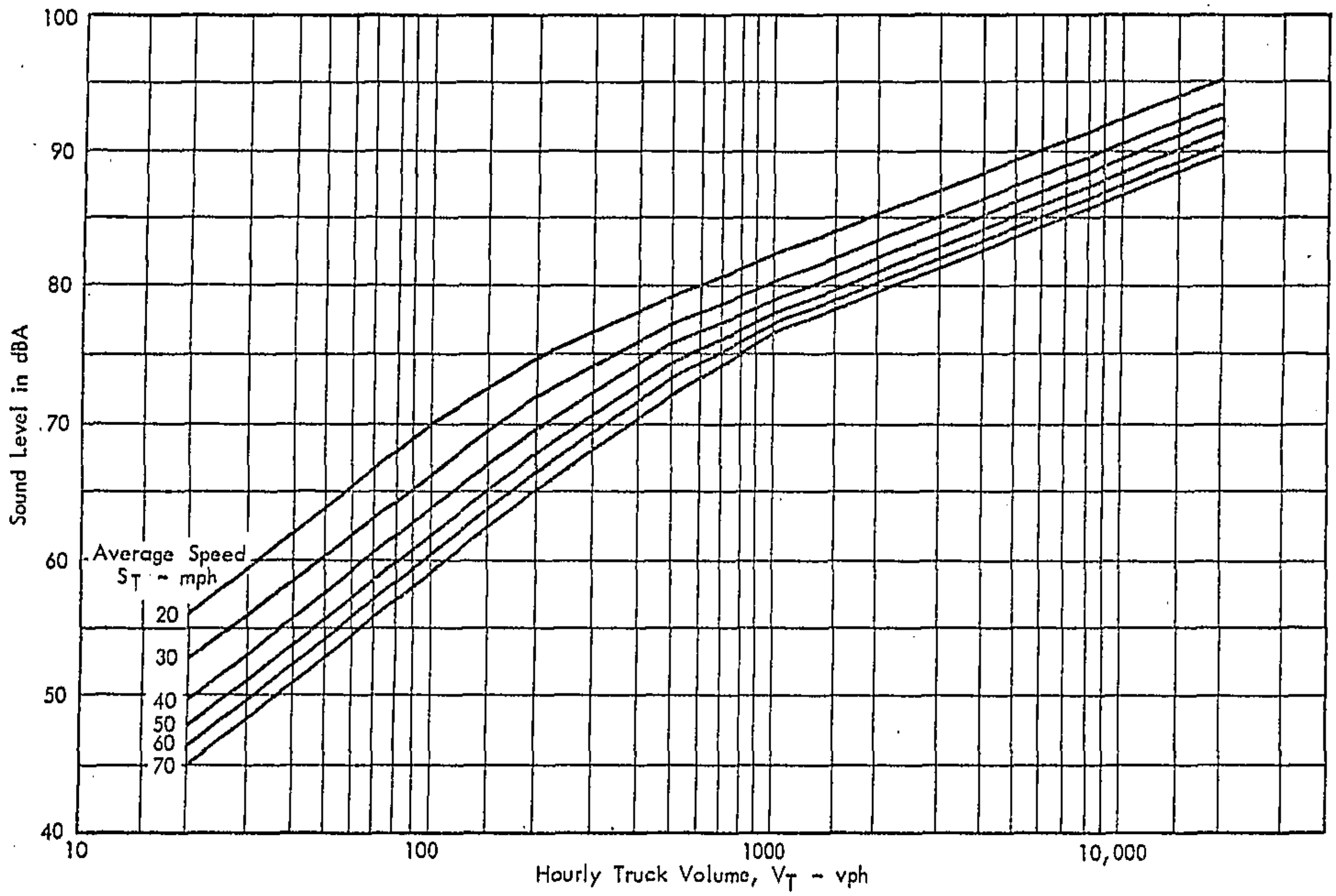


FIGURE B.4 PLOT OF L_{50} FOR TRUCKS AS FUNCTION OF VOLUME FLOW AND AVERAGE SPEED

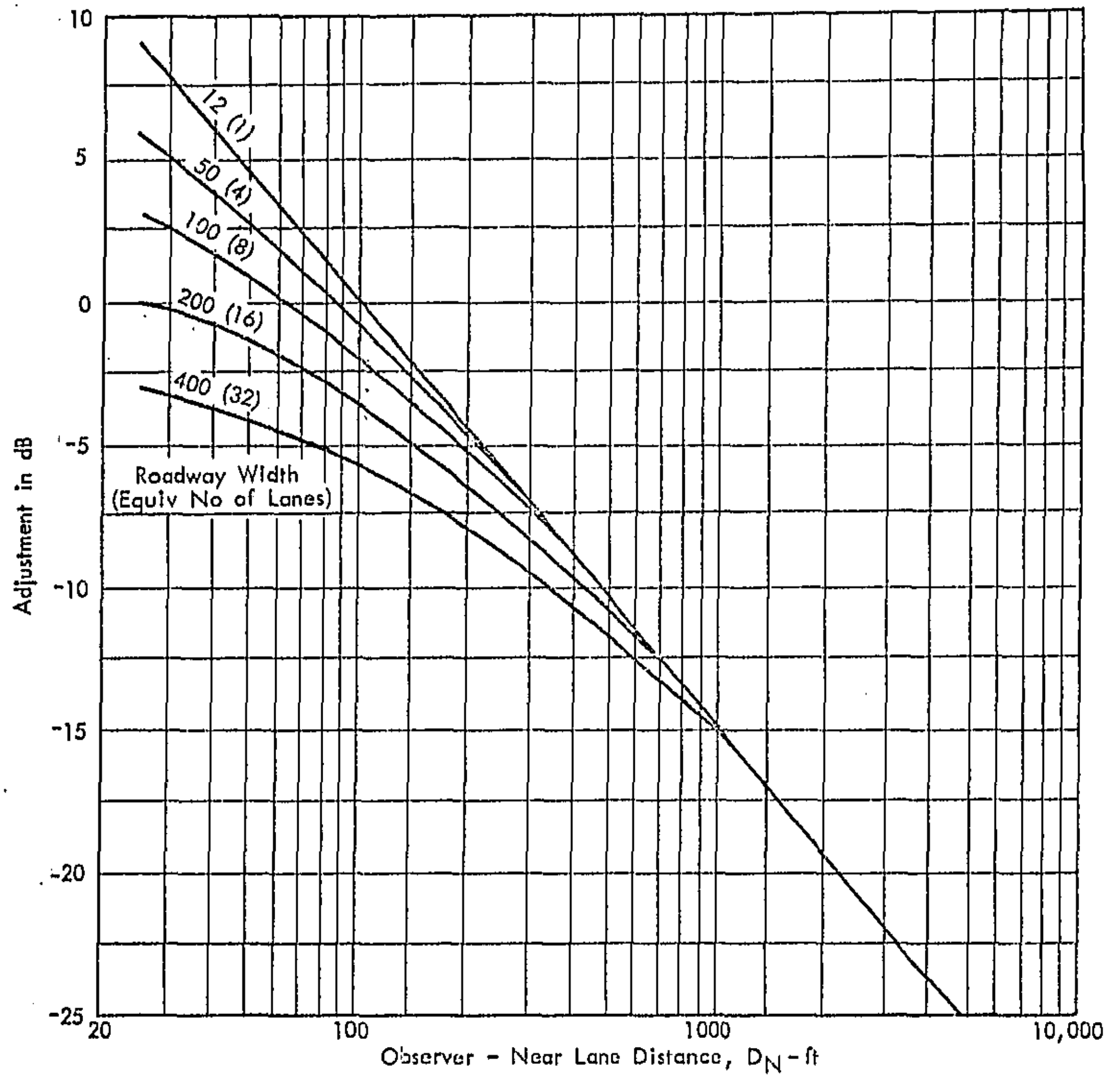


FIGURE B.5 DISTANCE ADJUSTMENT TO ACCOUNT