ACOUSTICAL ASSESSMENT PROCEDURE

FOR

ROADWAY IMPROVEMENT PROJECTS

Prepared for

CITY OF RIVERSIDE, CALIFORNIA

July, 1992

This document was adopted as part of the 1994 General Plan and is incorporated into the General Plan 2025 as this Appendix. The procedure remains as adopted in 1994 with the exception of Figure 2 – Land Use Compatibility For Community Noise Environments Outdoor Noise Levels which has been updated to reflect current practices.

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I. INTRODUCTION AND OVERVIEW

This report provides recommended guidelines for assessing the acoustical impacts resulting from roadway projects, as well as for establishing the threshold sound level increase values for these projects. Background material is included relating to sound level descriptors, which have been proposed by various investigators and agencies, and to the choice of the Land Use Compatibility Guidelines which have been previously recommended by Earth Metrics for inclusion in the City of Riverside Noise Element. Modelling procedures are described for use in calculating the existing and post construction sound levels for roadway projects. Discussion and guidelines are provided on impact evaluations in reference to City of Riverside Noise Element standards. Also discussion is included on CALTRANS/Federal Highway Administration (FHWA) acoustical criteria and procedures.

II. BACKGROUND

(a) Effects of Noise on People. Scientific literature is clear that excessive noise levels can have adverse effects on people, in terms of both physical and mental aspects, as well as in terms of the level of enjoyment of the environment. Some of these effects are difficult to measure, partly because individuals may vary appreciably in their sensitivity to noise. Nonetheless, noise effects are very real and can be quite significant. The following is a discussion of some of the possible effects of excessive noise:

Hearing Loss. Excessive noise can lead to a permanent deterioration in hearing ability which cannot be offset either through surgery or hearing aids. Although hearing loss normally occurs only after prolonged exposure to intensive noise, long-term exposure to moderately loud sounds has been known to cause hearing degradation.

Stress Effects. Excessive noise, especially above the level of 80 dBA, triggers a number of automatic physiological changes in the body. Usually these stress reactions (such as vascular constriction or blood pressure elevation) are only temporary, but as high noise levels become common, some of these effects may become chronic.

Sleep Disturbance. Obviously, noise can interfere with sleep and lead to fatigue, but sometimes in ways in which a sleeper is unaware. A sound which is insufficient to wake someone may still impair the quality of sleep.

(b) Acoustical Descriptors. A large number of sound level descriptors have been proposed for use with transportation noise and other community noise. One of the primary ways in which these descriptors can be classified relates to the treatment of the sound frequency spectrum. A second primary means of classification is concerned with the time variation or "time history" characteristics or the time "dimension" of the noise; transportation noise is inherently a fluctuating quantity.

In terms of the way the sound frequency characteristics are treated, two of the primary types of descriptors which have been prominently considered include "loudness" and sound level. Loudness, quantified in "sones" is calculated by a mathematical formula based on the levels in a series of nine octave frequency bands. Sound levels, on the other hand, can be read out directly from the measuring instrument (Sound Level Meter) using appropriate "weighting networks". There are several types of sound levels, labeled A-weighted, B-weighted, and C-weighted, which are obtained with appropriate meter settings. The type of sound level commonly used for rating of community noise is the "A-weighted" level, discussed further below. The A-weighting network, used to measure this level, deemphasizes low frequency noise, and is intended to represent the response of the human ear.

In terms of time variation, one approach has been the use of statistical exceedance percentages. For example, the L10, L50 and L90 are defined as sound levels exceeded ten percent, 50 percent, and 90 percent of the time, respectively. A second major approach has involved the use of the equivalent continuous level, or equivalent energy level, abbreviated "Leq". The Leq is described as a "dosage" type measure and is defined as the level of a steady noise which has the same sound energy content as a given time-varying noise.

The U.S. Environmental Protection Agency (EPA), based on studies described in its "levels" document (1974), has recommended the use of the A-weighted sound levels to account for noise frequency characteristics, and the use of the Leq to account for time-varying properties of the sound. Specifically, the descriptor recommended by EPA is the Day-Night average sound level (Ldn), which is a 24 hour A-weighted value of the Leq, with a nighttime "weighting" factor applied (see the Appendix for definitions).

In terms of the appropriate numerical value of the sound level for residential land use, the US EPA has reviewed the results of various studies (such as those illustrated in Figure 1) concerning the reaction of people to different absolute levels of noise (U.S. EPA, 1974). From studies of this type, the US EPA has recommended 55 Ldn as a long range goal and 60 Ldn as a short range goal for outdoor sound levels at residential land use. The State of California Office of Noise Control has recommended similar standards as the U.S. EPA. In Earth Metrics experience, a sound level limit of 60 Ldn or CNEL is the one most commonly applied by local jurisdictions in California.

