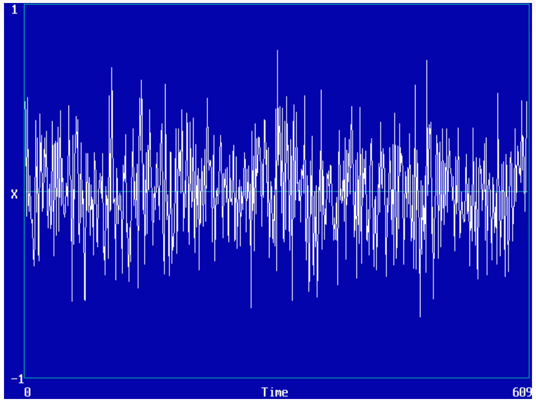
CE 453 Lecture 7

Noise Analysis

See: http://www.nonoise.org/library/highway/probresp.htm
and http://www.fhwa.dot.gov/environment/noise/index.htm
and http://www.fhwa.dot.gov/environment/audible/contents.htm

Noise

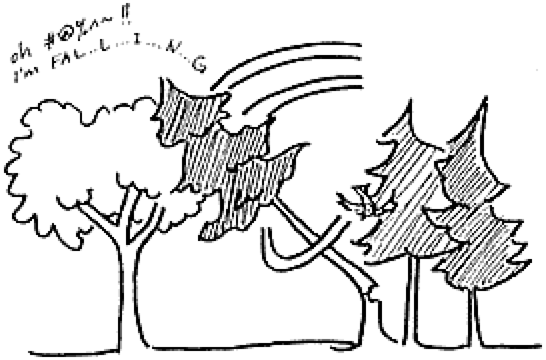
- What is noise?
- Who decides?



sprott.physics.wisc.edu/fractals/chaos

news.bbc.co.uk

www.stedmundsbury.gov.uk



www.plu.edu/scene/issue/1999/summer/img

Noise

- Undesirable or unwanted sound
- Subjective
- Impacts
  - Annoyance, disturbance
  - Stress
  - Physical and psychological damage

Transportation Noise

- Decreases with increasing distance – a corridor problem
- Generated by:
  - Engine
  - Exhaust
  - Aerodynamic friction
  - Interaction between tire-pavement

Control of Transportation Noise

- Federal -- Noise control act of 1972
  - Recognized noise as a major degrader of urban living
  - Encourage use of noise standards
- State and local governments
  - Also institute noise control

Noise Measurement

- Intensity of a single sound is measured on a relative of logarithmic scale
- Uses a unit called a bel (B) or subunit – decibel (dB)
- At 14 bels, sound is painful to human ear

Common Sounds

Source	Noise Level (dB)	Effect
Carrier deck jet operation, air raid siren	140	Painfully Loud
Jet takeoff at 200 feet	130	
Disco, thunderclap	120	Maximum Vocal Effort
Auto Horn at 3 feet	110	
Garbage Truck	100	
Heavy Truck at 50 feet, city traffic	90	Very Annoying, hearing damage (8-hr)
Alarm Clock at 2 feet, hair dryer	80	Annoying
Noise restaurant, freeway traffic, persons voice at 3 feet	70	telephone use difficult
Air conditioning unit at 20 feet	60	Intrusive
Light auto traffic at 100 feet	50	quiet
Living room, bedroom, quiet office	40	
Library, soft whisper at 15 feet	30	very quiet
	10	Sound just audible
	0	Hearing begins

Noise Propagation

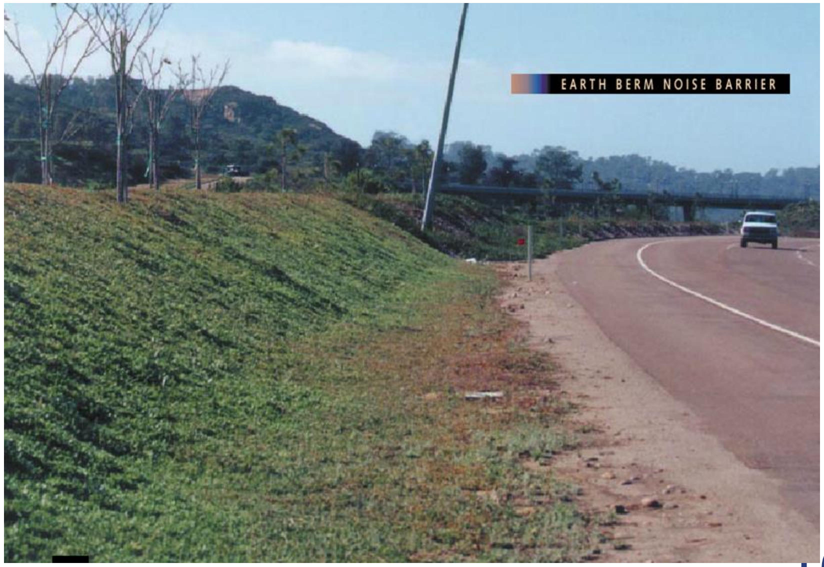
- Noise is generated at source and spreads spherically away from source
- Intensity diminishes with distance
- Losses also occur from sound energy being dissipated as sound is transferred by air particles
- Bending and diffraction occurs as sound waves encounter natural and manufactured solid objects

Noise Control Strategies

- Minimize noise levels
  - Source controls
    - Vehicle control devices – maintenance, traffic and highway design controls
  - Path controls
    - Sound barriers that reflect and diffuse noise
    - Buffer zones
  - Receiver-side controls
    - insulation

Noise abatement measures

- Traffic management (see next slide)
- Buffer zones
- Vegetation
- Noise insulation
- Relocating the highway

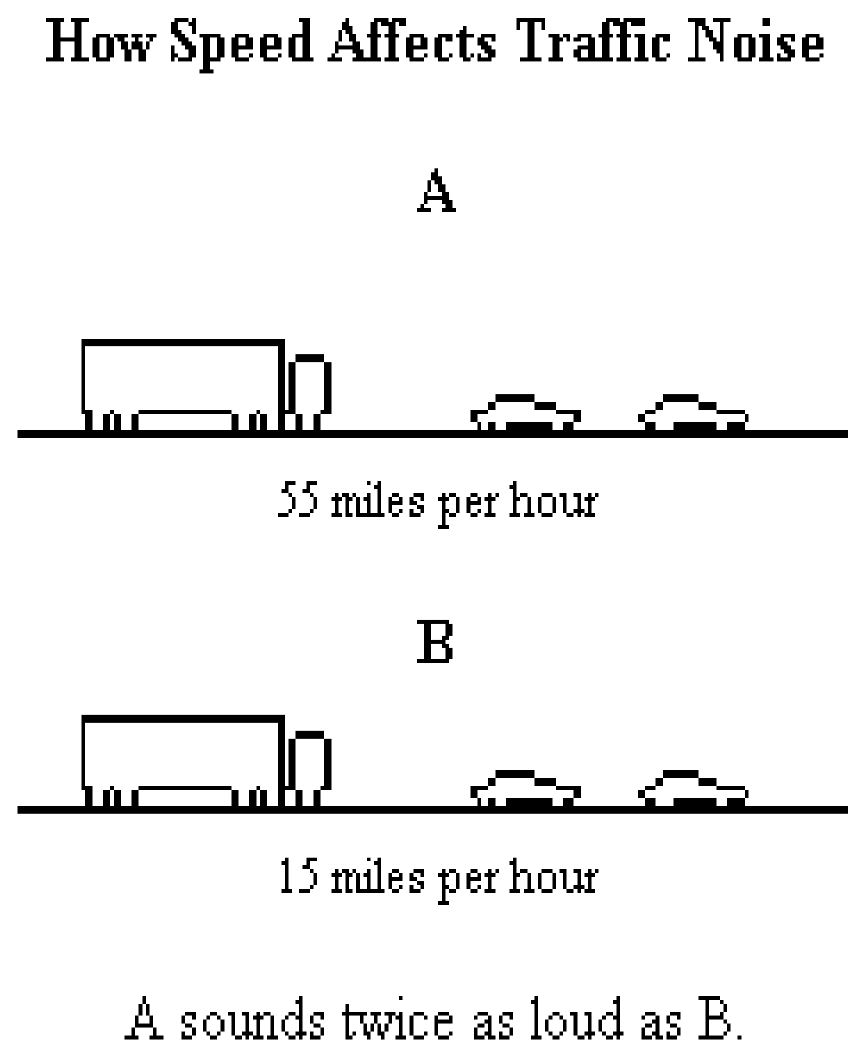


Traffic management measures

- Prohibit trucks
- Truck routes
- Prohibit daytime (or night-time) use
- Traffic signal timing
- Speed limits

- Will all these work?

Noise Source



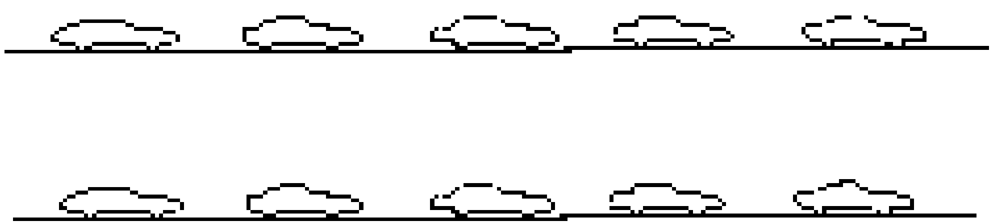
http://www.nonoise.org/library/highway/traffic/traffic.htm

How Trucks Affect Traffic Noise

A

One Truck

B



32 cars

A sounds as loud as B.