FOR OBSERVER - NEAR LANE DISTANCE AND WIDTH OF ROADWAY

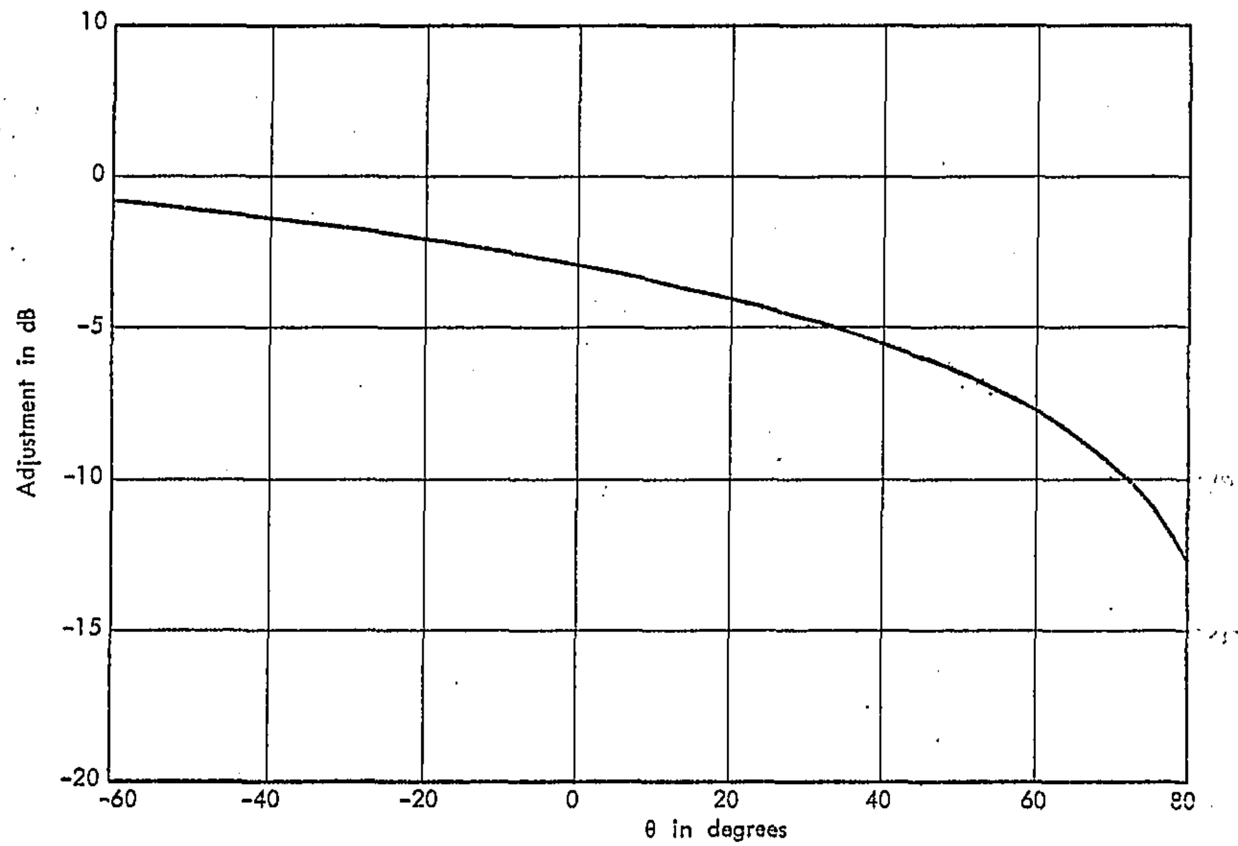


FIGURE B.6 ADJUSTMENT TO ACCOUNT FOR SEMI-INFINITE ELEMENT LENGTH

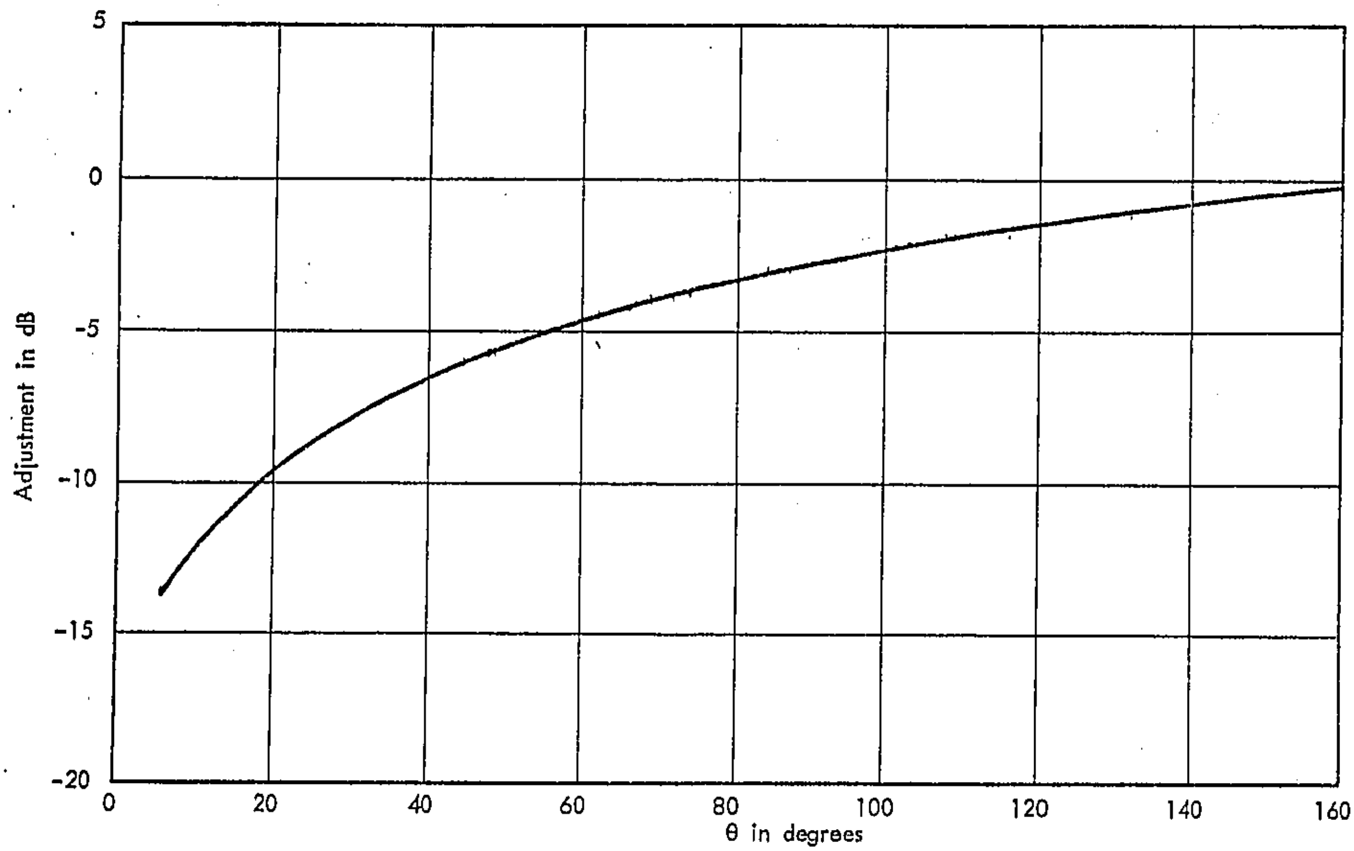