<u>(c) Comments from California Office of Noise Control</u>. Consultation was held by Earth Metrics with Mr. Russell Dupree, State of California Office of Noise Control (1992), regarding the sound level increase for a project which would typically be considered to represent an impact. Mr. Dupree noted that, based on Office of Noise Control experience, a three decibel increase in sound level (that is in the Ldn/CNEL) would generally be considered to be an impact, with an attendant need to address sound mitigation measures. However, as he also stated, it is difficult to make a categorical statement since this could vary with the environmental setting. For example, the increase and consequent impact would be more critical in a national park then at some other location. Another factor which needs to be considered is the absolute Ldn/CNEL level and whether the final level is in excess of the land use compatibility guidelines. Note the absolute level is simply the value of the Ldn/CNEL, for example, whether it is over 60, or between 60 and 70 (see Part III (b), page 7). The Land Use Compatibility Guidelines which have been recommended by Earth Metrics for the City of Riverside Noise Element are shown in Figure 2. Note: See page A-3 of the Noise Element (Earth Metrics Incorporated, 1991).

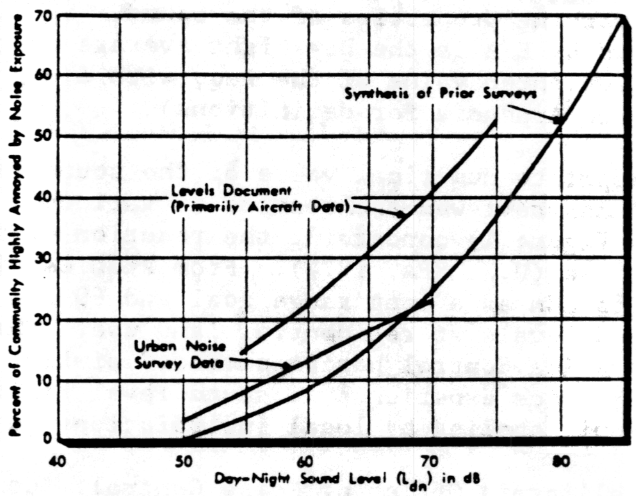

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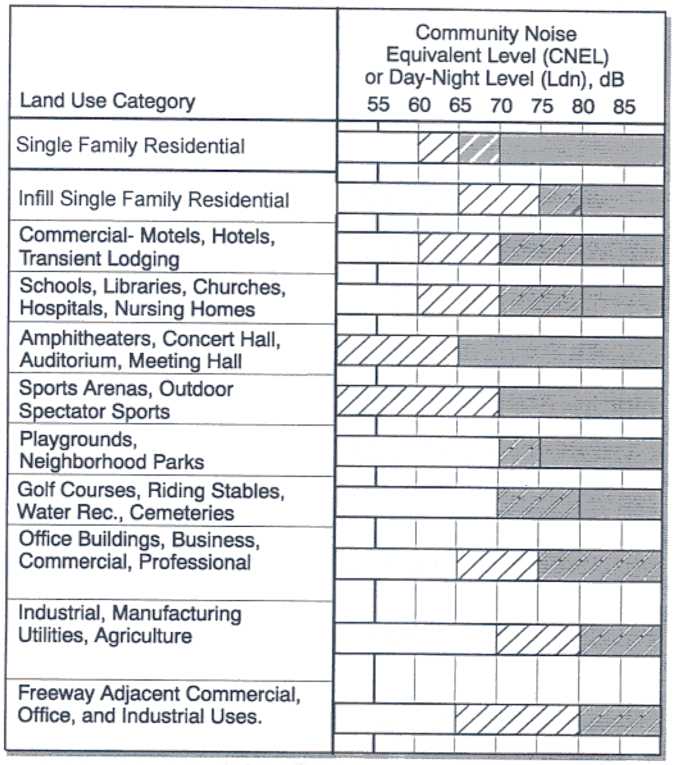
FIGURE 1. THREE RELATIONSHIPS BETWEEN ANNOYANCE AND OUTDOOR NOISE EXPOSURE

Source: Community Noise, American Society for testing and Materials, Stp 692, 1979



Nature of the noise environment where the CNEL or Ldn level is:

Below 55 dB
Relatively quiet suburban or urban areas, no arterial streets within 1 block, no freeways within 1/4 mile.

55-65 dB
Most somewhat noisy urban areas, near but not directly adjacent to high volumes of traffic.

65-75 dB
Very noisy urban areas near arterials, freeways or airports.

75+ dB
Extremely noisy urban areas adjacent to freeways or under airport traffic patterns. Hearing damage with constant exposure outdoors.

