North Carolina Department of Transportation

Traffic Noise Manual

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NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

TRAFFIC NOISE MANUAL

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1.0 INTRODUCTION

Some of the most invasive sources of noise in our lives are those associated with transportation. Traffic can be a dominant source of noise in our environments. Traffic noise is a problem of continuing and increasing public concern. Reaction to traffic- generated noise is a result of the responses to both physiological and psychological factors that vary from person to person.

The Federal-Aid Highway Act of 1970 mandated that the Federal Highway Administration (FHWA) develop noise standards for the abatement of highway traffic noise. FHWA prepared guidelines and standards for the abatement of highway traffic noise in the planning and design of federally funded highway projects. These standards comprise Title 23 of the United States Code of Federal Regulations Part 772 – *Procedures for Abatement of Highway Traffic Noise and Construction Noise* (23 CFR 772, July 2011). The document "Highway Traffic Noise: Analysis and Abatement Guidance" (December 2011) provides FHWA guidance for the analysis and abatement of highway traffic noise in accordance with 23 CFR 772. The 23 CFR 772 regulation (July 13, 2011) required each state highway agency to develop their own set of guidelines that satisfy the requirements of 23 CFR 772. In 2011, the North Carolina Department of Transportation (NCDOT) revised its *Traffic Noise Abatement Policy* and developed a *Traffic Noise Analysis and Abatement Manual* to comply with these federal requirements. The revised policy and manual became effective on July 13, 2011. The effective date of the current NCDOT policy is October 6, 2016.

The purpose of this *Traffic Noise Manual* is to provide both updated guidance and updated direction related to the performance of traffic noise analyses for NCDOT in order to assure conformance with the NCDOT noise policy and 23 CFR 772. Its intent is to provide such guidance and direction to NCDOT employees, consultants, local governments, and developers in their evaluation of traffic and construction noise and their development of appropriate noise reduction measures. The guidance contained in this manual is intended to supplement guidance contained in the FHWA's *Highway Traffic Noise: Analysis and Abatement Guidance*, and other FHWA guidance materials related to traffic noise analyses and the design of feasible and reasonable noise abatement measures.

2.0 DEFINITIONS

General definitions can be found in 23 CFR 772, which is included as Appendix B in this document. The following definitions expand on those that are part of 23 CFR 772, and are particularly useful in areas for which direction and guidance are provided in this manual.

A-Weighted Sound Level: A frequency weighting network used to account for changes in sensitivity as a function of frequency.

Acoustical Profile: The profile of the top of a noise barrier which is required in order to meet the acoustical requirements of the noise barrier. The top elevation of a constructed noise barrier at any point along the barrier must be equal to or higher than the acoustical profile's elevation at that point.

Adjacent Receptor: A benefited receptor that 1) represents a property that abuts the highway right of way or 2) has no benefited receptor between it and the highway. Where multiple buildings containing benefited receptors are on the same property, such as an apartment or condominium complex, only the building closest to the highway is an adjacent receptor. Adjacent receptors will most often, but not always, be part of the front row of benefited receptors.

Ambient Noise: The combination of all noise sources that occur, typically described for a specific environment, location, and/or period of time.

Approach Criteria: One (1) dB(A) below the Federal Noise Abatement Criteria (NAC) for the land use activity categories A through E. A receptor is considered impacted if the predicted hourly equivalent traffic noise level meets or exceeds the approach criteria value. The Approach Criteria value is one of two criteria that define noise impacts, the other being a substantial increase in predicted noise levels over existing noise levels.

Benefited Receptor: All receptors, both impacted and non-impacted, that receive a noise level reduction of 5 dB(A) or more through placement of a noise abatement measure.

Categorical Exclusion (CE): A category of actions which do not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment or an environmental impact statement is required. The term usually refers to the environmental document that supports this action.

Date of Public Knowledge: The date of approval of the final environmental document, determined by the approval of a Categorical Exclusion (CE) or the issuance of a State or Federal Finding of No Significant Impact (FONSI) or the issuance of a State or Federal Record of Decision (ROD).

Daytime Hours (Day): The hours of the day between 7:00 a.m. and 7:00 p.m.

Decibel (dB): The logarithmic unit for measuring sound pressure levels. For traffic noise measurements, decibels are most commonly reported in terms of the A- weighting frequency scale, which best includes the frequencies to which human hearing is typically most sensitive and is denoted by the abbreviation dB(A). (reference A-Weighted Sound Level, above)

Design Build Project: A project delivery system used in the construction industry. It is a method to deliver a project in which the design and construction services are contracted by a single entity known as the design-builder or design-build contractor.

Design Noise Report (DNR): A report that documents the methodology and findings of a final design noise analysis. The Design Noise Report typically follows the recommendation of a Traffic Noise Report that traffic noise impacts exist, and that abatement measures are preliminarily deemed to meet feasibility and reasonableness criteria. A Design Noise Report may be prepared without a Traffic Noise Report if project criteria indicate a high likelihood that abatement measures will meet feasibility and reasonableness criteria.

Design Year: The future year used to estimate the probable traffic volume for which a highway is designed. Design year is typically 20 years beyond the completion year of project construction.

Environmental Assessment (EA): An Environmental Assessment is a public document that serves to briefly provide sufficient evidence and analysis for determining whether to prepare an Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI), to aid an agency's compliance with the National Environmental Policy Act when no environmental impact statement is necessary, and to facilitate preparation of an EIS when one is necessary.

Environmental Impact Statement (EIS): An Environmental Impact Statement is required for major actions that significantly affect the quality of the human environment. An EIS is a full-disclosure document that details the process through which a transportation project was developed, includes consideration of a range of reasonable alternatives, analyzes the potential impacts resulting from these alternatives, and demonstrates compliance with other applicable environmental laws and executive orders.

Equivalent Receptor (ER): Receptors used to represent non-residential land uses. The number of equivalent receptors (or ER values) is determined by evaluating the person-hours-of-use-per-year associated with a non-residential land use and comparing it to the person-hours-of-use-per-year associated with a typical North Carolina single family residence.

Evening Hours (Evening): The hours of the day between 7:00 p.m. and 10:00 p.m.

Final Design Noise Analysis: The analysis of noise that is usually conducted during the final design phase of project development. This analysis is usually initiated after the completion of a preliminary design noise analysis' preliminary determination that noise impacts exist and that noise abatement is likely to be feasible and reasonable. A final design noise analysis may be prepared without a preliminary design noise analysis if sufficient design details are available and if there is a high likelihood that abatement measures will meet feasibility and reasonableness criteria. The final design noise analysis is documented in a Design Noise Report.

Finding of No Significant Impact (FONSI): When applicable, the conclusive determination after completion of the Environmental Assessment process that a highway project will not create any significant environmental impacts. The term usually refers to the environmental document that supports this action.

Holiday: Any weekend day or weekday recognized by the Federal and/or State Government as a non-working day.