FIGURE B.7 ADJUSTMENT TO ACCOUNT FOR FINITE ELEMENT LENGTH

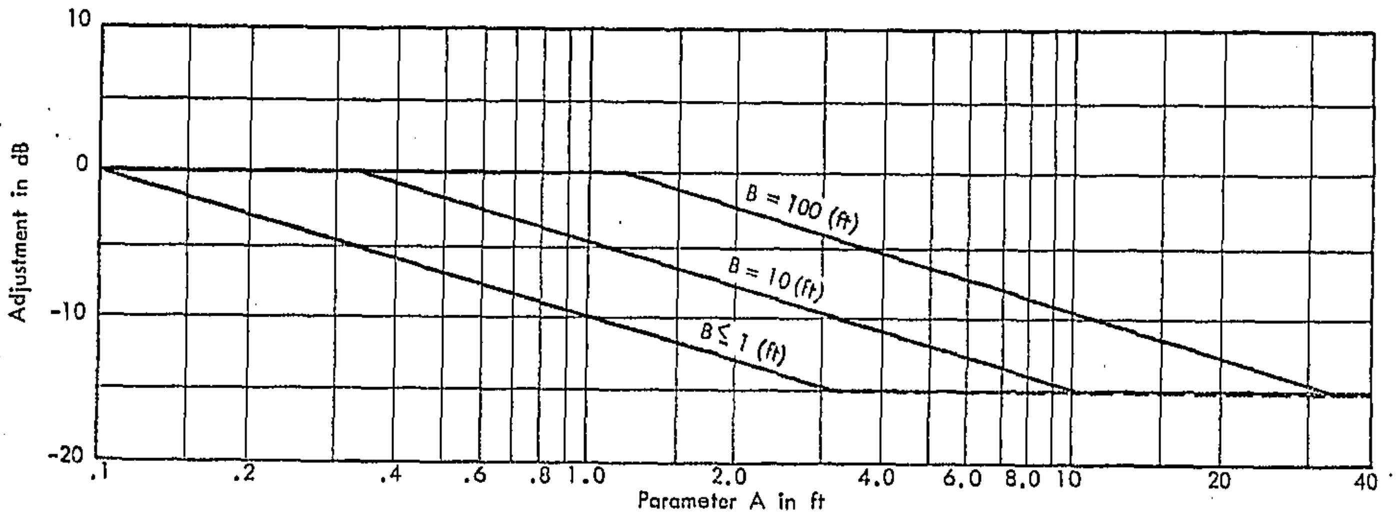


FIGURE B.8 ADJUSTMENT FOR ELEVATED AND DEPRESSED ROADWAY

ADJUSTMENT FOR FINITE BARRIER IN dB											
Infinite Barrier Performance	Parameter A										
	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
-5 dB	0	0	-1	-1	-1	-2	-2	-3	-4	-4	-5
-10 dB	0	0	-1	-1	-2	-3	-3	-4	-6	-7	-10
-15 dB	0	0	-1	-2	-2	-3	-4	-5	-7	-10	-15