Normally Acceptable
Specific land use is satisfactory, based on the assumption that any
building is of normal conventional construc-tion, without any special

Conditionally Acceptable
New construction or development should be undertaken only after a detailed analysis of noise reduction require-ments is made and needed noise insulation features included in design. Conventional construction, but with closed windows and fresh air supply systems

Normally Unacceptable
New construction or development should generally be discour-aged. If new construc-tion or development does proceed, a de-tailed analysis of noise reduction requirements must be made and needed noise insulation features included in design.

Clearly Unacceptable
New construction or development should generally not be undertaken.

The Community Noise Equivalent Level (CNEL) and Day-Night Noise Level (Ldn) are measures of the 24-hour noise environment. They represent the constant A-weighted noise level that would be measured if all the sound energy received over the day were averaged. In order to account for the greater sensitivity of people to noise at night, the CNEL weighting includes a 5-decibel penalty on noise between 7:00 p.m. and 10:00 p.m. and a 10-decibel penalty on noise between 10:00 p.m. and 7:00 a.m. of the next day. The Ldn includes only the 10-decibel weighting for late-night noise events. For practical purposes, the two measures are equivalent for typical urban noise environments.

SOURCE: STATE DEPARTMENT OF HEALTH,
AS MODIFIED BY THE CITY OF RIVERSIDE

FIGURE 2. LAND USE COMPATIBILITY FOR COMMUNITY NOISE ENVIRONMENTS OUTDOOR NOISE LEVELS

III. ESTABLISHMENT OF SCREENING GUIDELINES

(a) Factors Affecting Traffic Noise. Primary factors affecting traffic noise include: vehicle volume; vehicle speeds; type of vehicles; and receptor distance. In addition, other factors which become significant at times include: roadway surface; roadway grade; roadway elevation or depression; terrain and topography; and shielding by intervening structures. Roadway grade, along with the type of brakes, is a significant factor for trucks but not generally for automobiles. Elevated and depressed roadways both result in reduced sound levels relative to the at-grade configuration, as can be seen from Figure 3. The effect of the elevation difference on sound levels is less at the upper floor levels than at the ground and first floor level. For elevated roadways, the effect of the elevation difference is significant only out to a certain distance, typically 300 feet from the roadway edge of pavement as indicated in Figure 3.

In general, where the roadway is shielded by local terrain, the sound level is naturally reduced. For example, if one half of the roadway and traffic is shielded at the near lanes of a depressed roadway, the sound levels will be reduced approximately three dBA. As a general rule, if the roadway and traffic is three quarters shielded, the sound levels will be reduced by an amount up to six decibels. In some cases, the primary change associated with a project will be in the traffic volume. The sound energy emitted is directly proportional to the traffic volume, with the result that the Leq is given by the equation:

$$Leq = 10 \log V_2/V_1$$

Where: Leq is the equivalent energy level (and the basis of the Ldn)

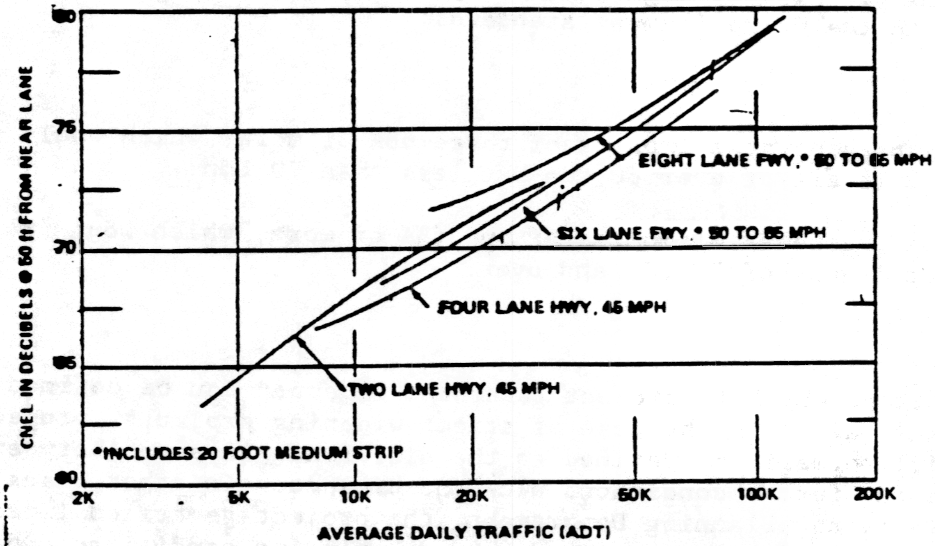
V_2 = traffic volume after the project
V_1 = existing traffic volume

To illustrate this relation, a doubling of the traffic volume (if other factors remain equal) results in a sound level increase of three dBA (in terms of Leq and Ldn). Likewise, a tripling of the traffic volume would result in a sound level increase of five dBA. A 25 percent increase in the traffic volume would result in a one dBA increase in the Leq/Ldn.