http://www.nonoise.org/library/highway/traffic/traffic.htm

How Traffic Volume Affects Noise

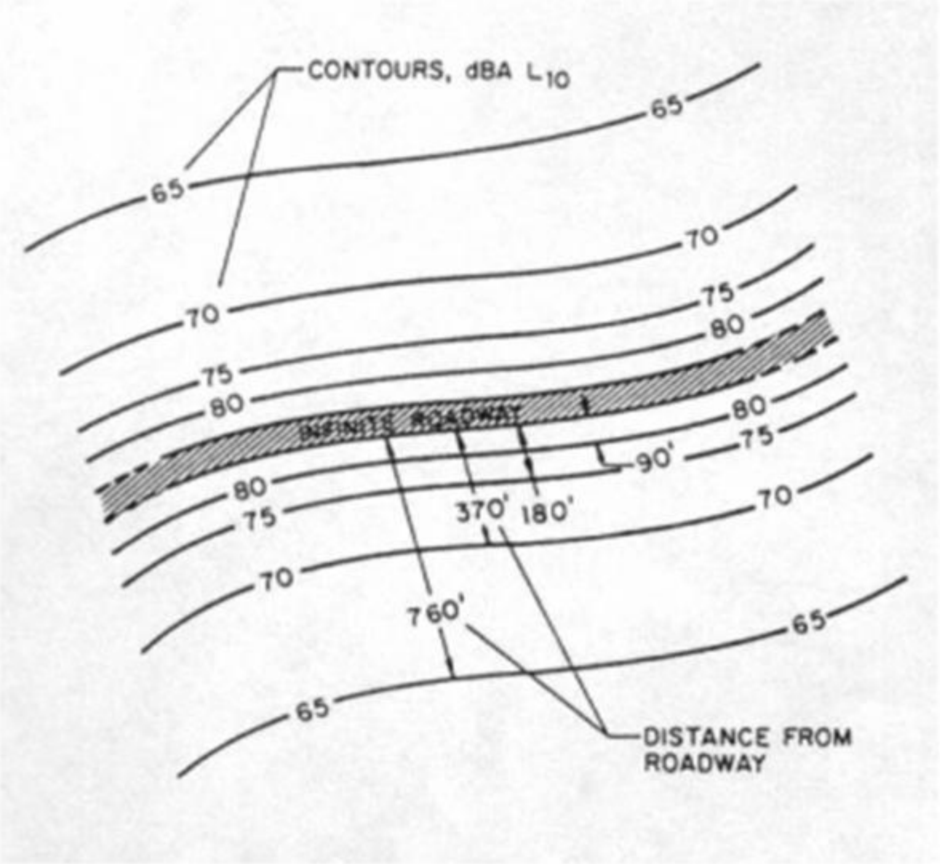
A

2000 vehicles per hour

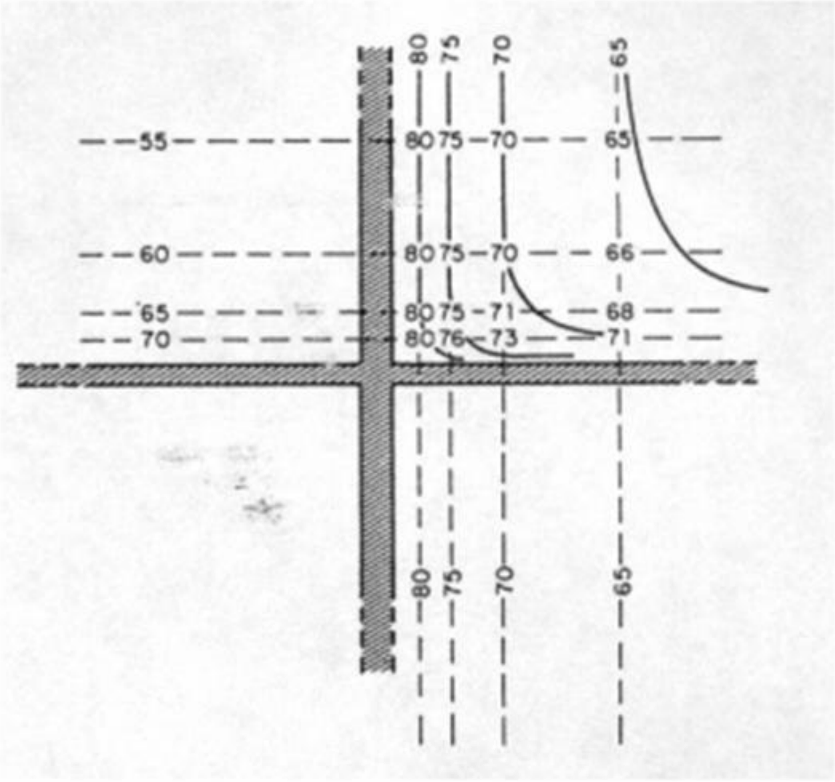
B

200 vehicles per hour

A sounds twice as loud as B.



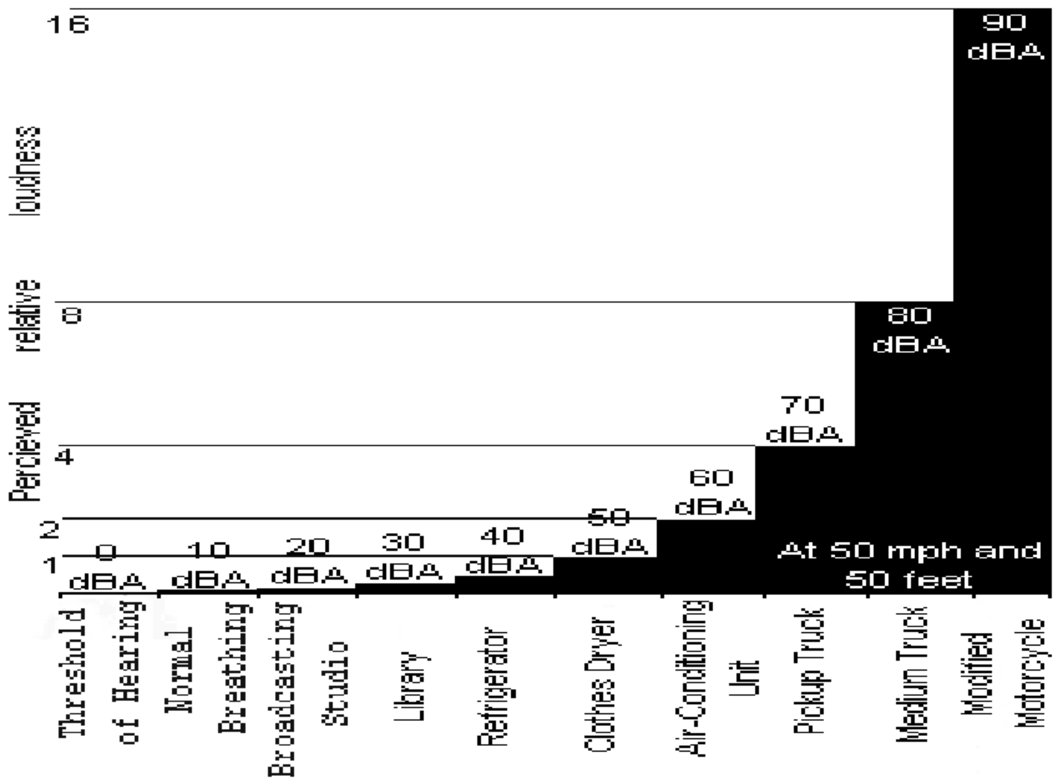
Paths:
Effects of distance
And adding sources



Receivers: Perceptions of noise

Table 3: Decibel Changes, Loudness, and Energy Loss

Sound Level Change	Relative Loudness	Acoustic Energy Loss
0 dBA	Reference	0
-3 dBA	Barely Perceptible Change	50%
-5 dBA	Readily Perceptible Change	67%
-10 dBA	Half as Loud	90%
-20 dBA	1/4 as Loud	99%
-30 dBA	1/8 as Loud	99.9%



http://www.nonoise.org/library/highway/traffic/traffic.htm

Number of people annoyed
At different sound levels

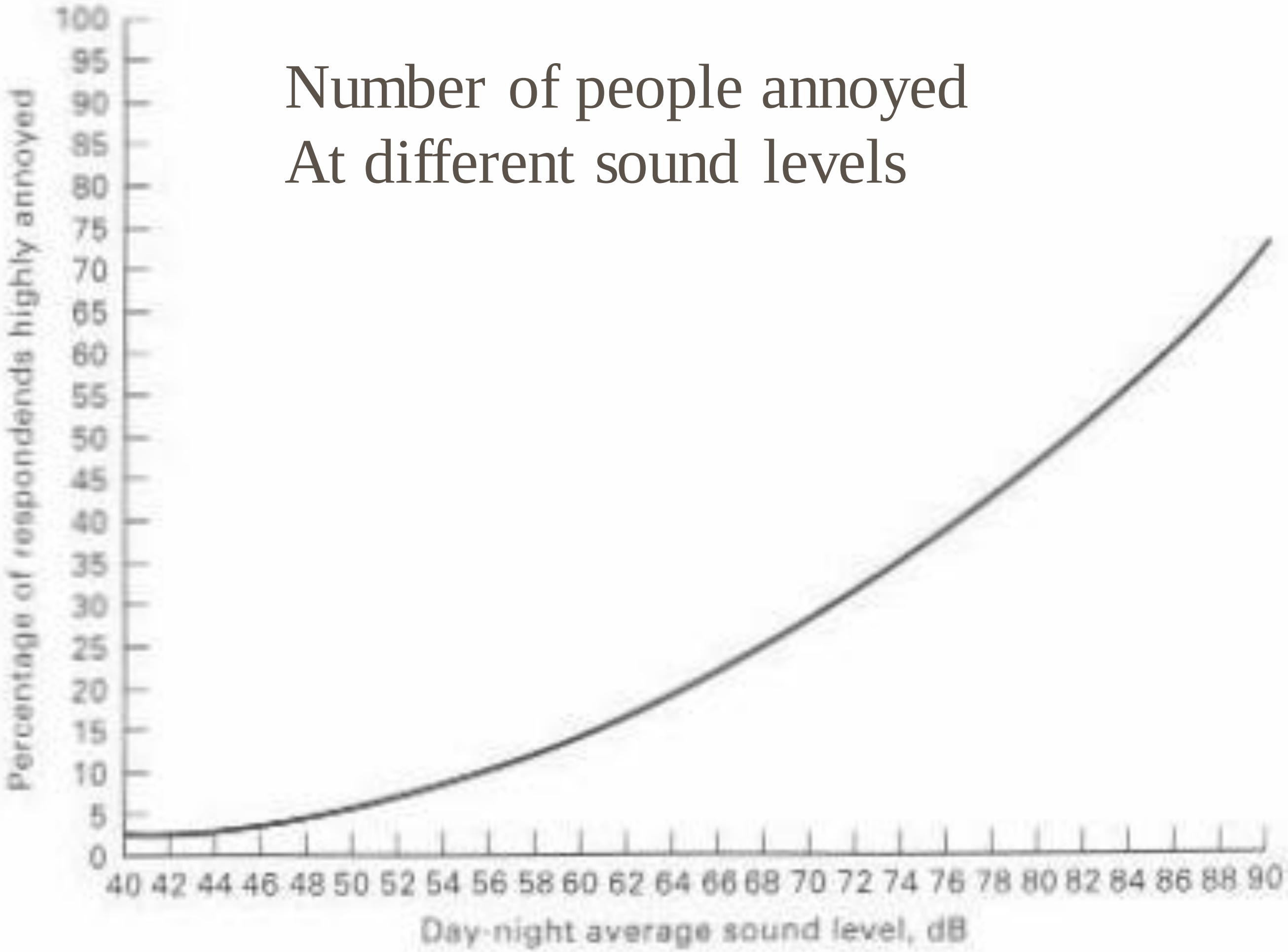


Figure 8-11 Relationship between noise exposure and percentage of community highly annoyed. (Adapted from S. Fidell, D. Barber, and T. Schultz, "Updating a Dosage-Effect Relationship on the Prevalence of Annoyance Due to General Transportation Noise," *Journal of the Acoustical Society of America*, Vol. 89, No. 1, 1991.)

Table 7: Building Noise Reduction Factors

Building Type	Window Condition	
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
	Storm Windows	25 dB
Masonry	Single Glazed	25 dB
Masonry	Double Glazed	35 dB