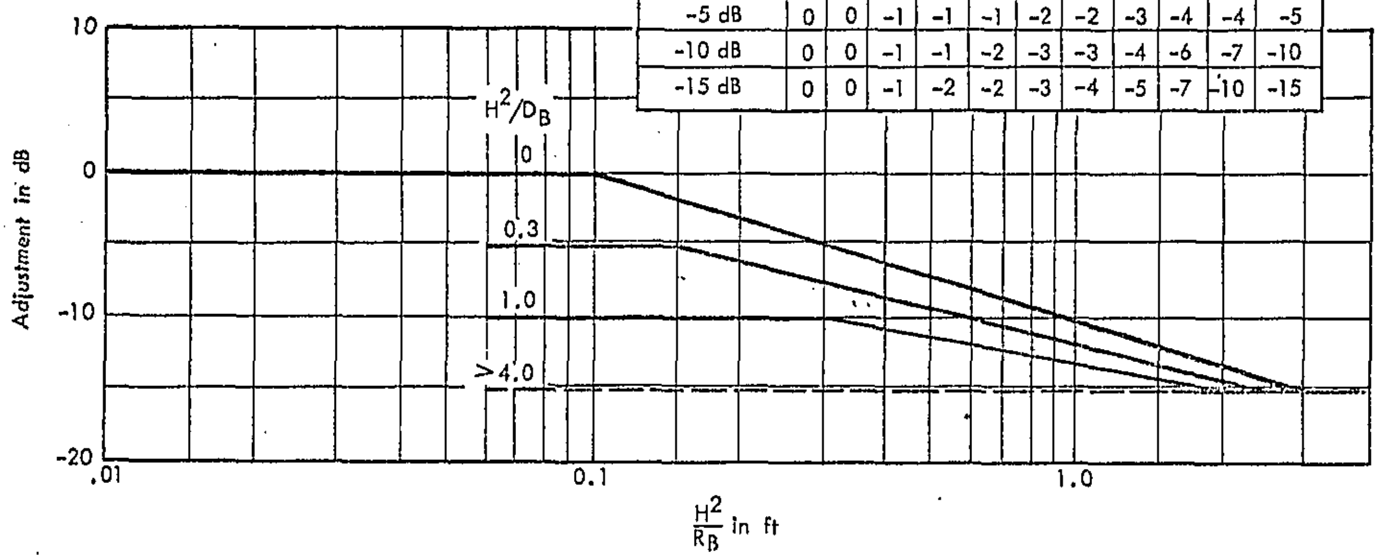


FIGURE B.9 ADJUSTMENT FOR ROAD-SIDE INFINITE BARRIERS

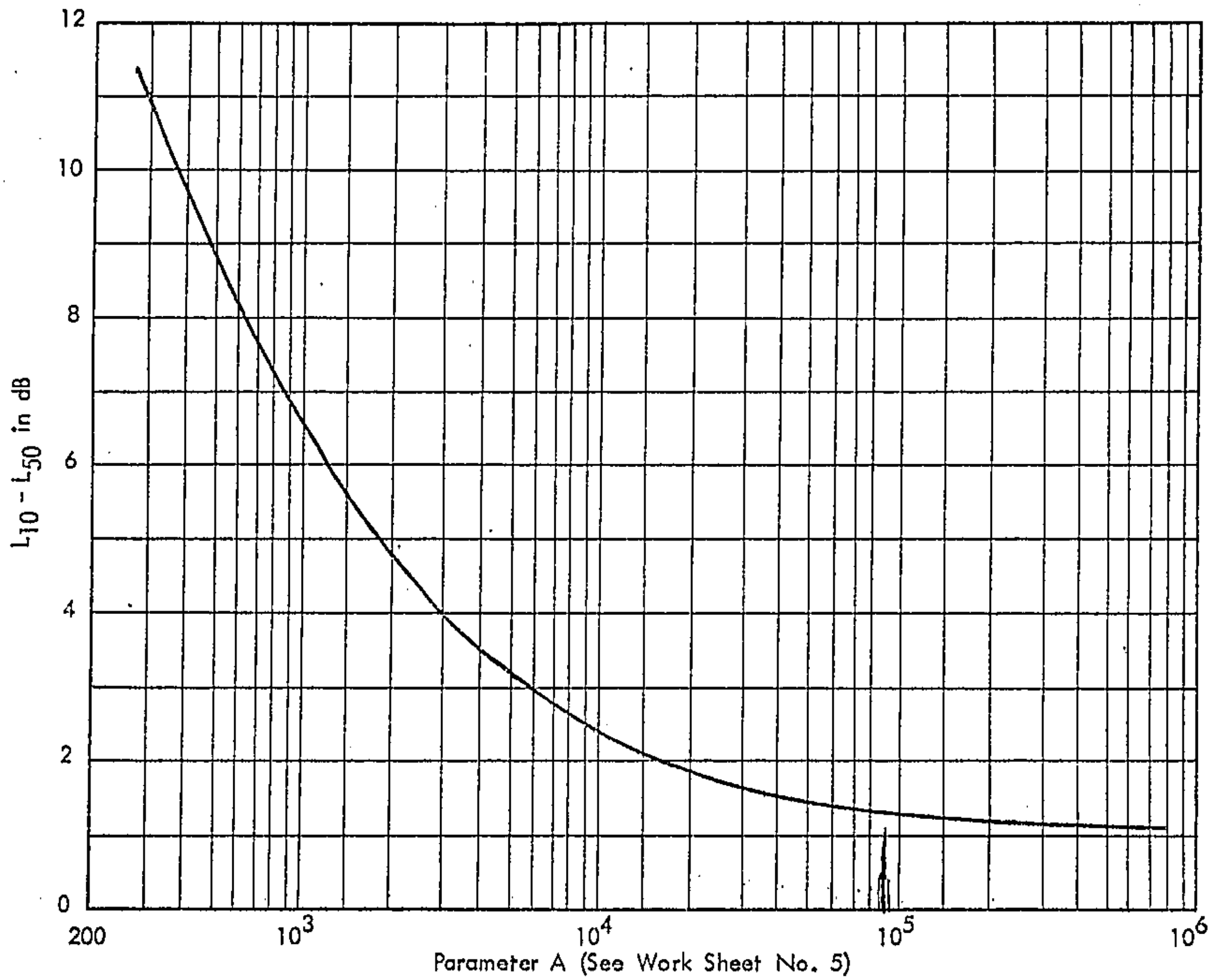


FIGURE B.10 ADJUSTMENT TO L_{50} TO OBTAIN L_{10}

PERCENTAGE GRADIENT	%	≤ 2	3 - 4	5 - 6	≥ 7
ADJUSTMENT IN dB	dB	0*	+2	+3	+5

* The influence of gradients of 2% or less is considered to be negligible

TABLE B.1 ADJUSTMENT FOR INCREASED NOISE LEVEL OF TRUCKS ON GRADIENTS

Surface Type	Description	Adjustment in dB
Smooth	Very Smooth, Seal Coated Asphalt Pavement.	-5
Normal	Moderately Rough Asphalt and Concrete Surface.	0
Rough	Rough Asphalt Pavement with Large Voids 1/2" or Larger in Diameter, Grooved Concrete.	+5

TABLE B.2 CLASSIFICATION OF ROAD SURFACE AS IT RELATES TO SURFACE INFLUENCE ON VEHICLE NOISE

VEHICLE TYPE	ADJUSTMENT IN dB	
	L_{50}	L_{10}
AUTOS	0	+ 2
TRUCKS	0	+ 4

TABLE B.3 LEVEL ADJUSTMENT FOR INTERRUPTED FLOW

Source	Sound Level - dB	Antilog Columns - Left Digit of Sound Level								Antilog Table	
		9	8	7	6	5	4	3	2	Right Digit of Sound Level	Antilog
1	65				3	1	6	2		0	1000
2	73			1	9	9	5			1	1259
3	69				7	9	4	4		2	1585
4	82		1	5	8	5				3	1995
5	56					3	9	8	1	4	2512
										5	3162
										6	3981
										7	5013
										8	6311
Total	83		1	8	9	9	5	4	1	9	7944

COMMENTS ON EXAMPLE

For 65 dB, enter antilog table with "5" to obtain the antilog "3162", etc.

Enter "3162" on work sheet, with "3" in column 6, since the left digit of 65 dB sound level is "6". This is done for all the other listed sound levels. The column in the example add to 1899541. Round off to four digits - 1900. From antilog table, 1900 is closest to 1995, the antilog of "3". The right digit of the total sound level is therefore "3".
In the example, the left most digit of the total sound level antilog is "1" and it appears in the column headed "8". The left digit of the total sound level is therefore "8", which with Step 5 determines the total sound level as "83".

The total sound level of 65, 73, 69, 82, and 56 dB is thus 83 dB.