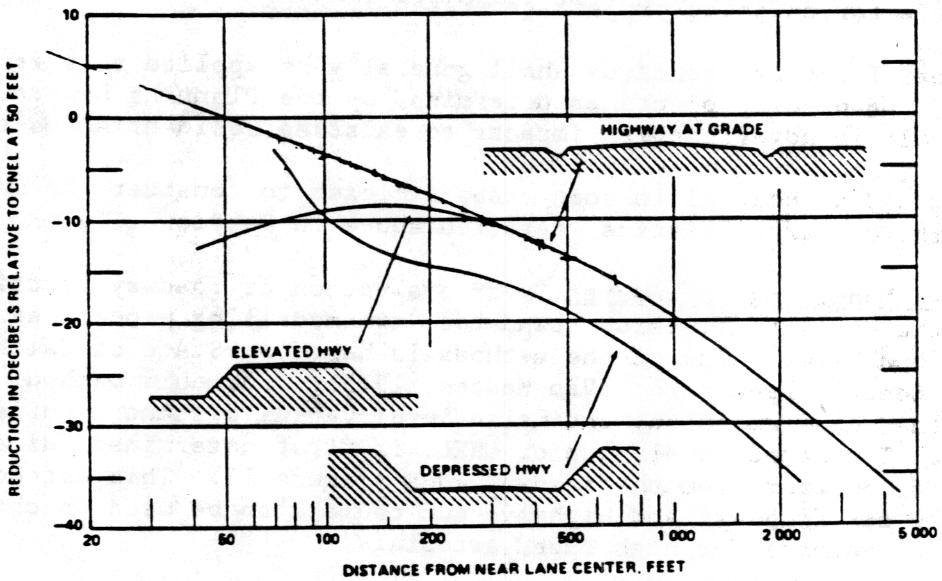
In some cases, specific information on projected traffic mix and speed are not available; it is commonly assumed in this case that the future values are similar to those existing. It is of course advisable to obtain any information available relative to these quantities. This is especially important for newly opened roadways.

It is noted that, in addition to the effect of the numerical increases in sound levels, changes in the perceived character of a neighborhood can occur with the introduction of heavy trucks and an increase in the traffic speed.

In some cases, sports cars can have a disproportionate effect on the sound levels and neighborhood character.



CNEL for traffic noise (heavy truck to auto mix of 4%)



CNEL reduction for various highway configurations

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FIGURE 3. SOUND LEVEL CALCULATION CURVES

Source: Noise Control Engineering Journal, 1975

(b) Assessment under City of Riverside General Plan. Based on a review of current practice, consultation with State of California Office of Noise Control guidelines published by the U.S. EPA and other investigators as described above, Earth Metrics recommends the following criteria for determining potentially significant impacts on existing residential uses in reference to the Noise Element standards:

> Project-generated impacts of three dBA or more, which would result in sound levels of over 60 Ldn but less than 70 Ldn.
>
> Project-generated impacts of one dBA or more, which would result in sound levels of 70 Ldn and over.

It should be noted that "project generated impacts" can be defined in a number of different ways. In the case of street widening projects, project-generated impacts will normally be defined as the difference in sound between existing conditions and future conditions plus the project. In other cases as deemed appropriate by the Planning Department, the project-generated impacts will be defined as the difference in sound between existing conditions and existing conditions plus the project. The Planning Department shall in all cases be responsible for defining project-generated impacts.

The above-referenced standards shall generally be applied to street widening projects, and other projects as determined by the Planning Department that could result in adverse noise impacts to existing residential uses.

Also it would be helpful in some cases at least to consider the matter of "neighborhood characteristics" referred above in Section IIIa.

(c) Noise Modelling Procedures. For evaluation of roadway traffic noise against the City of Riverside standards, two modelling procedures can be used as described below. One of the methods is based on State of California Office of Noise Control procedures (Van Houten, 1975). For this method, reference is made to the noise emission, and noise level versus distance, curves shown in Figure 1. The sound level, Ldn or CNEL, is first determined for a reference distance of 50 feet from the roadway edge (Figure 1). This method is applicable for freeways and highways but could also be used to obtain a reasonable estimate for high speed arterials.