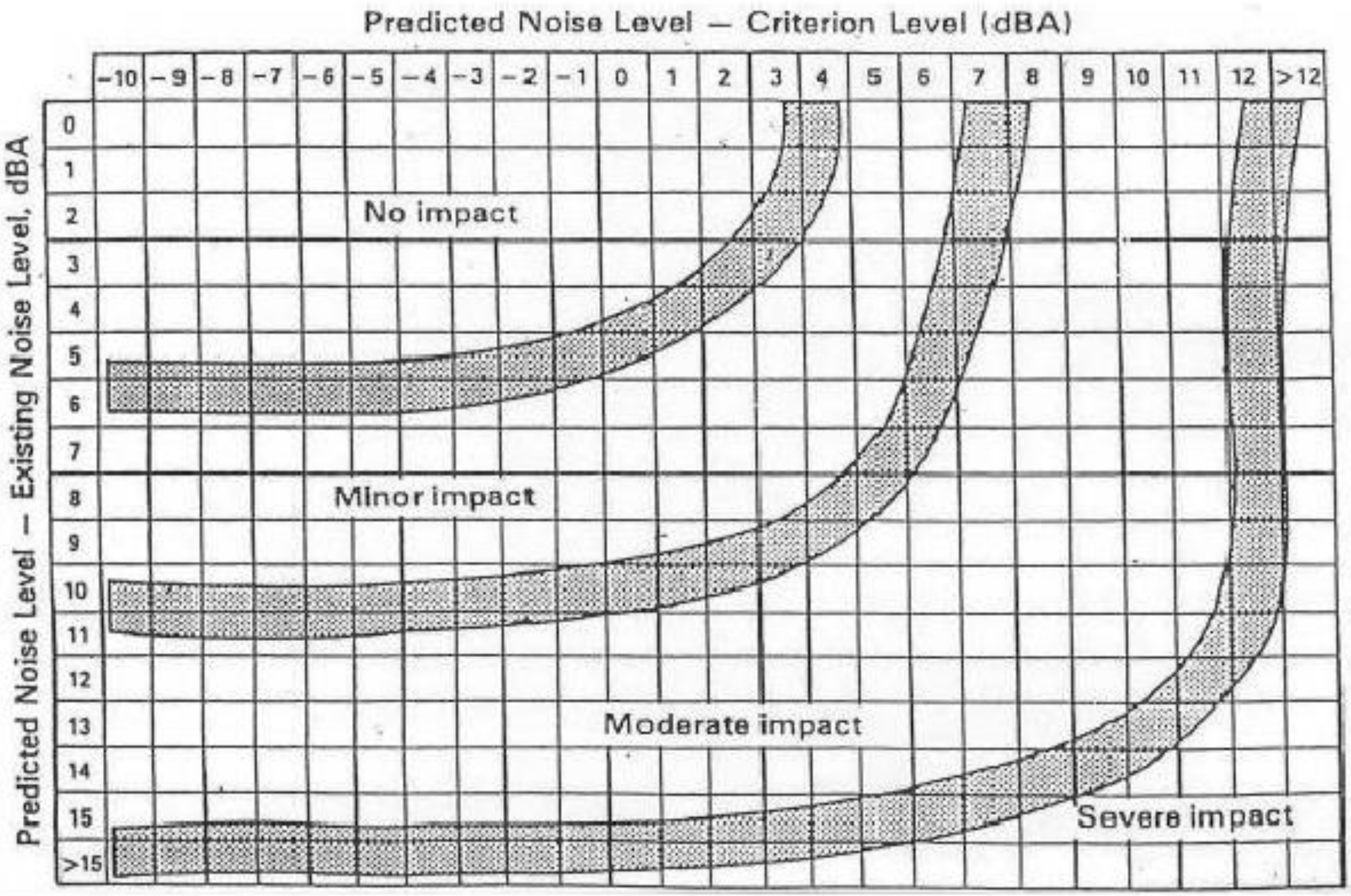
http://www.nonoise.org/library/highway/policy.htm

Table 1. FHWA Noise Abatement Criteria in dBA (hourly A-weighted sound level).

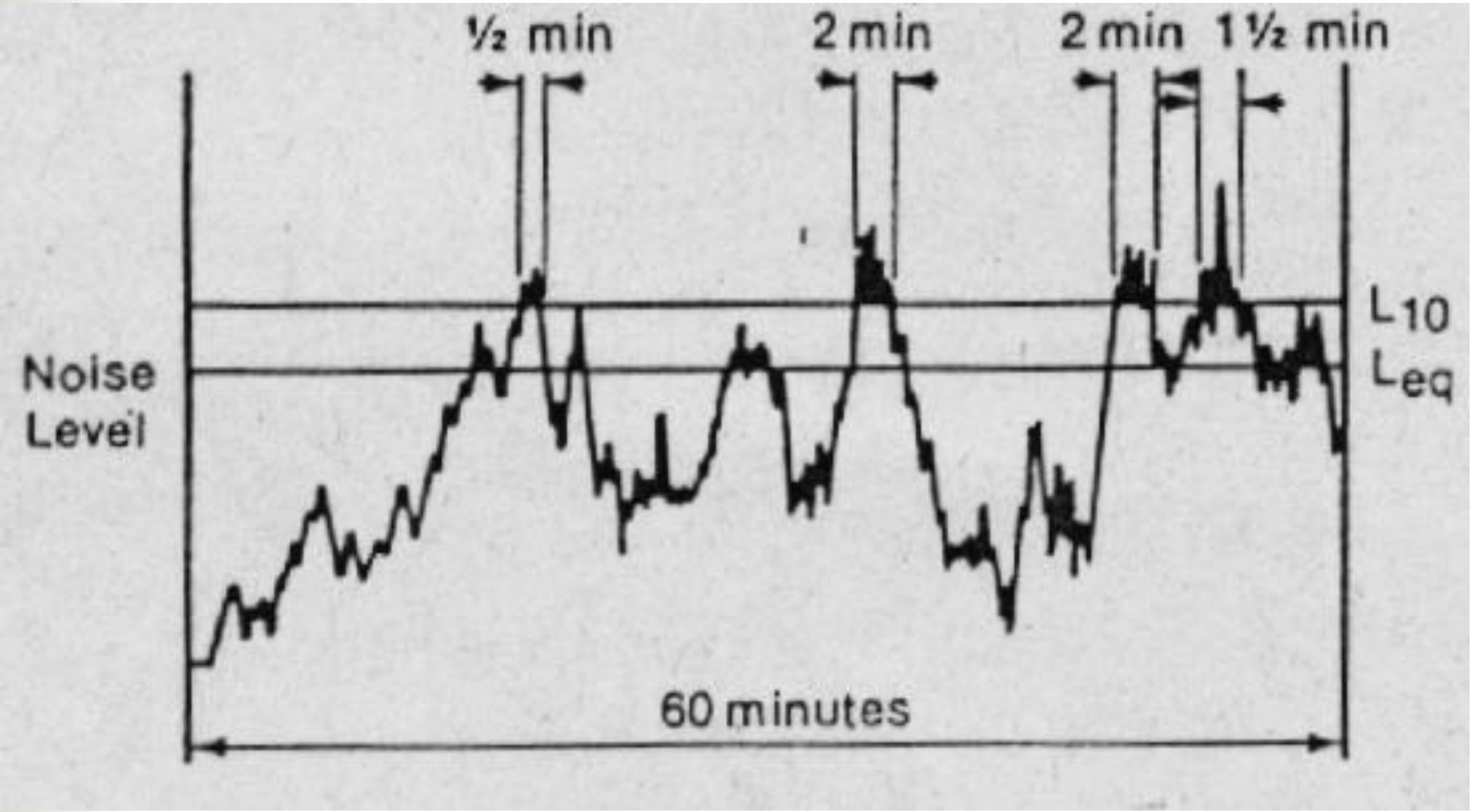
Activity Category	NAC, $L_{eq}(h)$	Description of Activity Category
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.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

NOTE: These sound levels are only to be used to determine impact. These are the absolute levels where abatement must be considered. Noise abatement should be designed to achieve a substantial noise reduction - not the noise abatement criteria.

Figure 1. Impact Criteria for Determining Severity of Noise Impact for the Consideration of Noise Abatement



What are L_{10} and L_{eq}?



L_{10} is usually about 3dB greater than L_{eq}

http://www.nonoise.org/library/highway/traffic/traffic.htm

What are L_{10} and L_{eq}?

The equivalent sound level is the steady- state, A-weighted sound level which contains the same amount of acoustic energy as the actual time-varying, A-weighted sound level over a specified period of time. If the time period is 1 hour, the descriptor is the hourly equivalent sound level, Leq(h), which is widely used by SHAs as a descriptor of traffic noise. An additional descriptor, which is sometimes used, is the L10. This is simply the A-weighted sound level that is exceeded 10 percent of the time.

http://www.nonoise.org/library/highway/policy.htm#II

State of the Art is FHWA's Traffic Noise Model (TNM)

- Modeling of five standard vehicle types, including automobiles, medium trucks, heavy trucks, buses, and motorcycles, as well as user-defined vehicles.
- Modeling of both constant-flow and interrupted-flow traffic using a 1994/1995 field-measured data base.
- Modeling of the effects of different pavement types, as well as the effects of graded roadways.
- Sound level computations based on a one-third octave-band data base and algorithms.
- Graphically-interactive noise barrier design and optimization.
- Attenuation over/through rows of buildings and dense vegetation.
- Multiple diffraction analysis.
- Parallel barrier analysis.
- Contour analysis, including sound level contours, barrier insertion loss contours, and sound-level difference contours.
- Available for $695 at McTrans http://mctrans.ce.ufl.edu/

Example Problem

Problem: Find dBA L_{10}

- **500 ft from road**
- **2 lane road**
- **2400 vehicles per hour**
- **5 percent trucks**
- **60 mph**

#cars = .95x2400=2280

FIGURE 4.9 Sheet____of____

TRAFFIC NOISE COMPUTATION TALLY

NOISE LEVEL, dBA

Project______________________________ Engineer____________

Segment______________________________ Date ____________

Autos/hr.___2280___ Trucks/hr.___120___ Miles/hr.___60___

Highway Width________feet. Observer____________

Comments____

Item	A	T	A	T	A	T	A	T
L_{50} reference at 100 feet								
Distance, width adjustment								
L_{10}-L_{50} adjustment								
L_{10} reference at observer								
Segment adjustment								
Barrier adjustment								
Miscellaneous Adjustments: Gradient								
Miscellaneous Adjustments: Road surface								
Miscellaneous Adjustments: Foliage								
Miscellaneous Adjustments: Rows of houses								
L_{10} at observer, by veh. type								
L_{10} at observer, summed								

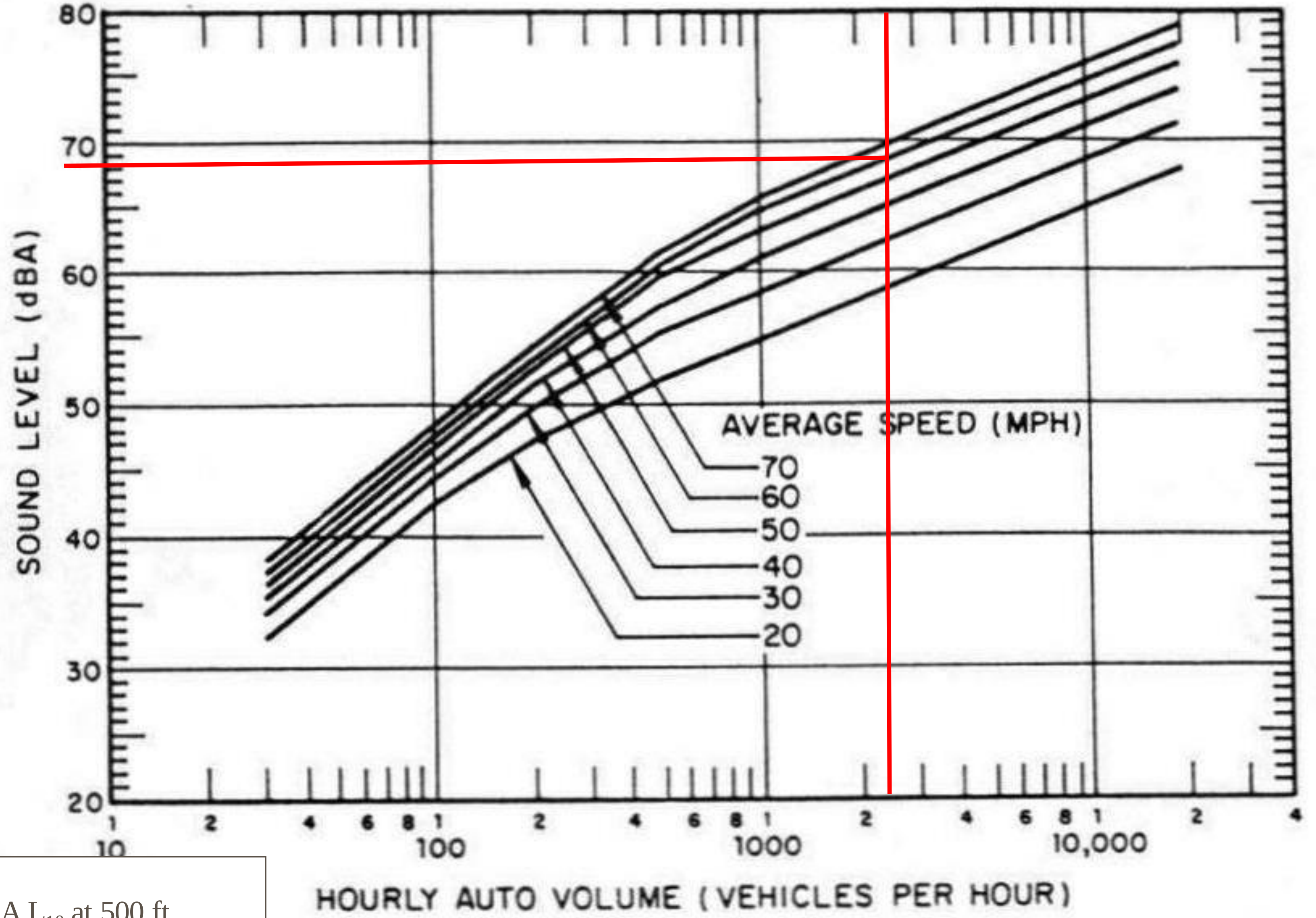


FIGURE 4.1

L_{50} SOUND LEVEL VS. AUTO VOLUME

AT 100-FOOT REFERENCE DISTANCE

Problem: Find dBA L_{10} at 500 ft
From a 2 lane road carrying:
2400 vehicles per hour
5 percent trucks, at
60 mph … cars = .95x2400=2280
L_{50} dBA for cars at 100' = 68 dBA