Impacted Receptor: A receptor for which the predicted hourly equivalent traffic noise level 1) meets or exceeds the approach criteria value found in Table 1 of the NCDOT *Traffic Noise Policy* or 2) exceeds the existing ambient noise level by 10 dB(A) or more.

Insertion Loss: The reduction of traffic noise levels, in dB(A), that directly results from installation of a noise reduction measure. Insertion Loss only pertains to the reduction in traffic noise levels, and is not synonymous with Noise Level Reduction (NLR), which also accounts for non-traffic noise sources.

L_{eq}: The equivalent steady-state sound level, which in a defined period of time, contains the same amount of acoustic energy as a time-varying sound level during the same period of time.

$L_{eq(h)}$: The equivalent sound level for a one-hour period of time.

NEPA (National Environmental Policy Act): Federal legislation that establishes environmental policy for the nation. It provides an interdisciplinary framework to ensure that decision-makers adequately take environmental factors into account.

Nighttime Hours (Night): The hours of the day between 10:00 p.m. and 7:00 a.m.

Noise: Any unwanted sound.

Noise Abatement Criteria (NAC*):* Noise levels for various land uses that, if approached or exceeded, require consideration of noise abatement. The NAC are not intended to represent acceptable noise levels or noise abatement design goals. Compliance with the noise regulations is a prerequisite for the granting of Federal-aid highway funds for construction or reconstruction of a highway (refer to Table 9.2). Along with Substantial Noise Increase, defined below, one of two criteria to determine noise impacts created by a proposed highway project.

Noise Abatement Measure: Any method used to reduce traffic noise levels, such as noise walls and earthen berms.

Noise Barrier: A measure that provides noise abatement. Such a measure can be either a noise wall, a berm consisting of a variety of materials, or a wall/berm system.

Noise Contour: A linear representation of equal noise levels, similar to elevation contour lines on a topographic map.

Noise Level Reduction (NLR): The reduction in $L_{eq(h)}$ noise levels accounting for all known noise sources and attenuating measures. For traffic noise analyses, NLR is the assessment of barrier insertion loss, IL, screened against measured or otherwise quantified noise sources. For example, if a barrier adjacent to a proposed highway on new alignment was predicted to reduce worst noise hour traffic noise levels at an impacted receptor from 66 dB(A) to 54 dB(A), the Insertion Loss would be 12 dB(A). However, if the measured existing ambient noise level at the receptor was 57 dB(A), then the *actual* reduction in worst noise hour noise levels would be 66 dB(A) – 57 dB(A), or 9 dB(A). Because barriers can only reduce traffic noise levels, NLR is the actual reduction in worst hour noise levels as described in the example, and is the appropriate metric by which to quantify predicted barrier effectiveness.

Noise Reduction Design Goal: The minimum-required predicted noise level reduction resulting from design of a traffic noise abatement measure. The NCDOT noise reduction design goal is 7 dB(A), and must be achieved for at least one benefited receptor for the abatement measure to meet NCDOT reasonableness criteria.

Noise Study Area (NSA): A group or grouping of receptors into an area that is influenced by similar noise sources.

Non-Residential Land Use: Defined by FHWA as Noise Abatement Category C, D, and E land uses.

Optimized Barrier: A noise barrier design with a horizontal alignment and vertical (top) profile based upon an appropriate TNM model, that is designed to find a balanced approach that 1) provides the greatest amount of traffic noise level reduction per barrier quantity (noise wall area or earth berm volume), 2) provides noise level reduction benefits to as many predicted impacted receptors as possible, 3) meets applicable feasibility and reasonableness criteria and 4) addresses all other pertinent engineering considerations such as, but not limited to, lines-of-sight, visual impacts, social impacts and with-barrier noise levels.

Peak Hour Traffic: Highest hourly traffic volume in a 24-hour period, not to be confused with the worst noise hour traffic.

Permitted: The approval of a building permit for an individual lot or site. Approval of a development plat or any other development plan does not meet the permitted criteria.

Practicable: Available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes. This determination only applies to state funded projects that do not utilize federal-aid highway funds and do not require FHWA approval.

Preliminary Design Noise Analysis: The analysis of noise conducted during the preliminary design phase of project development. The results of this analysis are usually summarized or incorporated into the appropriate NEPA/SEPA document prepared for the environmental clearance of a proposed project; the results of which are provided in a Traffic Noise Report.

Property Owner: An entity that holds legal ownership of land or other real property.

Public Hearing: A forum which is open to the general public to present information related to a project and to obtain formal input from the public.

Public Meeting: A forum which is open to the general public or specific portions of the public to present and discuss information related to a project with attendees, to answer questions from attendees, and to obtain input from attendees. Public meetings are generally less formal than public hearings and may only deal with specific topics, such as traffic noise.

Receptor: A discrete or representative location of a noise sensitive area(s), for any of the land uses listed in Table 1 of 23 CFR 772.

Record of Decision (ROD): The final step in the Environmental Impact Statement process, where by the Federal and/or State Government issues final approval of the environmental documentation.

Sound Level Meter (SLM): An instrument used to measure sound levels, as specified by ANSI S1.4-1983. A Type-I or Type II sound level meter must be used to obtain all sound level data for NCDOT preliminary design noise analyses, final design noise analyses, and construction noise analyses pertaining to NCDOT projects.

Substantial Noise Increase: Along with the NAC, defined above, one of two criteria to determine noise impacts created by a proposed highway project. A receptor is considered impacted if the predicted future hourly equivalent noise level exceeds the existing ambient noise level by 10 dB(A).

TNM Receptor: A location where traffic noise levels are modeled using the TNM. It is synonymous with the term "receiver" used in the TNM. A TNM Receptor may represent one or more receptors, and may represent a measurement site used in validating the TNM.

Traffic Noise Impacts: Noise levels that are predicted to approach or exceed the NAC or represent a substantial noise increase at noise-sensitive receptors in the project area.

Traffic Noise Model (TNM): The computer modeling program created by FHWA used to predict hourly equivalent traffic noise levels. The TNM version 2.5 or another model determined by FHWA to be consistent with the methodology of TNM shall be used on all federal- and state-funded highway projects in North Carolina for which traffic noise analysis is required.

Traffic Noise Report (TNR): A report that documents the methodology and findings of a preliminary design noise analysis.