A second method, more appropriate for city street analysis, will be used by the city for evaluation of transportation noise. The procedure is based on FHWA data and procedures (1978). The FHWA procedure predicts noise through equations requiring a detailed analysis of the noise sources and roadway characteristics (refer to the manual). A quick, preliminary calculation can be made by using nomograph procedures (see Figure 4).

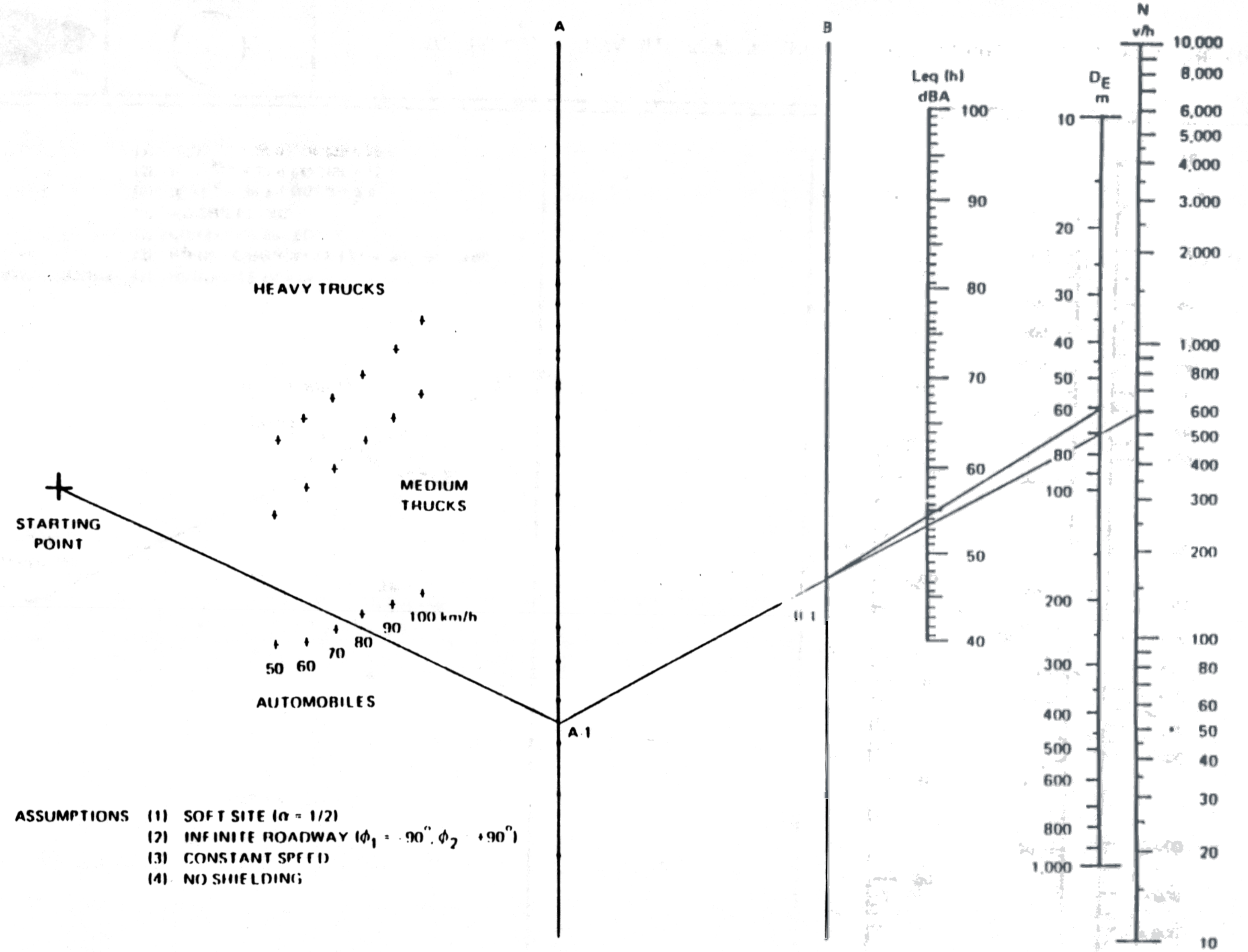

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FIGURE 4a. FHWA HIGHWAY TRAFFIC NOISE PREDICTION NOMOGRAPH (SOFT SITE)

Source: Federal Highway Administration, 1978

PROBLEM 13 (Continued)