FIGURE 4.9 Sheet____of____

TRAFFIC NOISE COMPUTATION TALLY
NOISE LEVEL, dBA

Project______________________ Engineer____________

Segment______________________ Date____________

Autos/hr. 2280 Trucks/hr. 120 Miles/hr. 60

Highway Width________feet. Observer____________

Comments______________________________________

Item		A	T	A	T	A	T	A	T
L_{50} reference at 100 feet		68							
Distance, width adjustment									
L_{10}-L_{50} adjustment									
L_{10} reference at observer									
Segment adjustment									
Barrier adjustment									
Miscellaneous Adjustments	Gradient								
	Road surface								
	Foliage								
	Rows of houses								
L_{10} at observer, by veh. type									
L_{10} at observer, summed									

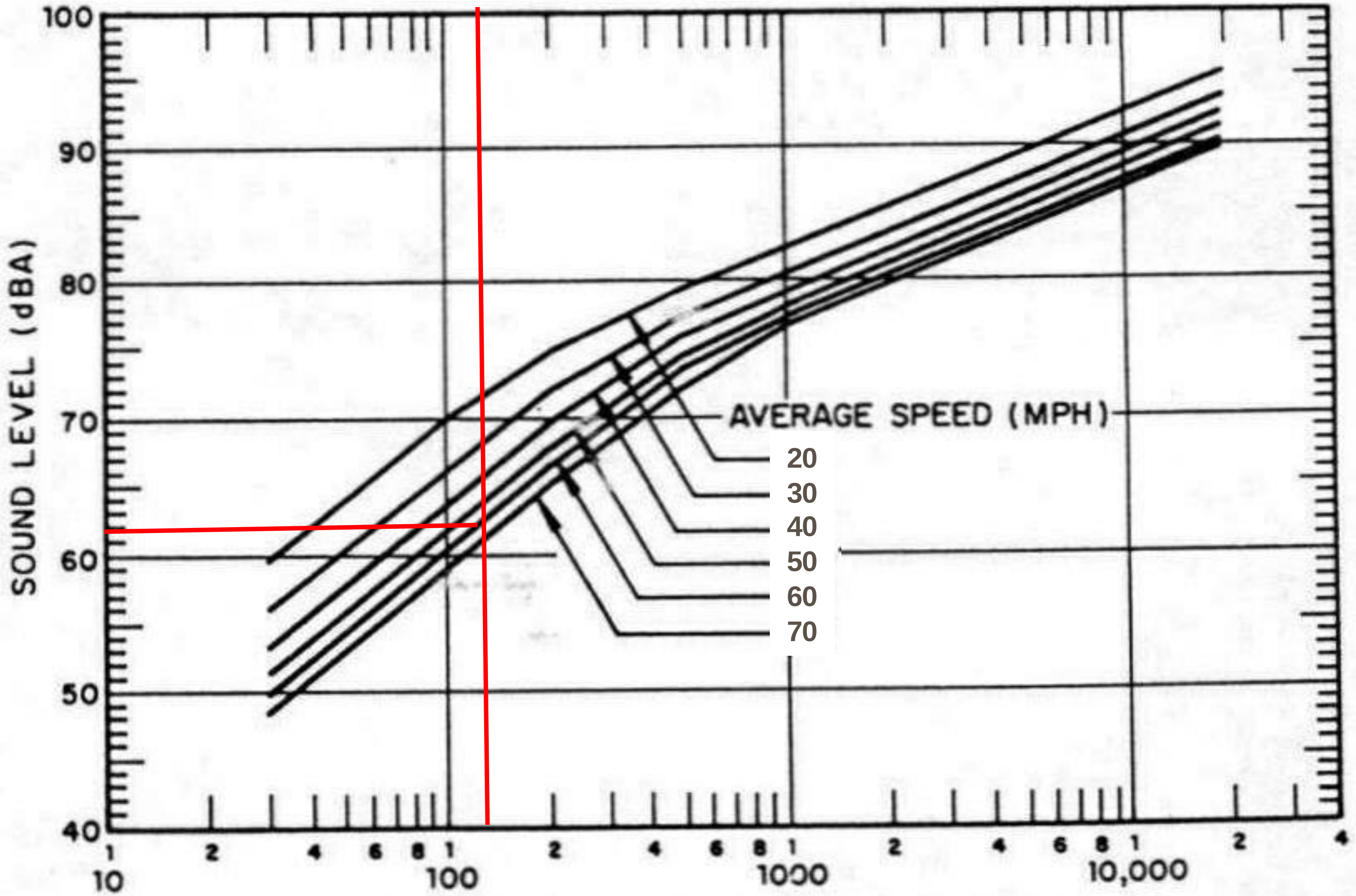


FIGURE 4.2

L_{50} SOUND LEVEL VS. TRUCK VOLUME AT 100-FOOT REFERENCE DISTANCE

Problem: Find dBA L_{10} at 500 ft
From a 2 lane road carrying:
2400 vehicles per hour
5 percent trucks, at
60 mph … trucks = .05x2400=**120**
L_{50} dBA for trucks at 100'= 62 dBA

FIGURE 4.9 Sheet____of____

TRAFFIC NOISE COMPUTATION TALLY

NOISE LEVEL, dBA

Project________________ Engineer____________

Segment________________ Date ____________

Autos/hr. 2280 Trucks/hr. 120 Miles/hr. 60

Highway Width________ feet. Observer____________

Comments________________________

Item		A	T	A	T	A	T	A	T
L_{50} reference at 100 feet		68	62						
Distance, width adjustment									
L_{10}-L_{50} adjustment									
L_{10} reference at observer									
Segment adjustment									
Barrier adjustment									
Miscellaneous Adjustments	Gradient								
	Road surface								
	Foliage								
	Rows of houses								
L_{10} at observer, by veh. type									
L_{10} at observer, summed									

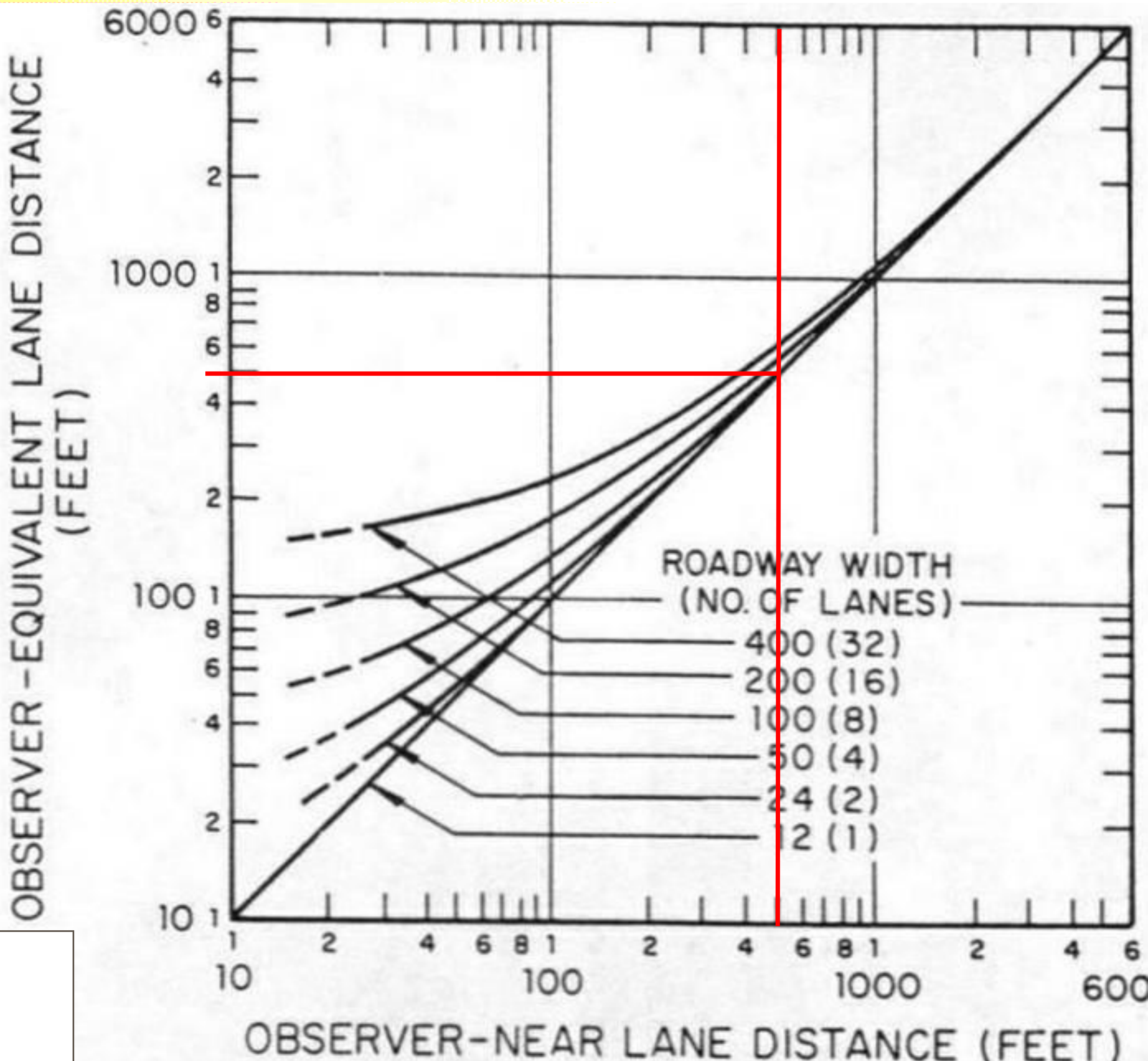


FIGURE 4.3

EQUIVALENT LANE DISTANCE VS. NEAR LANE DISTANCE

Problem: Find dBA L_{10} at **500 ft**
From a **2 lane** road carrying:
2400 vehicles per hour
5 percent trucks, at
60 mph …
O-ELD = 500’