Type I Project: Type I Projects include:

(a) The construction of a highway on new location; or,

(b) The physical alteration of an existing highway where there is either:

(i) Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or,

(ii) Substantial Vertical Alteration. A project that removes shielding, exposing the line-of-sight between the receptor and the traffic noise source. This occurs when either the highway vertical alignment is altered, or when the intervening topography between the highway traffic noise source and receptor is altered,

(c) The addition of a through-traffic lane(s). This includes the addition of a through-traffic lane that functions as a HOV lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,

(d) The addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

NOTE: The FHWA noise guidance recommends that State highway agencies take a broad approach to defining auxiliary lanes with respect to Type I projects as defined in paragraph (4) of the definition of Type 1 project in 23 CFR 772.5. Although the function of an auxiliary lane differs depending on the type of facility, an auxiliary lane should classify the project as Type I if the auxiliary lane is 2,500 feet or longer (see the AASHTO Policy on Highway Design or Green Book and Institute of Transportation Engineers (ITE) Manual "Freeway and Interchange Geometric Design Handbook" for more information). (FHWA Noise Policy FAQ item C2)

(e) The addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or,

(f) Restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane; or,

(g) The addition of a new or substantial alteration of a weigh station, rest stop, ride- share lot or toll plaza.

(h) If a project is determined to be a Type I project under this definition then the entire project area as defined in the environmental document is a Type I project.

Type II Project: A Federal or Federal-aid highway project for noise abatement on an existing highway. For a Type II project to be eligible for Federal-aid funding, the highway agency must develop and implement a Type II program in accordance with 23 CFR 772.7(e).

Type III Project: A Federal or Federal-aid highway project that does not meet the classifications of a Type I or Type II project. Type III projects do not require a noise analysis.

Weekday: Excluding holidays, the days of the week between Monday and Friday, inclusive.

Weekend: Excluding holidays, the days of the week including Saturday and Sunday.

Worst Noise Hour: The hour within a day in which the highest magnitude hourly equivalent sound level occurs. The worst traffic noise hour typically occurs when traffic is flowing freely at a high volume relative to the peak traffic hour volume, with a high percentage of trucks.

3.0 TRAFFIC NOISE FUNDAMENTALS

Sound is created when an object moves – the rustling of leaves as the wind blows, the air passing through our vocal chords, the almost invisible movement of stereo speakers. The movements cause the vibrations of the molecules in the air to move in waves like ripples on water. When the vibrations reach our ears, we hear them.

Noise is unwanted or irritating sound. It is emitted from many sources including airplanes, factories, railroads, commercial businesses, and highway vehicles. Steady-state highway traffic noise is predominantly a composite of noises from the vehicles' engine exhaust, drive train, and tire-roadway interaction.

The magnitude of sound (and noise) is typically described by the logarithm of the ratio of the sound pressure to a reference sound pressure, which is usually twenty micro-Pascals (20 μPa). Since the range of sound pressure ratios varies greatly – over many orders of magnitude, a base-10 logarithmic scale is used to express sound levels in dimensionless units of decibels (dB). The commonly accepted limits of human hearing to detect magnitudes of sound are between the threshold of hearing at 0 decibels and the threshold of pain at 140 decibels.

Sound frequencies are represented in units of Hertz (Hz), which correspond to the number of vibrations per second of a given tone. A cumulative sound level is equivalent to ten times the base-10 logarithm of the ratio of the sum of the sound pressures of all frequencies to the reference sound pressure. To simplify the mathematical process of determining sound levels, sound frequencies are grouped into ranges, or bands, each typically representing either one octave or 1/3 octave of the sound frequency spectrum. Since the cumulative sound level is a representation of the total sound pressure (energy), cumulative sound levels are then calculated by adding all the sound pressure levels of each band, and multiplying the logarithm of the ratio of the result and the reference sound pressure level (e.g., 20 μPa) by ten.

The commonly accepted limits of human hearing to detect sound frequencies are between 20 Hz and 20,000 Hz, and human hearing is most sensitive to the frequencies between 1,000 Hz and

6,000 Hz. Although people are generally not as sensitive to lower-frequency sounds as they are to higher frequencies, most people's ability to hear high-frequency sounds is reduced as they age. To accommodate varying receptor sensitivities, frequency sound levels are commonly adjusted, or filtered, before being logarithmically added and reported as a single sound level magnitude of that filtering scale.

Table 3.1: Comparison of Unweighted vs. A-Weighted Sound Levels for a Truck

Octave-Band Center Frequency (Hz)	A	B	C=A+B
	Unweighted Sound Level from a Truck (dB)	**Adjustment of Unweighted Sound to Reflect What Human Ear Hears (dB)**	**Sound Level that Human Ear Perceives = A-Weighted Sound Level or dB(A)**
31	75	-39	36
63	78	-26	52
125	83	-16	67
250	84	-9	75
500	81	-3	78
1000	75	0	75
2000	71	1	72
4000	63	1	64
8000	54	-1	53
	89		**82**
	Total Unweighted Sound Level in dB		**Total A-Weighted Sound Level in dB(A)**

The A-weighted decibel filtering scale applies numerical adjustments to sound frequencies to emphasize the frequencies at which human hearing is sensitive, and to minimize the frequencies to which human hearing is not as sensitive. In essence, the A-weighting approximates the sound that a person with average hearing perceives. This concept of A-weighting is illustrated in Table 3.1 above for a single truck. The actual (unweighted) sound produced by the truck is comprised of various frequencies (left column of the table) and produces a sound level for each frequency (Column A) resulting in a total noise level of 89 decibels (dB). However, the human ear perceives (hears) each frequency differently. The adjustments that reflect how the human ear perceives or filters each frequency's sound level are listed in Column B of the table. Column C contains each frequency's adjusted (or A-weighted) sound levels, resulting in a total A-weighted sound level of 82 dB, expressed as 82 dB(A). Thus, while the truck's sound level is 89 dB, it is perceived by the human ear to be 82 dB(A).

Several examples of noise levels, expressed in dB(A), are listed in Table 3.2. A review of Table 3.2 indicates that most individuals are exposed to fairly high noise levels from many sources on a regular basis.

Table 3.2: Common Indoor and Outdoor Noise Levels

Common Outdoor Noise Levels	Noise Level (dB(A))	Common Indoor Noise Levels
	110	Rock Band
Jet Flyover at 1,000 feet	100	Inside Subway Train (NY)
Gas Lawn Mower at 3 feet		
Diesel Truck at 50 feet	90	Food Blender at 3 feet
Noisy Urban Daytime	80	Garbage Disposal at 3 feet
Gas Lawn Mower at 100 feet	70	Vacuum Cleaner at 10 feet
Commercial Area		Normal Speech at 3 feet
	60	
		Large Business Office
Quiet Urban Daytime	50	Dishwasher Next Room
Quiet Urban Nighttime	40	Small Theater, Large Conference Room (Background)
Quiet Suburban Nighttime		Library
	30	
Quiet Rural Nighttime		Bedroom at Night, Concert Hall (Background)
	20	
		Broadcast and Recording Studio
	10	
	0	Threshold of Hearing

Adapted from Guide on Evaluation and Attenuation of Traffic Noise, American Association of State Highway and Transportation Officials (AASHTO). 1974 (revised 1993).