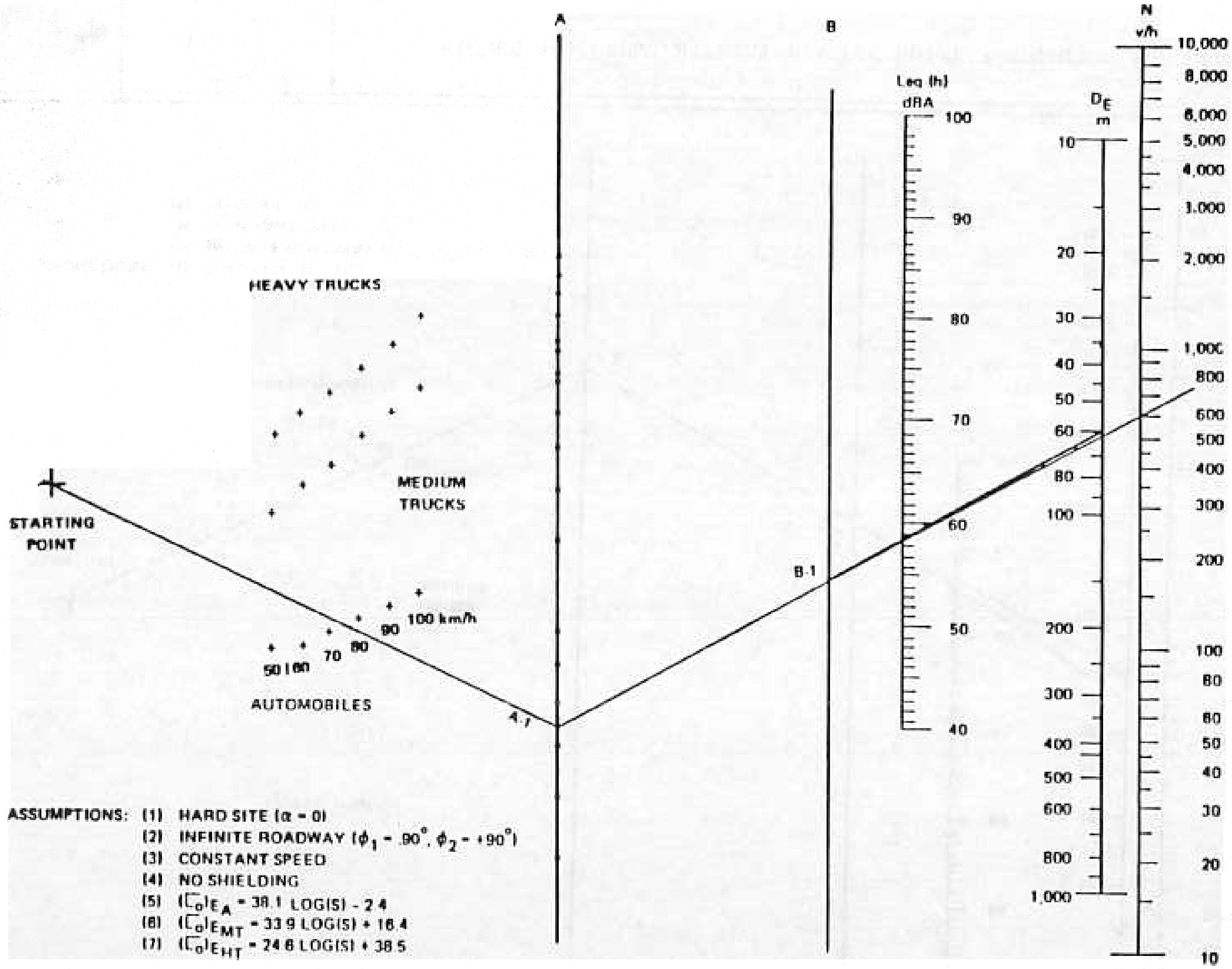

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FIGURE 4b. FHWA HIGHWAY TRAFFIC NOISE PREDICTION NOMOGRAPH (HARD SITE)

Source: Federal Highway Administration, 1978

The required nomograph input quantities include the number of heavy trucks, medium trucks and automobiles per hour as well as the speed and the distance. The distance in question is the "equivalent distance" which for most planning purposes can be considered to be measured from the center line of the roadway to the receptor. Calculations are made separately for each type of vehicle and the results are subsequently combined by the process of decibel addition (see Table 1).

To use the nomograph, one first draws a line through the starting point and the respective speed point for automobiles (or medium or heavy trucks, as the case may be), and then marks the intersection of that line with the vertical line marked "A", as illustrated in Figure 4. From that point on line A, referred to as point "A-1" in the example, a second line is drawn to intersect the vertical line labeled "N" at the far right side of the nomograph at the appropriate traffic volume point; the point where this line intersects line A is then marked (shown in the illustration as point "B-1"). Then from point "B-1", a third line is drawn to the vertical line labelled "D" at the appropriate effective distance expressed in meters (to convert the distance in feet to distance in meters divide by 3.28). The intersection of this line with the Leq (h) line is then read as the result: that is, the equivalent energy level. (Note: "soft site" refers to typical grass-covered terrain; "hard site" refers to pavement or equivalent hard surface).