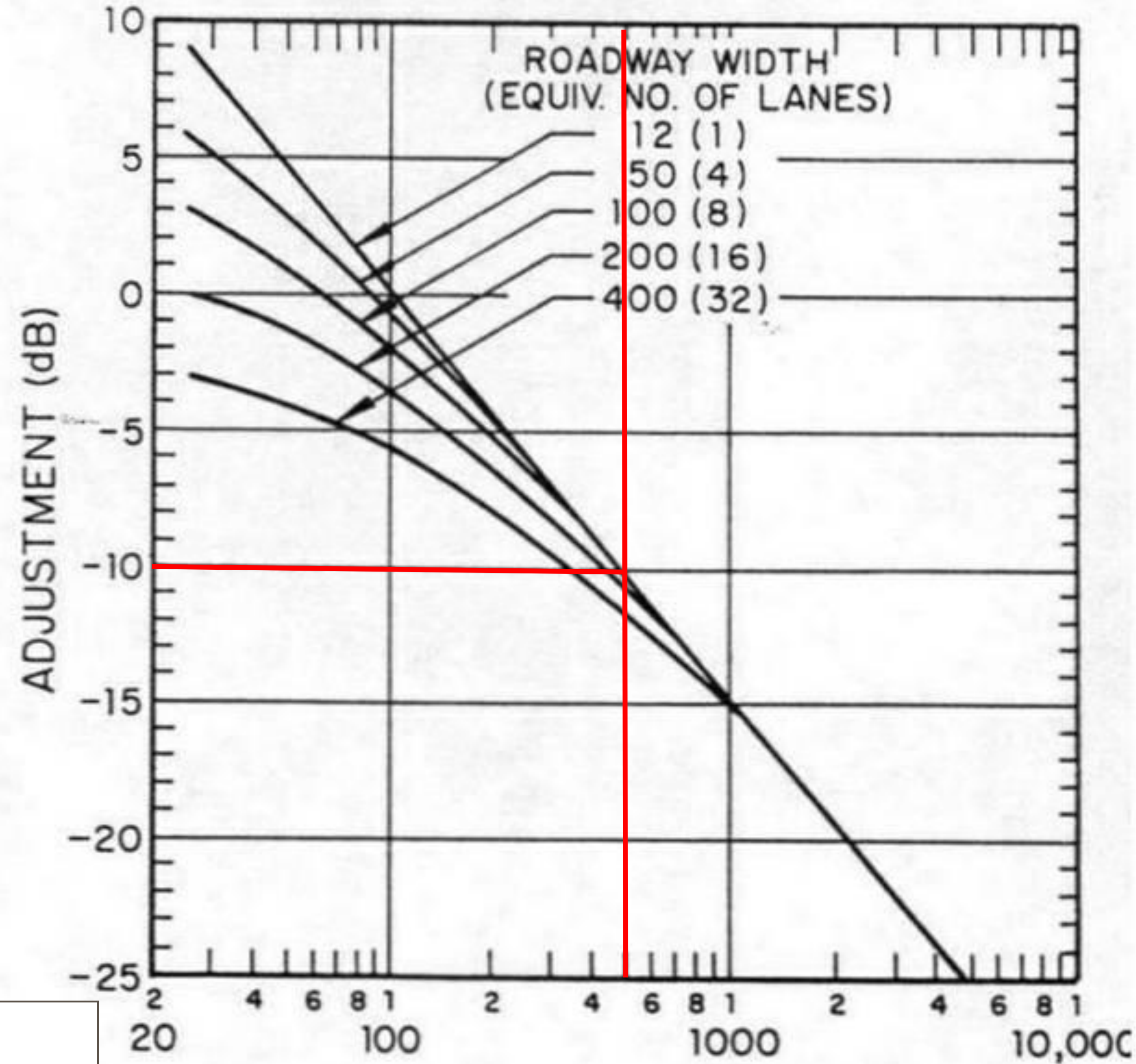


FIGURE 4.4

DISTANCE ADJUSTMENT TO 100-FOOT REFERENCE DISTANCE

Problem: Find dBA L_{10} at **500 ft**
From a road carrying:
2400 vehicles per hour
5 percent trucks, at
60 mph …
Adjustment from 100ft ref = -10 dB

FIGURE 4.9 Sheet____of____

TRAFFIC NOISE COMPUTATION TALLY

NOISE LEVEL, dBA

Project____________________ Engineer__________

Segment____________________ Date __________

Autos/hr. 2280 Trucks/hr. 120 Miles/hr. 60

Highway Width________ feet. Observer__________

Comments______________________________

Item		A	T	A	T	A	T	A	T
L_{50} reference at 100 feet		68	62						
Distance, width adjustment		-10	-10						
L_{10}-L_{50} adjustment									
L_{10} reference at observer									
Segment adjustment									
Barrier adjustment									
Miscellaneous Adjustments	Gradient								
	Road surface								
	Foliage								
	Rows of houses								
L_{10} at observer, by veh. type									
L_{10} at observer, summed									

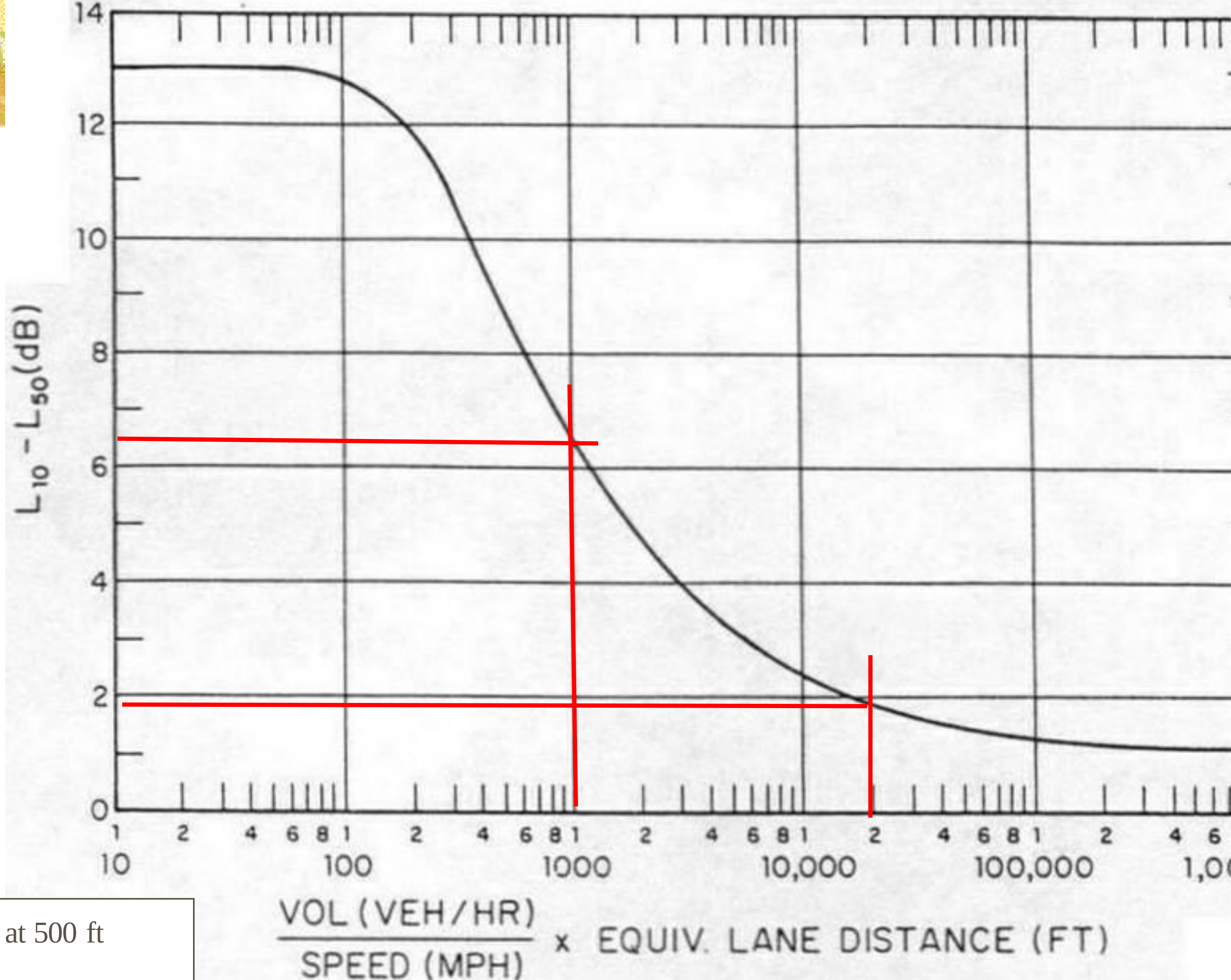


FIGURE 4.5

L_{10} - L_{50} ADJUSTMENT

Problem: Find **dBA L_{10}** at 500 ft
From a road carrying:
2400 vehicles per hour
5 percent trucks, at
60 mph … **vol/speed*ELD = 19,000 for cars, 1,000 for trucks**
L_{10} - L_{50} = 2 dBA cars, 6.5 dBA trucks

FIGURE 4.9 Sheet____of____

TRAFFIC NOISE COMPUTATION TALLY
NOISE LEVEL, dBA

Project______________________ Engineer____________

Segment______________________ Date____________

Autos/hr. 2280 Trucks/hr. 120 Miles/hr. 60

Highway Width________feet. Observer____________

Comments______________________________________

Item		A	T	A	T	A	T	A	T
L_{50} reference at 100 feet		68	62						
	Distance, width adjustment	-10	-10						
	L_{10}-L_{50} adjustment	2	6.5						
L_{10} reference at observer		60	58.5						
	Segment adjustment								
	Barrier adjustment								
Miscellaneous Adjustments	Gradient								
	Road surface								
	Foliage								
	Rows of houses								
L_{10} at observer, by veh. type		60	58.5						
L_{10} at observer, summed									

Adding 2 sources

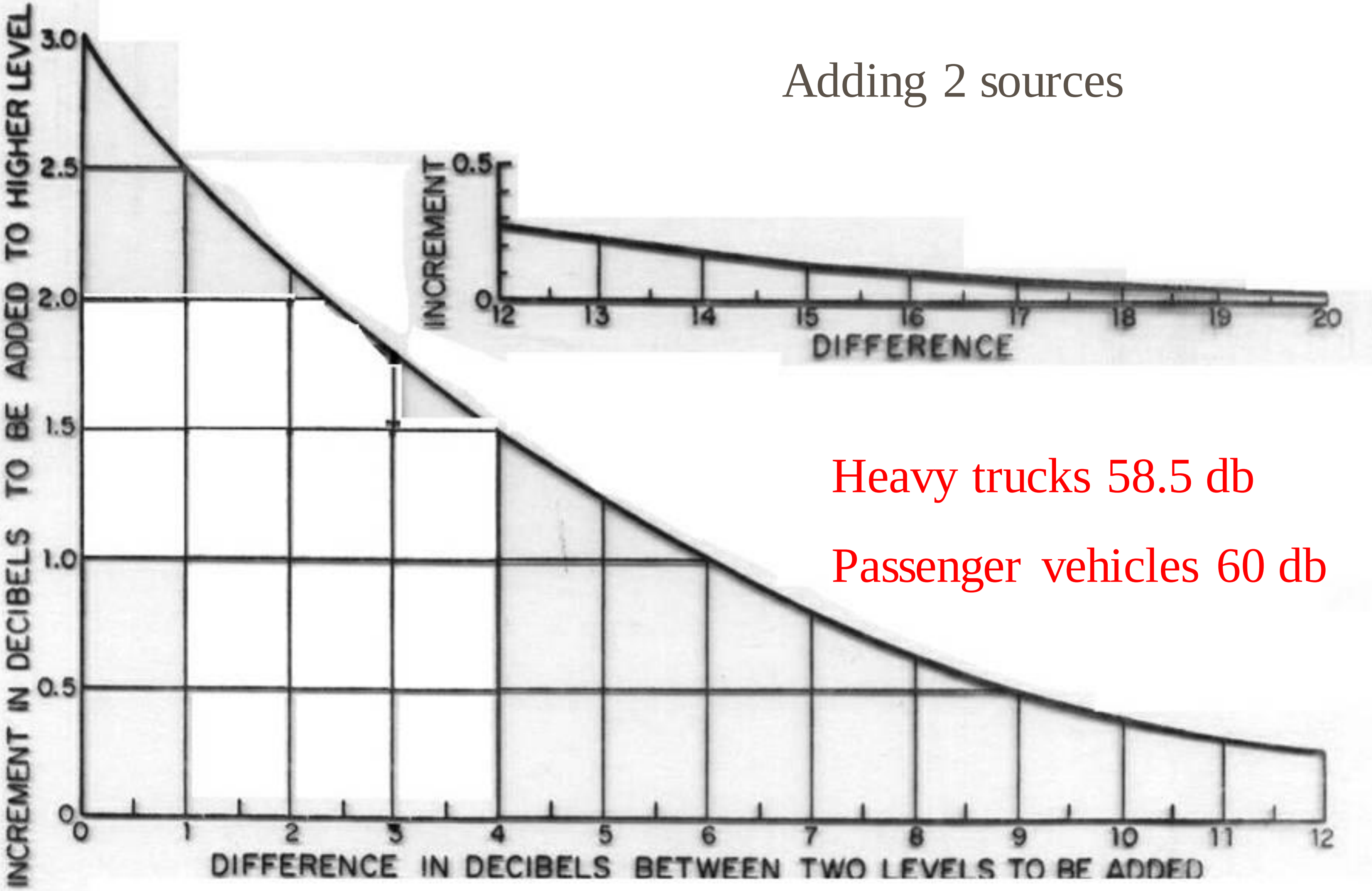


FIGURE I.I CHART FOR COMBINING SOUND LEVELS BY "DECIBEL ADDITION"