The degree of disturbance or annoyance from exposure to unwanted sound depends upon three factors:

1. The amount, nature, and duration of the intruding sound
2. The relationship between the intruding sound and the existing (ambient) sound environment; and
3. The situation in which the disturbing sound is heard

In considering the first of these factors, it is important to note that individuals have varying sensitivity to sound. Loud sounds bother some people more than other people, and some individuals become increasingly upset if an unwanted sound persists. The time patterns of sound also enter into perception as to whether or not a sound is offensive. For example, sounds that occur during nighttime (sleeping) hours are usually considered to be more offensive than the same sounds in the daytime.

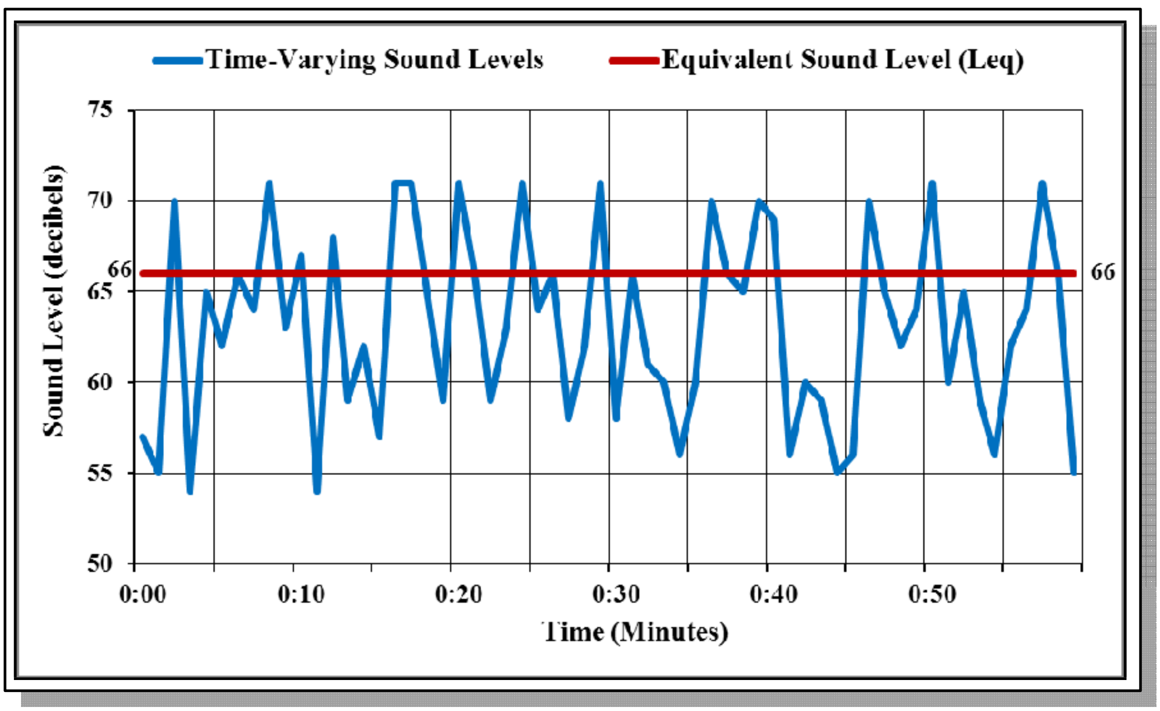
With regard to the second factor, individuals tend to judge the annoyance of an unwanted sound in terms of its relationship to sounds from other sources (background sound levels). A car horn blowing at night when background sound levels are low would generally be more objectionable than one blowing in the afternoon when background sound levels are typically higher. The response to sound stimulus is analogous to the response to turning on an interior light. During the daytime an illuminated bulb simply adds to the ambient light, but when eyes are conditioned to the dark of night, a suddenly illuminated bulb can be temporarily blinding.

The third factor – situational sound – is related to the interference of sound levels with activities of individuals. In a 60 dB(A) environment such as is commonly found in a large business office, normal conversation would be possible, while sleep might be difficult. Loud sounds may easily interrupt activities that require a quiet setting for greater mental concentration or rest; however, the same loud sounds may not interrupt activities requiring less mental focus or tranquility.

Over time, individuals tend to accept the sounds that intrude into their lives, e.g. regularly scheduled trains or subways in a city, particularly if the sounds occur at predicted intervals and are expected. Attempts have been made to regulate many types of unwanted sounds (or noise) including airplane noise, factory noise, railroad noise, and highway noise.

In addition to sound varying in frequency, sound intensity fluctuates with time. The L_{eq}, or equivalent sound level, is the equivalent steady-state sound level which in a stated period of time contains the same acoustic energy as a time-varying sound level during the same period. This sound descriptor has gained wide acceptance as a good representation of the aforementioned three factors. With regard to traffic noise, fluctuating sound levels associated with traffic are represented in terms of L_{eq}, the steady, or equivalent, sound level with the same energy.

Figure 3.1: Time-Varying Sound Levels vs. Equivalent Sound Level (Leq)



Because decibels are logarithmic representations of large ratios, they cannot be added arithmetically. A chart for approximate decibel addition is shown in Table 3.3. A doubling of the sound source produces a 3 dB(A) increase. For example, two trucks producing 90 dB(A) each will combine to produce 93 dB(A), not 180 dB(A). Also, assuming the same distribution of vehicle types, doubling the traffic volume from 400 vehicles per hour (vph) to 800 vph would create a 3 dB(A) noise level increase if the traffic speed remained constant.

Table 3.3: Rules for Combining Sound Levels by Decibel Addition

For sound levels known or desired to an accuracy of +/- 1 decibel:

When two decibel values differ by	Add the following amount to the higher value
0 or 1 dB(A)	3 dB(A)
2 or 3 dB(A)	2 dB(A)
4 or 9 dB(A)	1 dB(A)
10 dB(A) or more	0 dB(A)

As referenced in Table 3.4, variations of three dB(A) or less are commonly considered barely perceptible to normal human hearing. A five decibel (5 dB(A)) change is more readily noticeable. An increase or decrease of 10 dB(A) in the sound pressure level is typically perceived as a doubling or halving of the sound level intensity. For example, a sound at 70 dB(A) will sound twice as loud as a sound at 60 dB(A).

Generally, sound intensity decreases in proportion to distance from the source. Sound levels from a point source will generally decrease by 6 dB(A) or more for each doubling of distance away from the point of origin because the sound energy dissipates from a spherical source. Sound levels from a line source such as steady vehicle traffic on a highway will generally decrease by 3 dB(A) or more for each doubling of distance away from the line of origin because the sound energy dissipates from a cylindrical source. Empirical evidence has shown that noise levels produced by highway traffic decrease at varying rates, converging at approximately a 4.5 dB(A) reduction per doubling of distance from the highway, depending upon several attenuating factors including distance, intervening ground hardness/softness, structures, forestation, ground elevations, source-to-receptor spatial relationships, weather, and other factors.