The procedure for converting from peak hour Leq to Ldn is as follows: Express peak hour traffic volumes as a percentage of the Average Daily Traffic (ADT). Determine the fraction of the ADT which occurs during daytime hours and the fraction for the nighttime hours. For Ldn calculation the hours between 10 P.M. and 7 A.M. are considered night hours. Then refer to Figure A-1 of the Appendix for the adjustment of the measured Leq value necessary to convert to Ldn. For example, if the peak hour is assumed to be 10 percent of the ADT and 70 percent of the ADT occurs during daytime hours, the final Ldn will be +2 dBA in reference to the measured Leq.

The procedure described above may be used to determine the approximate existing sound level at a given receptor location; likewise it may be used to predict the future level at the same location, and the results in terms of increase and final level evaluated against the impact criteria presented in Section IIIb. In some cases, the expected change is in the traffic volume only. (In many cases the traffic mix and the speed are assumed to remain the same as at present). If the roadway capacity is increased by adding lanes symmetrically on the "inside", that is, adjacent to the median, the effective distance would remain the same. In this case, the sound level increase could be calculated as:

$$10 \log_{10} \quad V_2/V_1$$

where V_2 = projected traffic volume
V_1 = existing traffic volume

The nomograph and other modelling procedures should be used with care. For environmental impact reports a more detailed noise evaluation should

TABLE 1. DECIBEL ADDITION

DIFFERENCE BETWEEN TWO LEVELS (dB)	ADD TO HIGHER LEVEL (dB)
0	3
1	2 1/2
2	2
3	2
4	1 1/2
5	1
6	1
7	1
8	1/2
9	1/2
10	1/2
More than 10	0

Source: Yerges, 1978.

include model calibration to verify the assumptions used for noise prediction. Model calibration requires actual field measurements of noise and prediction variables such as vehicle counts, speed surveys, shielding considerations, and terrain considerations. Noise measurements should be made at a minimum 50 foot equivalent distance (distance to roadway centerline), where possible.

The CALTRANS noise prediction model follows FHWA procedures. It is noted that CALTRANS normally uses sound measurement data to "calibrate," for terrain effects and other factors, the results obtained by modelling. It may also be noted that CALTRANS uses the "Calveno" noise emission curves. These curves for various vehicle types are intended to represent a refinement on the FHWA nomograph as applied to vehicle emissions in California.

(e) Sample Calculation. The following illustrates a calculation of traffic noise level using an roadway category described in the General Plan, that is for a 110-foot-wide (right-of-way), four lane, divided roadway, with approximate capacity of 33,000 vehicles per day. The day/night traffic split has been assumed to be 70/30 in percent of Average Daily Traffic (ADT); also the peak hour volume has been assumed to be ten percent of the ADT.

Vehicles per hour:	3,300 in peak hour
Equivalent distance (de):	90 feet (for typical residential setback)
Heavy truck percentage:	1.0 (assumed)
Heavy trucks per hour:	33
Automobiles per hour:	3,267
Speed:	40 mph (assumed)
Terrain:	"soft site"
Calculated Leq, autos:	65 dBA
Calculated Leq, trucks:	62.5 dBA
Total Leq:	67 dBA
Ldn:	69

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APPENDIX

GLOSSARY OF TERMS FOR NOISE ELEMENT

Noise: Any unwanted sound typically erratic in character within the normal frequency limits for hearing can be described as noise.

Decibel, dB: A unit of measurement describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micropascals (20 micronewtons per square meter).

A-Weighted Level: The sound level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter deemphasizes the very low and very high frequency components of the sound in a manner similar to the response of the human ear and gives good correlation with subjective reactions to noise. The A-weighted sound level is used in most current local, state, and federal standards and guidelines for community noise.

L10: The A-weighted sound level exceeded ten percent of the sample time. Similarly, L50, L90, etc. The L10 is sometimes referred to as the "intrusive" level, the L50 is a median or average level, and the L90 is frequently used as a measure of the "background" sound level.

Leq: Equivalent Energy Level, or the sound level corresponding to a steady state sound level containing the same total energy as a time varying signal over a given period. Leq is typically computed over 1-, 8-, and 24-hour sample periods.

CNEL: Community Noise Equivalent Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after addition of five decibels to sound levels in the evening from 7 P.M. to 10 P.M. and after addition of 10 decibels to sound levels in the nighttime from 10 P.M. to 7 A.M.