Heavy trucks 58.5 db

Passenger vehicles 60 db

Difference = 60 – 58.5 = 1.5

Add 2.3 db to higher

60 + 2.3 = 62.3 db due to both sources

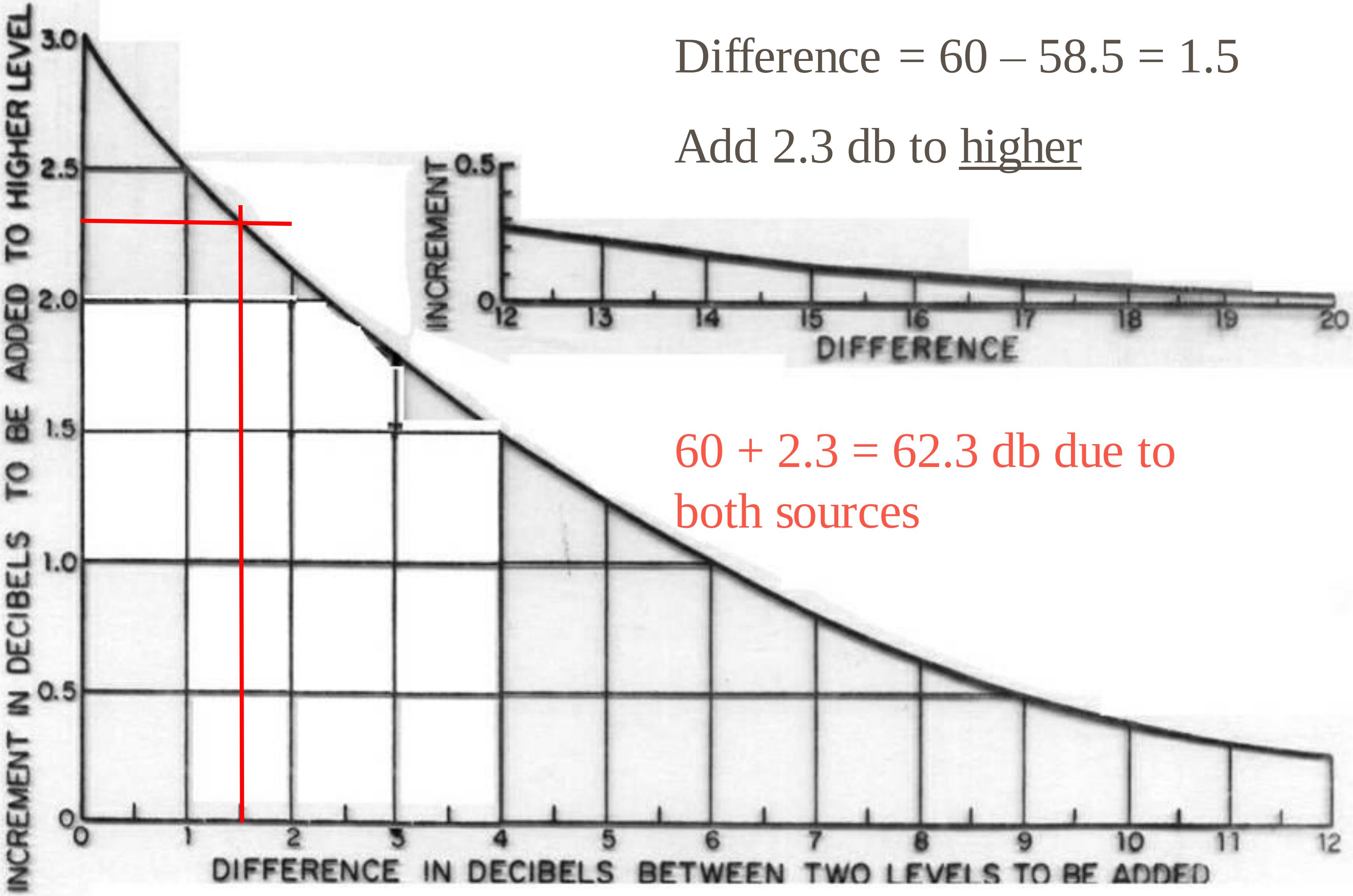


FIGURE 1.1 CHART FOR COMBINING SOUND LEVELS BY "DECIBEL ADDITION"

FIGURE 4.9 Sheet____of____

TRAFFIC NOISE COMPUTATION TALLY
NOISE LEVEL, dBA

Project________________________ Engineer____________

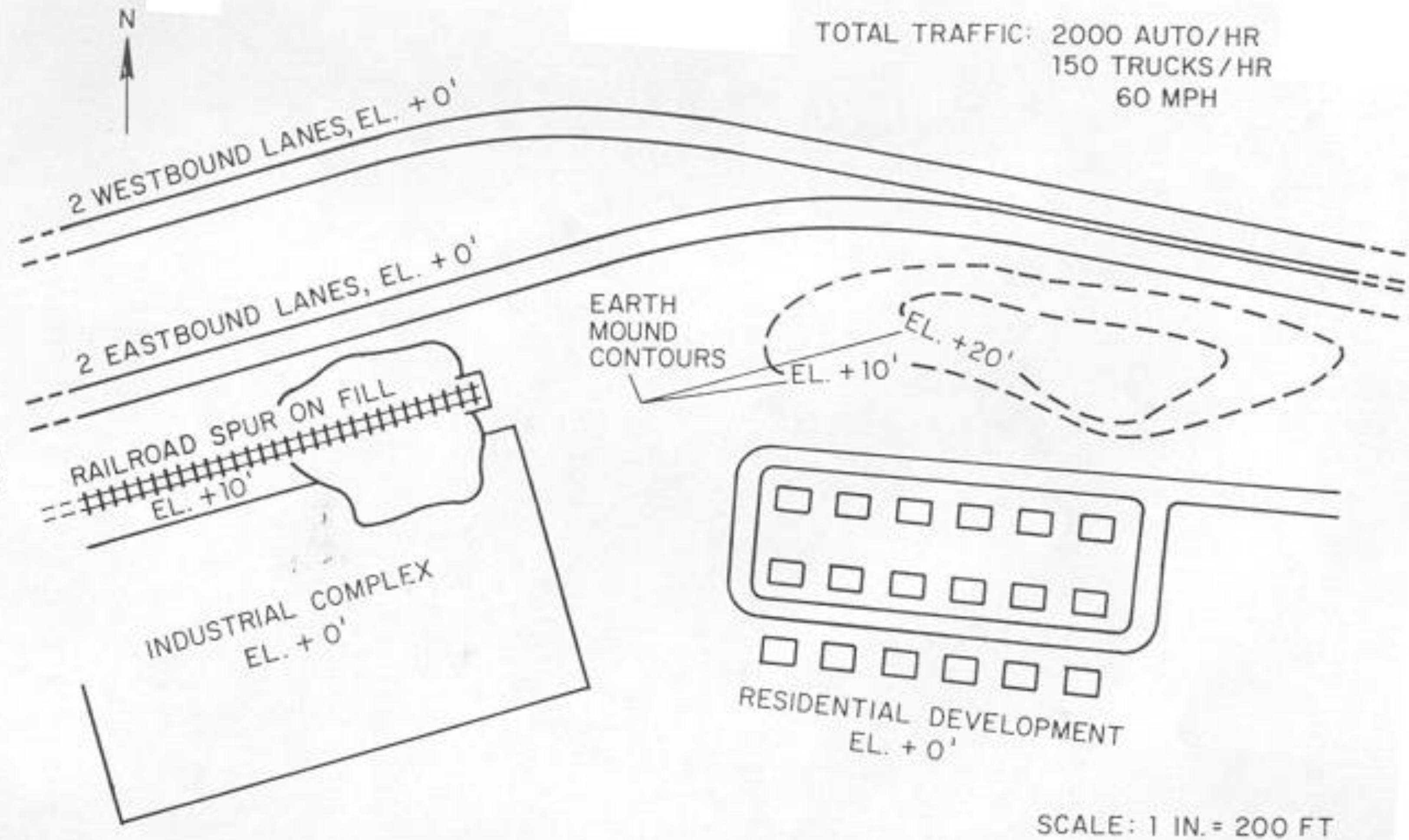
Segment________________________ Date ____________

Autos/hr. 2280 Trucks/hr. 120 Miles/hr. 60

Highway Width________feet. Observer____________

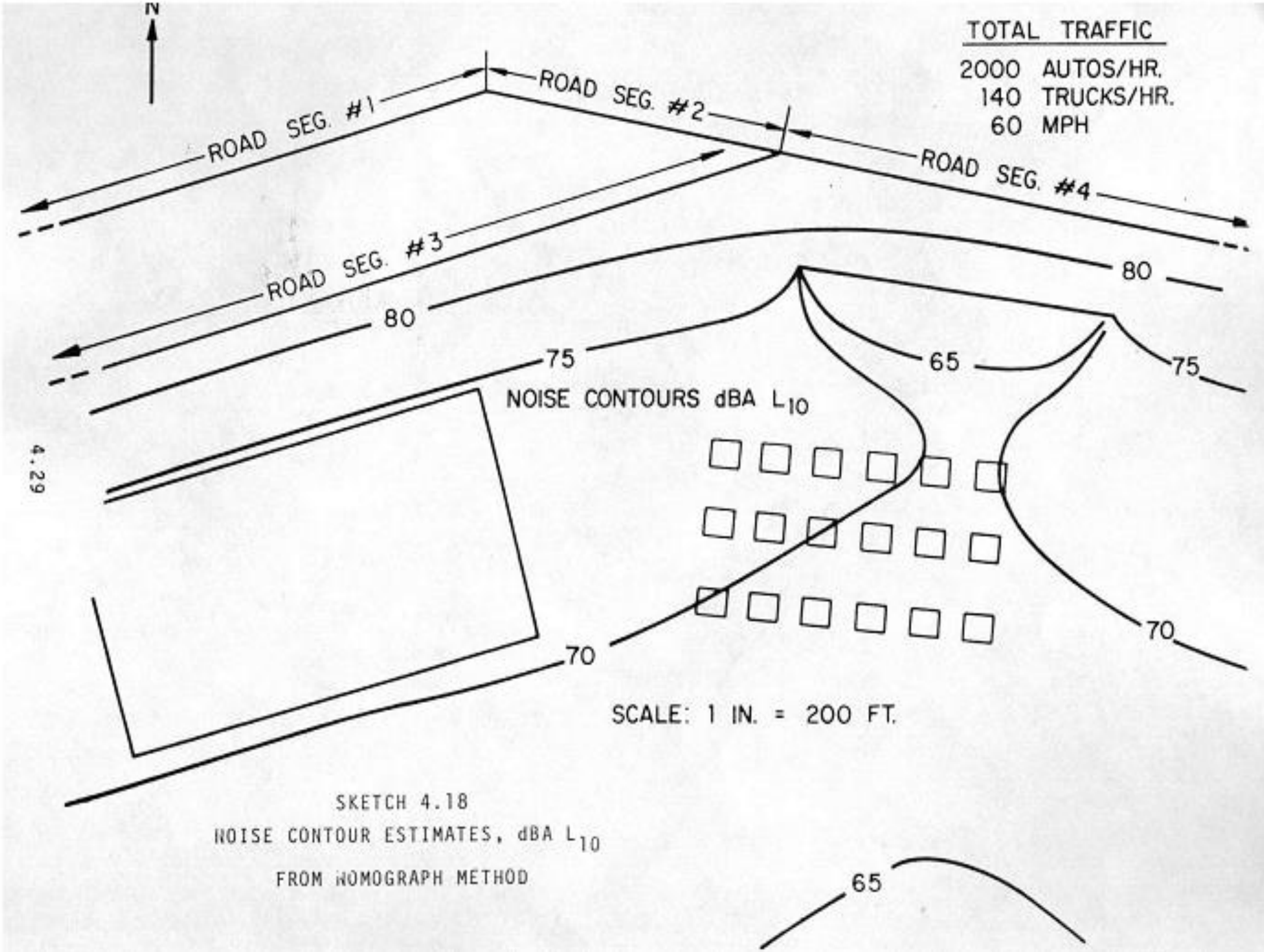
Comments____________________________________