TABLE B.4 EXAMPLE FOR DECIBEL ADDITION

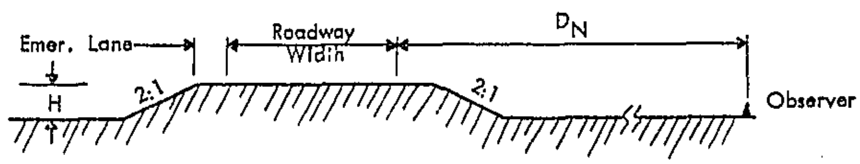
Observer Category	STRUCTURE			L_{50} DAY	L_{50} NIGHT	L_{10} DAY	L_{10} NIGHT
1	Residences		Inside*	45	40	51	46
2			Outside*	50	45	56	51
3	Schools		Inside*	40	40	46	46
4			Outside*	55	-	61	-
5	Churches		Inside	35	35	41	41
6	Hospitals		Inside	40	35	46	41
7	Convalescent Homes		Outside	50	45	56	51
8	Offices	Inside	a) Stenograph	50	50	56	56
			b) Private	40	40	46	46
9	Theaters		a) Movies	40	40	46	46
			b) Legitimate	30	30	36	51
10	Hotels, Motels		Inside	50	45	56	51

* Either inside or outside design criteria can be used depending on the utility being evaluated

TABLE B.5 RECOMMENDED DESIGN CRITERIA

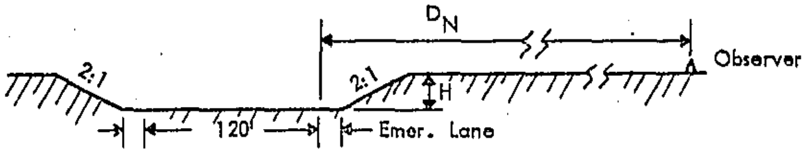
	DISTANCE FROM OBSERVER TO NEAR-LANE IN FEET																			
	50	100	150	200	250	300	350	400	450	500	600	700	800	900	1000	1200	1400	1600	1800	2000
Distance Adjustment in dB	0	-2	-5	-7	-8	-9	-10	-10	-11	-11	-12	-13	-13	-14	-15	-16	-17	-18	-19	-20

TABLE B.6 DISTANCE ADJUSTMENT TO ACCOUNT FOR OBSERVER - NEAR LANE DISTANCE AND A 120 FOOT ROADWAY WIDTH



Height of Elevation Roadway	Distance from Observer to Near Lane (D_N)						
	100'	200'	300'	400'	600'	800'	1600'
H (feet)	Adjustment in dB						
5	- 5.0	- 1.0	0	0	0	0	0
10	-10.0	- 6.5	- 4.5	- 3.5	- 1.5	0.5	0
15	-12.0	- 9.0	- 7.0	- 5.5	- 3.5	- 2.0	- 0.5
20	-12.5	- 9.0	- 7.5	- 6.0	- 4.0	- 2.5	- 1.0
25	-13.5	-10.0	- 8.5	- 7.0	- 5.0	- 3.5	- 1.0
30	-14.5	-11.5	- 9.5	- 8.0	- 6.0	- 4.5	- 1.5
40	-15.0	-13.5	-11.0	- 9.5	- 7.5	- 6.0	- 2.5
50	-15.0	-14.0	-12.0	-10.5	- 8.5	- 7.0	- 4.0

TABLE B.7 ELEVATED ROADWAY ADJUSTMENT FOR SHORT METHOD ONLY



Depth of Depressed Roadway	Distance from Observer to Near Lane (D_N)						
	100'	200'	300'	400'	600'	800'	1600'
H (feet)	Adjustment in dB						
0	0	0	0	0	0	0	0
5	- 6.0	- 5.5	- 5.0	- 5.0	- 5.0	- 5.0	- 5.0
10	-10.5	-10.5	-10.5	-10.5	-10.5	-10.5	-10.5
15	-13.0	-13.5	-13.5	-13.5	-13.5	-13.5	-13.5
20	-12.0	-14.0	-14.0	-14.0	-15.0	-15.0	-15.0
25	-11.0	-14.0	-15.0	-15.0	-15.0	-15.0	-15.0
30	-10.0	-14.5	-15.0	-15.0	-15.0	-15.0	-15.0
40	- 9.0	-14.5	-15.0	-15.0	-15.0	-15.0	-15.0
50	-	-14.5	-15.0	-15.0	-15.0	-15.0	-15.0

TABLE B.8 DEPRESSED ROADWAY ADJUSTMENT FOR SHORT METHOD ONLY

Observer Category	STRUCTURE	GEOGRAPHIC AREA	CONDITION	
			Open Windows	Closed Windows
1	Residences	South & South West	12	20
		North & North East	17	25
3	Schools	South & South West	12	20
		North & North East	17	25
5	Churches	All Areas	20	30
6	Hospitals Convalecent Homes	All Areas	17	25
8	Offices	All Areas	17	25
9	Theaters	All Areas	20	30
10	Hotels, Motels	South & South West	12	20
		North & North East	17	25