Table 3.4: Relationships Between Changes in Sound Levels and Loudness

Sound Level Change	Relative Change in Loudness Perceived by Humans
+30 dB(A)	Eight Times as Loud
+20 dB(A)	Four Times as Loud
+10 dB(A)	Twice as Loud
+5 dB(A)	Readily Perceptible
+3 dB(A)	Barely Perceptible
0 dB(A)	**No Change**
-3 dB(A)	Barely Perceptible
-5 dB(A)	Readily Perceptible
-10 dB(A)	Half as Loud
-20 dB(A)	1/4 as Loud
-30 dB(A)	1/8 as Loud

Since the sound levels associated with vehicles traveling on highways are almost always considered to be either intruding, annoying, unwanted, or disturbing to nearby receptors of such sounds, the term noise is usually used in describing the levels, impacts, and abatement associated with vehicles traveling on highways.

For the purpose of highway traffic noise analyses, motor vehicles fall into one of five categories:

- Automobiles - vehicles with two axles and four wheels,
- Medium Trucks - vehicles with two axles and six wheels,
- Heavy Trucks - vehicles with three or more axles,
- Buses – vehicles suited for transport of nine or more passengers, and
- Motorcycles – open-cockpit vehicles with two or three wheels.

The emission levels of all of these vehicle types increase as a function of the logarithm of their speed.

The level of highway traffic noise is primarily dependent upon:

- the volume of the traffic,
- the percentages of the different types of vehicles in the volume of traffic,
- the speed of the traffic,
- pavement condition, and
- distance between the receptor and the roadway.

Generally, the loudness of traffic noise is increased by heavier traffic volumes, a higher percentage of trucks, and/or higher speeds. Vehicle noise is predominantly a combination of noise emissions from engines, exhausts, and tire/pavement interaction. Traffic noise is also dependent upon other factors such as roadway geometry (e.g. inclines and/or declines), defective equipment, and vehicle operation. Assuming constant vehicle mix and speed, a tenfold increase in traffic volumes (200 vehicles per hour increases to 2000 vehicles per hour) sounds twice as loud. Traffic at 65 miles per hour sounds twice as loud as traffic at 30 miles per hour. One (1) truck at 55 miles per hour sounds as loud as ten (10) cars at 55 miles per hour.

4.0 LEGISLATION, REGULATIONS, AND ORDINANCES

Effective control of the undesirable effects of highway traffic noise requires that land use near highways be controlled, quieter vehicles be manufactured, and consideration of traffic noise impacts and abatement occur on qualifying highway projects.

The first component of effective highway traffic noise control is for local governments to develop and implement noise-sensitive land use planning regulations. The second requirement for the effective control of the undesirable effects of highway traffic noise is source control. The final component is the responsibility of Federal, State, and local governments to identify and, when feasible and reasonable, abate traffic noise impacts as part of individual highway projects.

4.1 Land Use Planning and Control

The FHWA and NCDOT have no authority to regulate land use planning or the land development process. The FHWA and other Federal agencies encourage State and local governments to practice land use planning and control in the vicinity of highways. The FHWA advocates that local governments use their power to regulate land development in such a way that noise-sensitive land uses are either prohibited from being located adjacent to a highway, or that the developments are planned, designed, and constructed in such a way that traffic noise impacts are minimized. When requested, NCDOT will provide information to assist local jurisdictions in the development of local noise controls. NCDOT strongly advocates the planning, design and construction of noise-compatible development and encourages its practice among planners, building officials, developers and others.

4.2 Source Control

The Environmental Protection Agency (EPA) coordinated all federal noise control activities through its Office of Noise Abatement and Control. However, in 1981, the EPA concluded that noise issues were best handled at the State or local government level. As a result, the EPA phased out the office's funding in 1982 as part of a shift in federal noise control policy to transfer the primary responsibility of regulating noise to state and local governments. The Noise Control Act of 1972 and the Quiet Communities Act of 1978 were not rescinded by Congress and remain in effect today, although essentially unfunded.

The Federal Motor Carrier Safety Administration has adopted regulations under Chapter 49 Code of Federal Regulations Section 325 – *Compliance with Interstate Motor Carrier Noise Emission Standards 49 (CFR 325)*. Section 325.7 defines allowable noise levels for motor carriers governed by the regulations.

4.3 Highway Project Noise Impact Determination and Abatement

The National Environmental Policy Act (NEPA) of 1969 provides broad authority and responsibility for evaluating and abating adverse environmental effects including highway traffic noise. NEPA directs the Federal government to use all practical means and measures to promote the general welfare and foster a healthy environment.

The Federal-Aid Highway Act of 1970 mandated that FHWA develop noise standards for abating highway traffic noise. The FHWA regulations for abatement of highway traffic noise in the planning and design of federally aided highways are contained in 23 CFR 772 – *Procedures for Abatement of Highway Traffic Noise and Construction Noise*. The entire 23 CFR 772 constitutes the FHWA noise standards.

A part of the FHWA noise standards in the Noise Abatement Criteria (NAC), which define noise levels for various land use activity categories that, when approached or exceeded, require the consideration of noise abatement. In developing the NAC, FHWA considered several factors, such as hearing impairment; annoyance, sleep, task interference; and interference with speech communication. The FHWA ultimately determined that the NAC should represent noise levels that are predominantly associated with interference of speech communication, and represent a compromise between noise levels that are desirable and those that are achievable.

The 23 CFR 772 regulations require specific actions by transportation agencies during the planning and design of highway projects, including:

- Defining acceptable criteria for determination of traffic noise impacts for different types of land uses and human activities,
- identifying traffic noise impacts,
- evaluating the feasibility of all potential abatement measures,
- evaluating the reasonableness of all feasible noise abatement measures (including acoustical criteria, cost-reasonableness, and the viewpoints of benefited property owners and tenants),
- incorporating feasible and reasonable noise abatement measures into the highway project plans, and
- coordinating with local officials by providing helpful information on noise-compatible land use planning and control.

Compliance with the noise regulations is a prerequisite for the granting of Federal-aid highway funds for construction or reconstruction of a highway.

5.0 APPLICABILITY

Projects utilizing federal-aid highway funds or that require FWHA approval

This manual applies to all Type I federal or federal aid highway projects in the State of North Carolina, including federal projects that are administered by local public agencies. The definitions of Type I, Type II, and Type III can be found in the NCDOT Traffic Noise Policy (see Appendix A of this document). The NCDOT Traffic Noise Policy and this manual were developed in accordance with 23 CFR 772.

Any highway project that utilizes federal-aid highway funds or that requires FHWA approval, regardless of funding source, must comply with 23 CFR 772.

Projects that are State funded

Projects that are State funded do not use the federal type designation for applicability.

For State-funded projects the NCDOT Traffic Noise Policy and this manual will apply if the project is located on a US or Interstate route that is full control of access and where the project involves adding a through-traffic lane.