Item	A	T	A	T	A	T	A	T
L_{50} reference at 100 feet	68	62						
Distance, width adjustment	-10	-10						
$L_{10}-L_{50}$ adjustment	2	6.5						
L_{10} reference at observer	60	58.5						
Segment adjustment								
Barrier adjustment								
Miscellaneous Adjustments: Gradient								
Miscellaneous Adjustments: Road surface								
Miscellaneous Adjustments: Foliage								
Miscellaneous Adjustments: Rows of houses								
Miscellaneous Adjustments:								
Miscellaneous Adjustments:								
L_{10} at observer, by veh. type	60	58.5						
L_{10} at observer, summed	62.3							



SKETCH 4.17

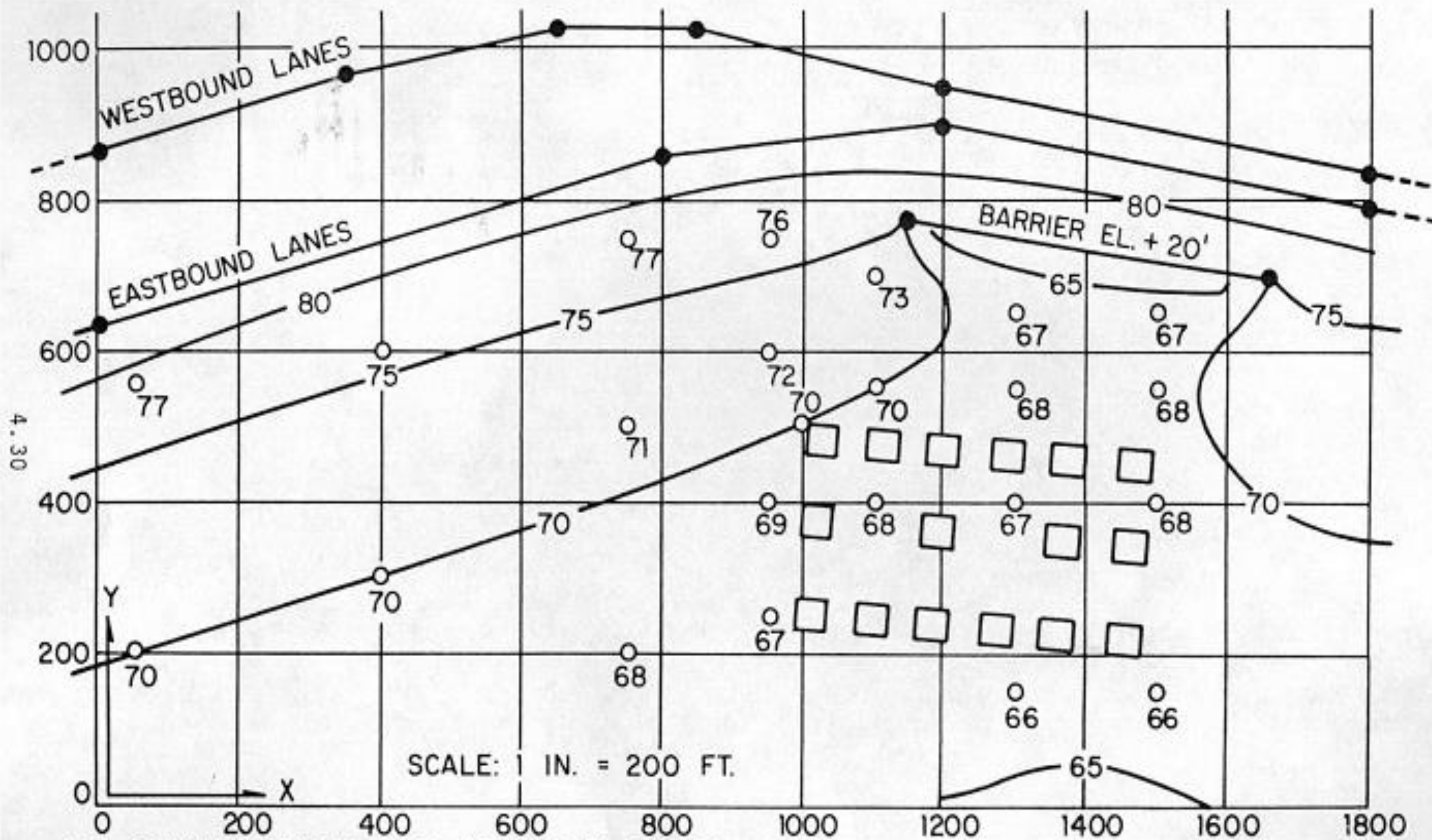
MAP OF DIVIDED HIGHWAY PROBLEM



SKETCH 4.18

NOISE CONTOUR ESTIMATES, dBA L_{10}

FROM NOMOGRAPH METHOD



● ROADWAY AND BARRIER INPUT DATA POINTS
○ RECEIVER LOCATION
71 COMPUTED NOISE LEVELS, dBA L_{10}
—75— NOISE CONTOURS, dBA L_{10}

SKETCH 4.19

COMPUTER INPUT/OUTPUT AND FINAL NOISE CONTOURS

Noise Barriers

Other Adjustments

Grade (trucks)

- +/- 3-4% = +2
- +/- 5-6% = +3
- +/- >7 = +5

Surface

- very smooth = -5 (auto only)
- very rough = +5

(auto, or truck>60mph)

Interrupted flow (L_{10})

- auto = +2
- Truck = +4

Foliage

- -5 for each 100’ >15’
- -10 max

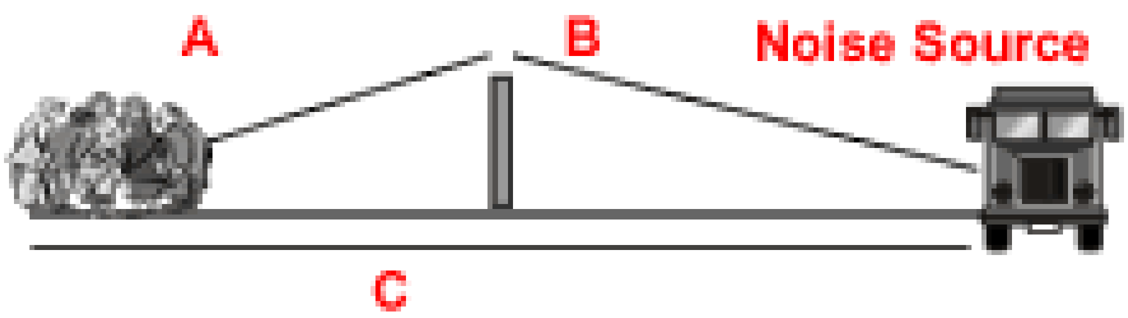
Rows of houses

- -5 for each
- -10 max

Noise Barriers (how they work)

Noise is "diffracted" over the barrier, this increases the distance it travel to the listener, thus decreasing the noise

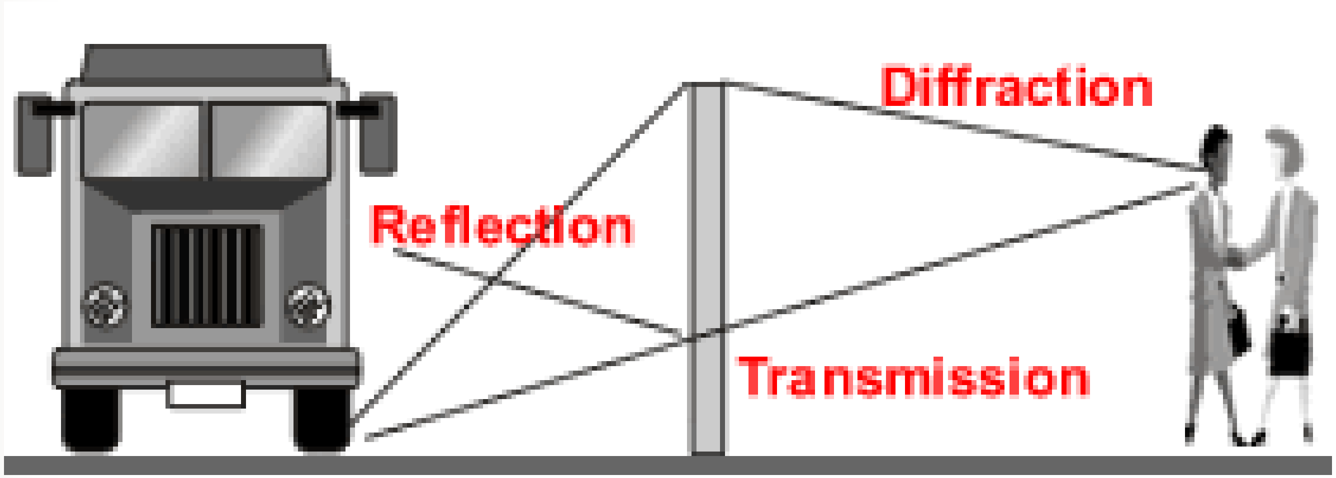
A + B > C



Source:http://www.urbislighting.com/uap1.html

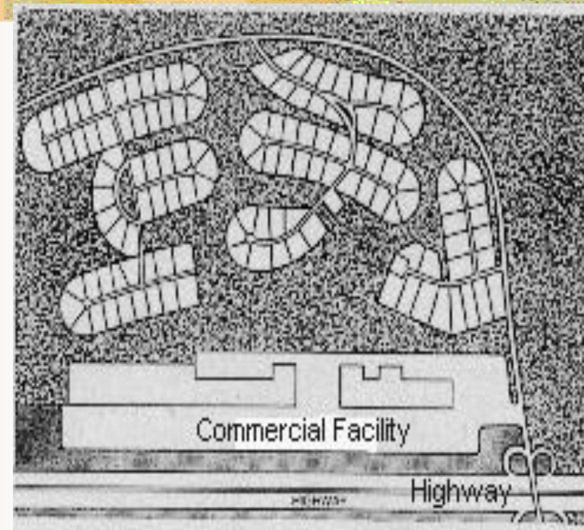
Noise Barriers (how they work)