Ldn: Day-Night Average Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after addition of 20 decibels to sound levels in the nighttime after 10 P.M. and before 7 A.M.

Note: CNEL and Ldn represent daily levels of noise exposure averaged on an annual or daily basis, while Leq represents the equivalent energy noise exposure for a shorter time period, typically on hour. The CNEL and Ldn show approximate numerical equivalence for typical urban traffic noise conditions.

Noise Contours: Lines drawn about a noise source indicating equal levels of noise exposure. The CNEL is the metric utilized herein to describe annoyance due to noise and to establish land use planning criteria for noise.

Ambient Noise: The composite of noise from all sources near and far. In this context, the ambient noise level constitutes the normal or existing level of environmental noise at a given location.

Intrusive Noise: That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, time of occurrence, and tonal or information content as well as the prevailing noise level.

Noisiness Zones: Defined area within a community wherein the ambient noise levels are generally similar (within a range of five dB, for example). Typically, all other things being equal, sites within any given noise zone will be of comparable proximity to major noise sources. Noise contours define different noisiness zones.

Pure Tone: Any sound which can be judged as a single pitch or a set of single pitches.

Fixed Point Source: Any stationary source of noise (e.g., factory).

Line Source: Typically, a stream of transportation generated noise as produced from vehicle traffic and trains.

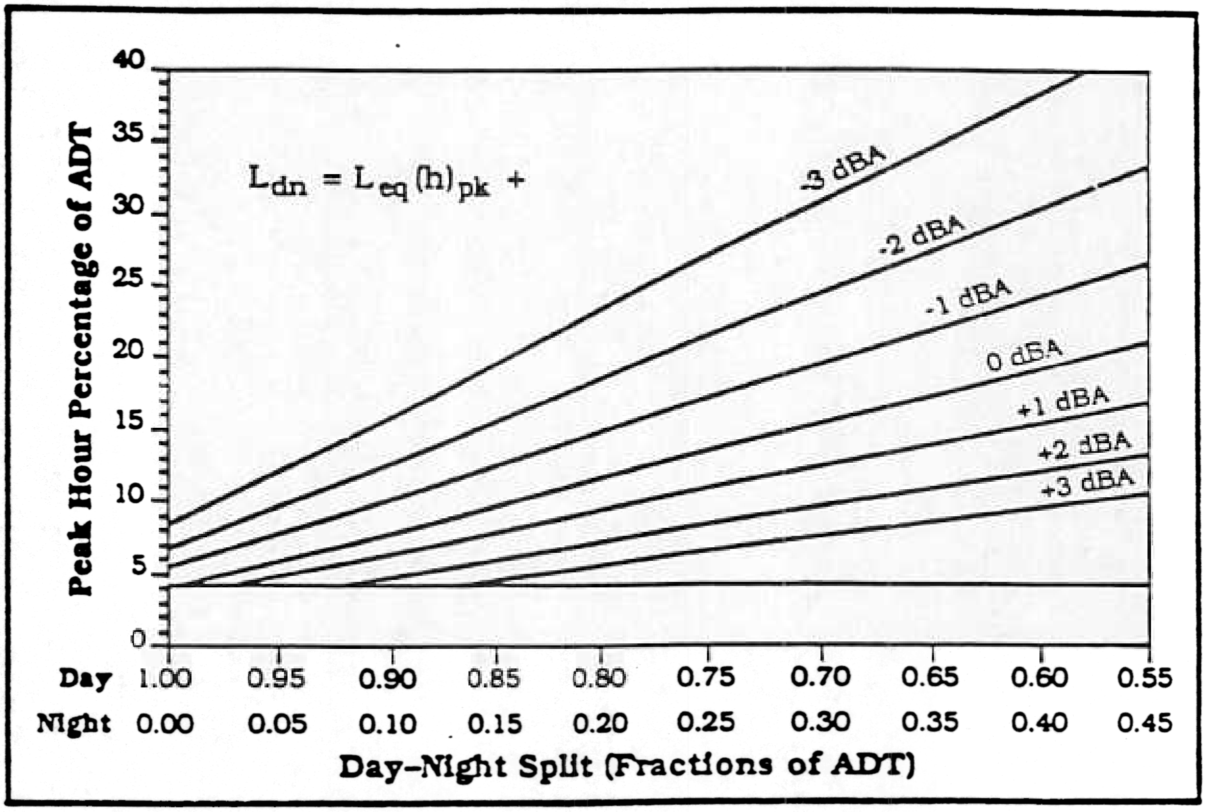

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FIGURE A - 1 RELATIONSHIP OF Ldn AND PEAK HOUR Leq AS A FUNCTION OF PEAK HOUR % OF ADT AND DAY-NIGHT SPLIT OF ADT