All other State-funded projects for which an Environmental Assessment (EA) or Environmental Impact Statement (EIS) is prepared will comply with the North Carolina Environmental Policy Act (SEPA) and the North Carolina Administrative Code. For these projects, a traffic noise analysis is required to identify traffic noise impacts. Noise barriers will be considered where practicable as determined by the Division Engineer.

Projects that are classified as State Minimum Criteria do not require a noise analysis provided the following conditions are met: 1) no federal-aid highway funds are utilized 2) no FHWA approval is needed and 3) the project does not involve adding a through-traffic lane to a US or Interstate route that is full control of access.

Date of Public Knowledge and its Relationship to NEPA/SEPA Documents

Projects with a Date of Public Knowledge on or after the effective date of the 2016 policy shall comply with this manual. A reevaluation of an environmental document does not typically establish or change the Date of Public Knowledge.

The effective date of applicability and their relationship to NEPA and, as applicable, SEPA documents is as follows:

- A noise analysis conforming to the new policy and manual is required for all NEPA/SEPA documents (CEs, FONSIs, and RODs) signed on or after October 6, 2016.
- A revised noise analysis conforming to the new policy and manual is not required for Programmatic CE's (Types I, II(A) & II(B)) signed before October 6, 2016 since consultations are not required.
- A revised noise analysis conforming to the new policy and manual is not required for full CE's (Type III(C)) signed before October 6, 2016, or for which consultation occurs on or after October 6, 2016, when the consultation confirms the CE classification is still valid. A revised noise analysis conforming to the new policy and manual is required when the consultation results in a decision to prepare either an EA or EIS.
- A revised noise analysis conforming to the new policy and manual is not required for FONSIs signed before October 6, 2016, or for which consultation (or re-evaluation) occurs on or after October 6, 2016, as long as the consultation (or re-evaluation) confirms the FONSI finding is valid.
- All other situations will be determined on a case-by-case basis in coordination with FHWA.
- Except as otherwise noted, projects with a Date of Public Knowledge before the effective date of the 2016 policy shall comply with the criteria of the 2011 manual.

5.1 Type I Projects

The NCDOT Traffic Noise Policy and this manual will be utilized for all Type I federal or federal-aid highway projects and include:

a) The construction of a highway on new location; or,

b) The physical alteration of an existing highway where there is either:

   i. Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition. NCDOT measures the distance from the center of the nearest travel lane to the closest receptor; or,

   ii. Substantial Vertical Alteration. A project that removes shielding, therefore exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor.

c) The addition of a through-traffic lane(s). This includes the addition of a through-traffic lane that functions as High Occupancy Vehicle (HOV) lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,

d) The addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

e) The addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or,

f) Restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane; or,

g) The addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

If a project is determined to be a Type I project under this definition then the entire project area as defined in the environmental document is a Type I project.

5.2 Type II Projects

NCDOT does not participate in Type II projects for noise abatement constructed on an existing highway.

5.3 Type III Projects

Type III projects do not meet the classification of either a Type I or Type II project. Type III projects do not require a noise analysis.

Generally, the list of projects described in 23 CFR 771.117(c) and (d) are Type III projects (see Appendix D of this document), with some exceptions as noted below, for which FHWA has determined the project clearly meets the definition of a Type I or Type II project.

- 771.117(c)(6) The installation of noise barriers or alterations to existing publicly owned buildings to provide for noise reduction.
- 771.117(c)(12) Improvements to existing rest areas and truck weigh stations. Improvements to existing rest areas and truck weigh stations that involve increased capacity for overnight parking, relocation of parking facilities closer to noise sensitive land uses or other changes in the configuration of the facility that would meet the description of a Type I project.
- 771.117(c)(13) Ridesharing activities. Construction or expansion of an existing ride-share lot and access roads to a ride-share lot are a Type I project.
- 771.117 (c)(26) Modernization of a highway by resurfacing, restoration, rehabilitation, reconstruction, adding shoulders, or adding auxiliary lanes (e.g., parking, weaving, turning, climbing). Construction of auxiliary lanes other than turn lanes are a Type I project per the definition of a Type I project provided in 772.5.
- **771.117 (d)(3) Bridge rehabilitation, reconstruction or replacement or the construction of grade separation to replace existing at-grade railroad crossings.**
- 771.117 (d)(5) Construction of new truck weigh stations or rest areas.

- Construction of new Rideshare lots under 771.117(c)(13) represents a new noise source and may require a noise analysis similar to an analysis conducted for rest areas. Section 772.5 classifies auxiliary lanes as Type I except for turn lanes. The bolded text in 771.117(d)(3) indicates that construction of a grade separation to replace existing at-grade railroad crossings may result in a significant change in the vertical alignment of an existing roadway. In some cases, the grade separation project results in an overall benefit to the noise environment due to reduced requirements to sound train horns at grade separated crossings. Highway agencies may consider this benefit in the noise analysis.

6.0 DATE OF PUBLIC KNOWLEDGE

NCDOT is not responsible for evaluating traffic noise impacts or implementing noise abatement measures to protect developed or undeveloped lands that were not permitted before a project's Date of Public Knowledge. NCDOT advocates use of local government authority to regulate land development, planning, design and construction in such a way that noise impacts are minimized.

The Date of Public Knowledge is when the public is notified of a proposed highway project's location and potential noise impacts. A project's Date of Public Knowledge is the approval date of its final environmental document, designated by the approval of a Categorical Exclusion (CE), the NCDOT or FHWA Finding of No Significant Impact (FONSI) for an Environmental Assessment (EA), or the NCDOT or FHWA Record of Decision (ROD) for an Environmental Impact Statement (EIS). A re-evaluation of an environmental document does not typically establish or change the Date of Public Knowledge.

The criteria for determining when undeveloped land is permitted for development is the approval date of a building permit for an individual lot or site. **Approval of a development plat or any other development plan does not meet the permitted criteria.** For undeveloped lands where no permits for development have been issued, noise level information shall be developed for use by local officials and others in future planning efforts. This information may be provided by developing noise contours or by providing information in tabular form. See Section 12.13 for more detail.

NCDOT treats any abandoned property as undeveloped land. An abandoned property is any property that requires substantial reconstruction and/or a new permit to resume active use. This exception applies only to those structures that are condemned or otherwise not useable in the current condition as evidenced by missing windows/doors, missing roof(s), etc. The analyst should check the status of such properties with local building code officials to verify the need for an occupancy permit or plans for redevelopment prior to treating these locations as undeveloped lands (Activity Category G). The analyst will include lands determined as undeveloped in the Information for Local Officials section of the noise analysis report (TNR or DNR as applicable).

7.0 PREVENTING TRAFFIC NOISE IMPACTS

NCDOT strongly advocates noise-compatible land use and development. To support this position, NCDOT will maintain the following processes to discourage future development that may create traffic noise impacts.