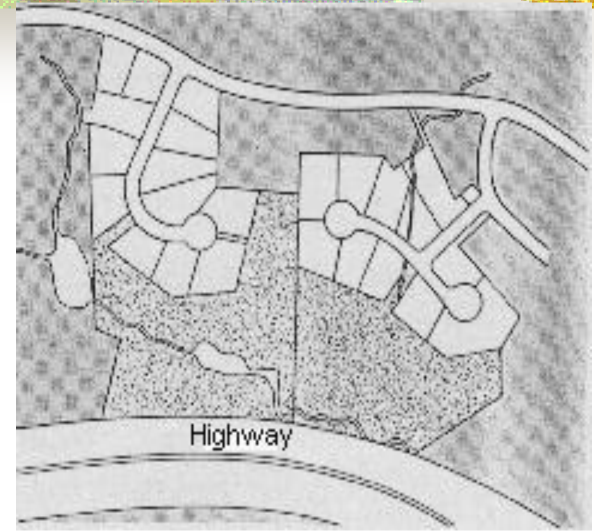
Noise is also reflected and/or absorbed



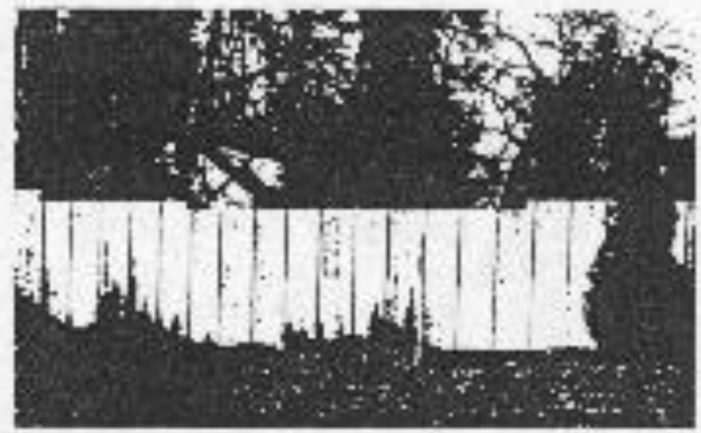
Source:http://www.urbislighting.com/uap1.html

Possible barriers



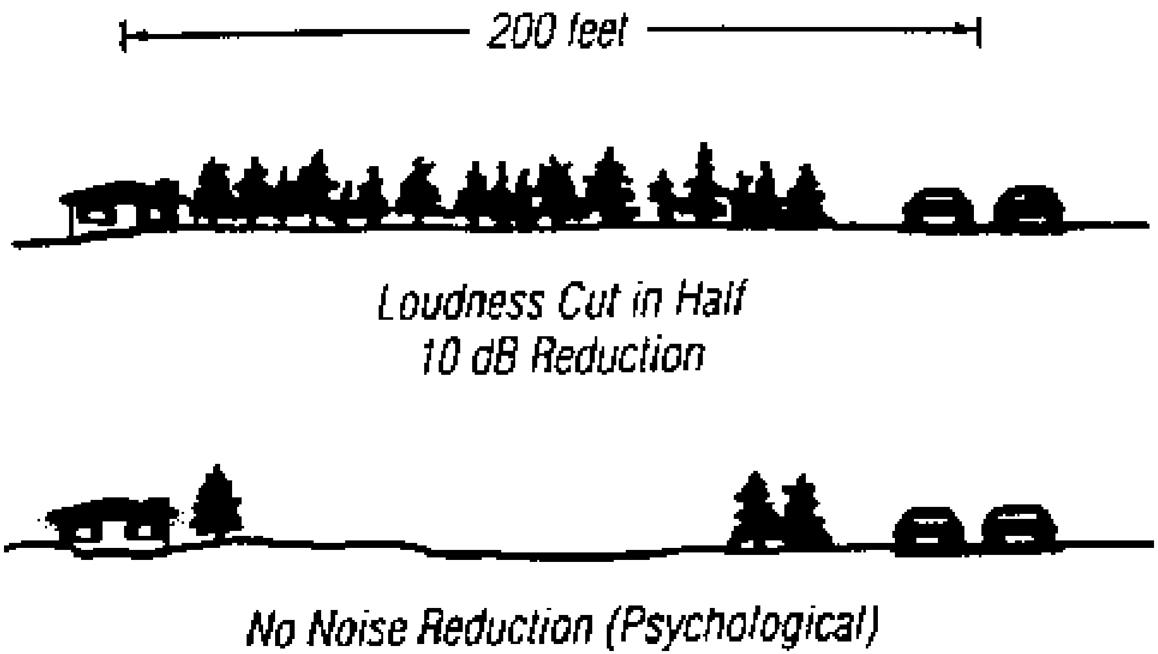


Earth Berm Noise Barrier



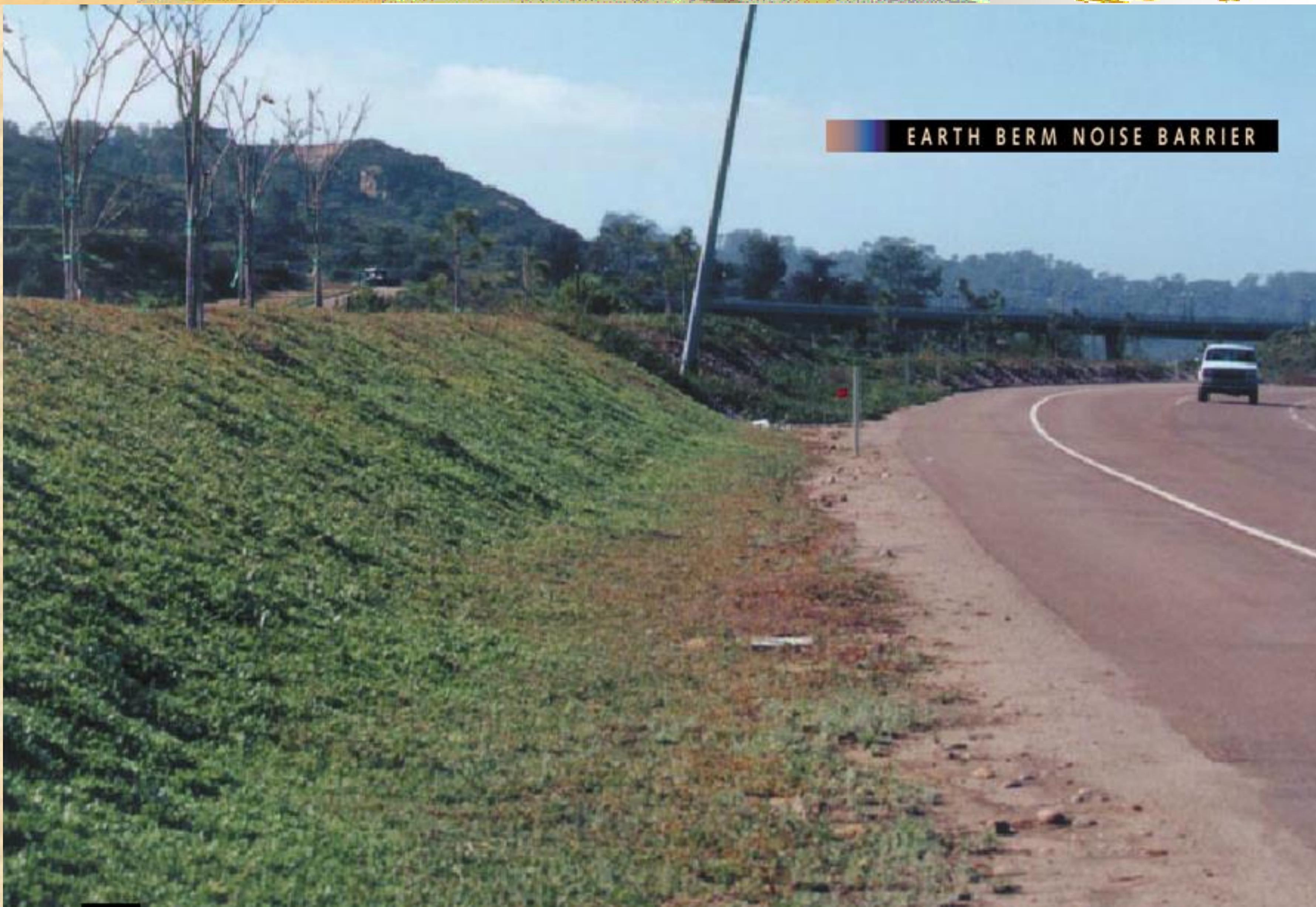
Wooden Noise Barrier

http://www.nonoise.org/library/highway/traffic/traffic.htm



Vegetation and Noise Reduction

http://www.nonoise.org/library/highway/traffic/traffic.htm



Source: FHWA, "Keeping the Noise Down, Highway Traffic Noise Barriers"

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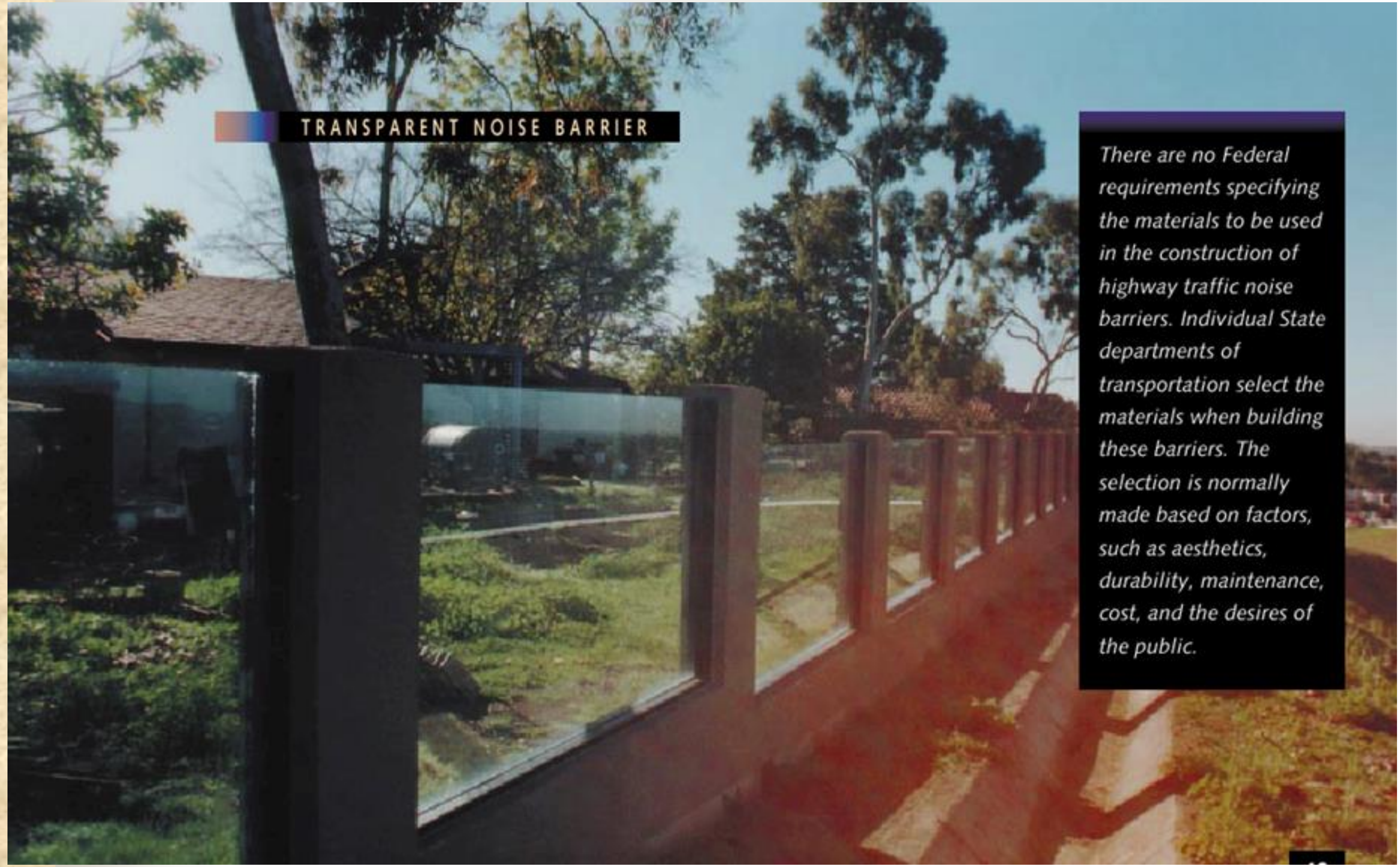

Source: FHWA, "Keeping the Noise Down, Highway Traffic Noise Barriers"