TABLE B.9 OUTSIDE - INSIDE NOISE REDUCTION

PREDICTED NOISE LEVEL - CRITERION LEVEL IN dB

PREDICTED NOISE LEVEL - AMBIENT LEVEL IN dB

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	>10
0												X	X	X	X	X						
1												X	X	X	X	X						
2												X	X	X	X	X						
3												X	X	X	X	X						
4												X	X	X	X	X						
5												X	X	X	X	X						
6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
14	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
>15																						

NO IMPACT

SOME IMPACT

GREAT IMPACT

TABLE B.10 IMPACT EVALUATION WHEN PREDICTED NOISE LEVELS EXCEED CRITERIA

APPENDIX C

FIGURES

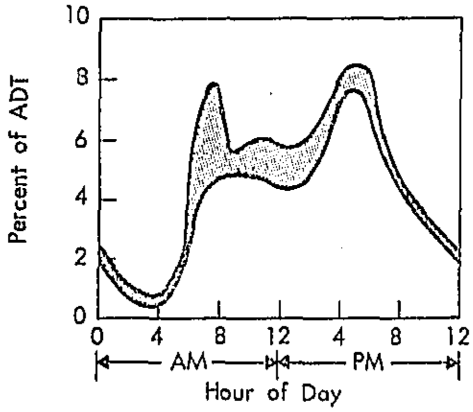


FIGURE C.1 ILLUSTRATIVE HOURLY VOLUME VARIATION WITH TIME OF DAY

(Derived from Highway Capacity Manual, Fig 3.6 and 3.7, Relating to Weekday Traffic on Rural and Urban Highway)

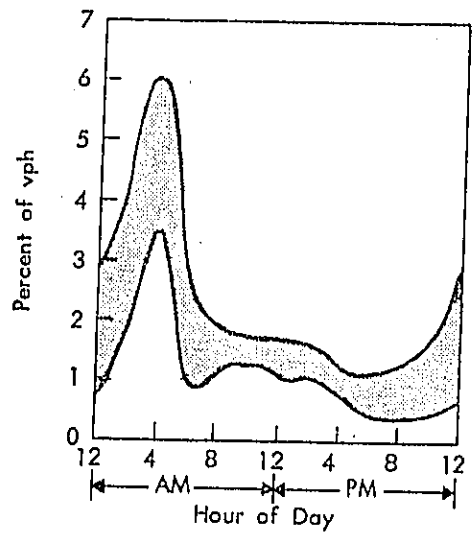


FIGURE C.2 ILLUSTRATIVE TRUCK/VEHICLE MIX VARIATION WITH TIME OF DAY

(Derived from Highway Capacity Manual, Fig 3.3, relating to Commercial Vehicle Activity on Urban Highways)

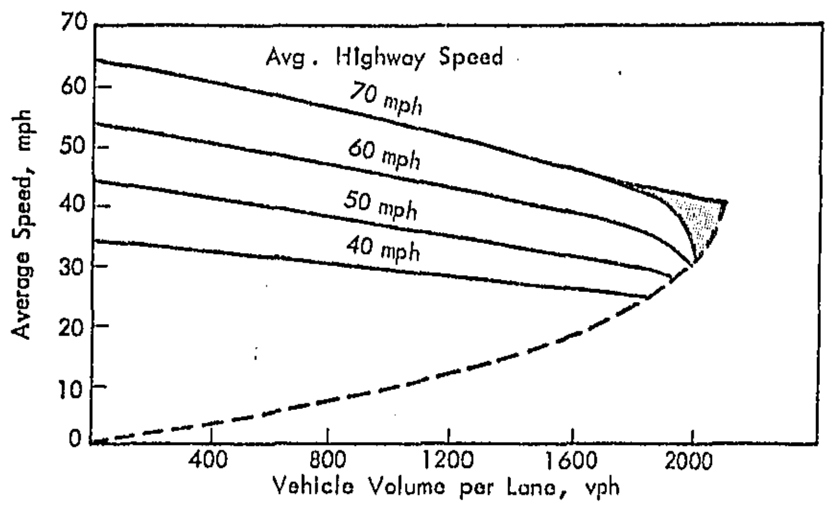


FIGURE C.3 ILLUSTRATIVE RELATIONSHIP BETWEEN TRAFFIC VOLUME PER LANE AND AVERAGE SPEED OF VEHICLE TRAVEL FOR UNINTERRUPTED FLOW

(Derived from the Highway Capacity Manual, Fig 3.41, for 6 Lane Freeways and expressways. For Different Road Configurations Use Appropraite Data From This Reference)