7.1 Coordination with Local Officials

NCDOT will provide copies of all Traffic Noise Reports and Design Noise Reports to local governments with jurisdiction over areas in which the highway project is proposed. This delivery will be completed as early in the project development process as possible to discourage future development that may be incompatible with predicted future traffic noise levels. These documents will contain information identifying areas that may be impacted by traffic noise, the best estimation of future noise levels for receptors in the vicinity of the project, future noise level information for undeveloped lands, and other appropriate highway project design information. If requested, NCDOT will assist local officials with coordination and distribution of information contained within these reports to residents, property owners, and developers.

When requested, NCDOT will provide information to assist local jurisdictions in the development of noise controls. NCDOT strongly advocates the planning, design, and construction of noise-compatible development and encourages its practice among planners, building officials, developers, and others.

Noise study areas showing “likely” noise barriers and/or proposed locations of any “recommended” noise barriers will be presented and discussed when holding Public Hearings and Public Meetings. Likely noise barriers are based on preliminary design traffic noise analyses and are described in environmental documents. Recommended noise barriers are based on final design noise analyses and are usually identified after the environmental document is completed. Property owners and tenants who are being balloted for a recommended noise barrier will be provided a visual of the noise barrier location prior to their casting a ballot.

8.0 ANALYSIS OF HIGHWAY TRAFFIC NOISE

The North Carolina Department of Transportation (NCDOT) performs and contracts several types of traffic noise analyses. Preliminary design noise analyses are usually conducted during the early phases of project design, when detailed study alternatives are known and preliminary plans have been developed to the degree that enables such noise analyses to be performed. These analyses usually occur concurrently with and in support of the environmental clearance document that is being prepared during this project development phase. Information related to these preliminary design noise analyses are reported in a Traffic Noise Report.

The results of the preliminary design noise analyses may require that traffic noise analyses be performed during the final design phase of project development, when more detailed engineering plans are available. Traffic noise analyses performed during this phase are usually more detailed and usually build upon analyses and determinations made during the preliminary design noise analyses. Traffic noise analyses performed during this phase are typically focused on the preferred alternative or selected alternative as identified in the environmental document. Results of the final design noise analyses are documented in a Design Noise Report. Final design noise analyses may be performed by NCDOT or its consultants or through a design build process by a design build team.

Regardless of the project phase, the type of traffic noise analysis required will depend upon project specifics and previously completed efforts. Communication is the key to producing accurate and comprehensive final results. The NCDOT Traffic Noise and Air Quality Group encourages collaboration and supports traffic noise analysis efforts not only at project initiation and after project completion, but also throughout the duration of each project.

8.1 NCDOT Traffic Noise Analyst Required Qualifications

Only qualified personnel shall perform highway traffic noise analyses for NCDOT. Qualified personnel must have successfully completed formal training in the area of Highway Noise Analysis and the use of the FHWA-approved Traffic Noise Model (TNM) software.

NCDOT pre-qualification requirements are found online at https://connect.ncdot.gov/business/Prequal/Pages/Private-Consulting-Firm.aspx. Qualified personnel must have demonstrated experience in conducting noise analysis studies for highway transportation projects and must have exhibited a working knowledge of procedures outlined in FHWA Report Number FHWA-PD-96-046, *Measurement of Highway-Related Noise*, and 23 CFR 772. All persons in charge of the performance of noise analyses must also be proficient in the use of the most currently approved version of FHWA Traffic Noise Model (TNM) software, and be able to support their analyses with expert testimony if required.

Alternatively, NCDOT shall reserve the right to qualify personnel based upon involvement in the development and/or instruction of noise models and/or training courses, or other relevant experience.

The above qualifications must be met by all persons providing quality assurance functions for NCDOT traffic noise analyses.

Persons who perform a traffic noise analysis may not also provide quality assurance for the same project. Traffic Noise Reports and Design Noise Reports must be sealed by a professional engineer licensed in North Carolina under whose supervision the reports were performed. NCDOT does not require that the professional engineer be prequalified to prepare traffic noise analyses.

8.2 Noise Level Rounding Convention

With the exception of TNM model validation (refer to Section 8.9) and the reporting of parallel barrier degradation values, all noise levels shall be rounded to the nearest whole decibel prior to conducting traffic noise impact assessment and insertion loss/noise level reduction calculations. Unless explicitly requested otherwise, all noise levels shall be stated in units of whole decibels in all NCDOT traffic noise reports and design noise reports.

8.3 Traffic Noise Analysis Initiation

Commencement of any traffic noise analysis by a consulting firm shall be preceded by a project initiation meeting between NCDOT Traffic Noise and Air Quality staff and the traffic noise analyst (consultant, municipality, etc.) performing the work. This meeting will identify and define the specific tasks required.

8.3.1 Preliminary Design Traffic Noise Analysis

Critical information necessary to initiate a preliminary design traffic noise analysis for a proposed highway project includes the proposed project description, preliminary project design plans for the alternatives under detailed study, appropriate scalable mapping, existing and future traffic data, anticipated posted and design speeds, right-of-way width, and the scope of the project (widening, improvement, new location, etc.). The planned roadway access (uncontrolled, partially controlled, limited controlled, fully controlled access) must also be known to appropriately determine feasibility of potential abatement options.

To adequately address traffic noise propagation, other design information is normally required, such as the proposed typical section, shoulder types, lane configurations, median barrier type and location, safety barriers, etc.. The existing and future traffic diagrams with traffic information (percentages and types of trucks, design hour volumes, and directional distribution) are essential in creating accurate noise models and in determining existing and future noise levels. Project mapping must be dated, scaled, and clearly display a north arrow and show all detailed study alternatives required to be evaluated. Mapping shall be at an appropriate scale to identify all noise sensitive land uses and clearly show all project elements needed to document traffic noise levels, impacts, and abatement.

Other useful information includes project relocation reports, names and locations of Section 4(f) lands under the DOT Act of 1966 and names and locations of historic properties under Section 106 of the National Historic Preservation Act.

8.3.2 Final Design Traffic Noise Analysis

Critical information necessary to initiate a final design traffic noise analysis for a proposed highway project includes essentially the same information as that required for a preliminary design traffic noise analysis plus the following additional information:

- Reasonably complete design plans.
- A copy of the Traffic Noise Report, including all TNM modeling files.
- Any updated traffic forecasts
- Any updated information pertaining to changed land uses (particularly new building permits) that may have occurred since approval of the TNR and prior to the Date of Public Knowledge.

8.4 Traffic Data Requirements

Traffic forecasts are essential in initiating traffic noise analysis during any project phase. These forecasts ideally include the Annual Average Daily Traffic (AADT), Design Hour Volume (DHV), average daily truck volume percentages for Tandem Tractor & Semi-Trailer (TTST), average daily truck volume percentages for Duals (trucks with more than 4 wheels but not a TTST), and directional percentage split in the peak hour volume. Additional traffic data may be required to determine the worst noise hour used in all traffic noise analyses.

The traffic characteristics that yield the worst noise hour predicted traffic noise levels shall be used for the assessment of existing, design-year build-, and design-year no-build conditions. The worst traffic noise conditions shall be evaluated as the lesser of the DHV percentage of the AADT or the maximum roadway vehicle capacity Level of Service C (LOS C) operating at the design speed. TTST and dual truck volumes shall be assessed at the predicted average daily volume percentages (note: NCDOT no longer divides the average daily truck volumes in half when calculating worst hour noise levels).

Example: TNM Traffic Volume Calculation – Directional Split w/LOS C Cap:

AADT = 100,000, DHV = 9%

Classified Vehicle Distribution = 4% Duals, 5% TTST (91% Automobiles) Roadway = Interstate, 3-Lane Directional Segment

Directional Split = 65% (Peak Direction) / 35% (Non-Peak Direction)

Peak Direction DHV = (100,000 VPD) x (9% DHV) x (65% Directional Volume) = 5,850 VPH

Non-Peak Direction DHV = (100,000 VPD) x (9% DHV) x (35% Directional Volume) = 3,150 VPH

LOS C Cap = (1,548 VPH/lane) x (3 lanes) = 4,644 VPH

Peak Directional DHV = 4,644 VPH (*lesser* of 5,850 or 4,644)

Non-Peak Directional DHV = 3,150 VPH (*lesser* of 3,150 or 4,644)

Peak Direction Autos = 4,644 VPH x 91% = **4,226** VPH

Peak Direction Medium Trucks = 4,644 VPH x 4% = **186** VPH Peak Direction Heavy Trucks = 4,644 VPH x 5% = **232** VPH Non-Peak Direction Autos = 3,150 VPH x 91% = **2,867** VPH

Non-Peak Direction Medium Trucks = 3,150 VPH x 4% = **126** VPH Non-Peak Direction Heavy Trucks = 3,150 VPH x 5% = **158** VPH

Example: TNM Traffic Volume Calculation – 50% / 50% Directional Split w/LOS C Cap:

AADT = 100,000, DHV = 9%

Classified Vehicle Distribution = 4% Duals, 5% TTST (91% Automobiles) Roadway = Interstate, 3-Lane Directional Segment

Directional Split = 50%/50%

Directional DHV = (100,000 VPD) x (9% DHV) x (50% Directional Volume) = 4,500 VPH

LOS C Cap = (1,548 VPH / lane) x (3 lanes) = 4,644 VPH Directional DHV = 4,500 VPH (*lesser* of 4,500 or 4,644)

Directional Autos = 4,500 VPH x 91% = **4,095** VPH Directional Medium Trucks = 4,500 VPH x 4% = **180** VPH Directional Heavy Trucks = 4,500 VPH x 5% = **225** VPH

(Note Applicable to Both Examples Above: Calculated classified vehicle volumes must be distributed appropriately throughout the modeled TNM roadway elements. For example, if truck travel is prohibited on the inside (fast) lane of a section of 4-lane interstate, then the number of trucks should be distributed only on the TNM roadway elements representing the three outer (slower) lanes.)

8.5 Project Area Reconnaissance

Prior to initiating any noise measurements or modeling activities, a project area reconnaissance may need to be conducted unless most or all of the bulleted data requirements listed below can be obtained without a reconnaissance. While it may be possible to conduct the field review concurrently with the initiation meeting with NCDOT, sufficient time must be allocated to obtain the following information. The need for a project area reconnaissance will be determined on a case-by-case basis.

- Define Noise Study Areas (NSAs) and establish relationship of NSAs located near the limits of the project study area and determine the extent of receptors within these NSAs to be included in the noise analysis. (See Section 8.7 below for further discussion.)
- Confirm and define topography and acoustically pertinent features of the study area, such as privacy fences that may need to be considered in the model validation process or in the modeling of existing noise levels
- Observe traffic flow conditions
- Identify any supplementary and/or non-highway noise sources in the study area
- Determine short-term and long-term measurement locations
- Determine where and how to model large parcels and non-residential land use activities for which equivalent receptor (ER) values must be calculated
- Obtain usage data required to calculate ER values
- Determine locations where upper story receptors need to be analyzed
- Identify Activity Category D land uses where measurement and/or analysis of interior noise levels is anticipated
- Make initial determinations related to which structures in the study area should be modeled as individual barriers or not modeled at all. Establish appropriate heights to assign to building barriers. If an analyst is initially uncertain as to whether a building should be included in the modeling process, the model validation process may help in making such a decision. For example, if a TNM validation run for a receptor validates without the inclusion of an intervening building, then there is probably no need to include that building in future TNM runs. Conversely, if the run does not validate in the absence of the building, then the building should probably be included in future TNM runs.
- Make determinations of where tree zones should be included in the models used for determining existing and future traffic noise levels (see Section 8.10.5).

- For final design noise analyses, identify any changes that have occurred since the completion of the Traffic Noise Report. Examples might include design changes, updated traffic forecasts and new building permits.

If a field reconnaissance is conducted, taking spot measurements with hand held sound level meters might help define the noise measurement sites and limits of noise measurements. These spot measurements will aide in determining the extent and limits of noise measurements necessary to define the existing noise environment from all sources in the noise study area(s) and to help determine the limits of potential traffic noise impacts. The duration of spot measurements depends on achieving a stable Leq, but in general should last at least five (5) minutes.

8.6 Noise Analysis Work Plan

Pertinent project data, including information obtained from the project field review (as applicable), shall be included in a Noise Analysis Work Plan which must be submitted to NCDOT for approval prior to initiation of any noise measurements or modeling. All proposed measurement and analysis locations should be included in a graphic (photo or plan base), with the noise abatement criteria (NAC) associated with each receptor identified in the work plan. 23 CFR 772.11(d)(4) stipulates that no spatial limits exist for which traffic noise analysis must be completed. Since all traffic noise impacts must be determined in the noise analysis process, the modeling of additional receptors may be necessary following initial noise modeling efforts if the initially identified receptors do not define the outer limits or distances from roadway(s) for which traffic noise impacts are predicted to occur. The measurement plan is intended for the analyst to use as a guide to measurement locations. NCDOT recognizes that there may be instances where measurement locations must be adjusted due to unforeseen circumstances encountered in the field.

The duration of noise measurements should be stated and the process by which large parcels and non-residential receptors (including those requiring calculation of equivalent receptors) are to be modeled shall be identified in the work plan. The work plan should also include a schedule for completing the traffic noise analysis.

The work plan shall discuss whether there is a need for model validation for projects that include new location alternatives (see Section 8.9). The work plan shall also include justification for including tree zones when predicting existing and future noise levels (see Section 8.10.5).

For projects where a noise analysis was prepared under the 2011 policy/manual and is being updated for compliance with the 2016 policy/manual, a work plan may not be necessary where ambient noise measurements have already been obtained and no additional field work is anticipated.

For final design noise analyses, the noise measurement and modeling data contained in the Traffic Noise Report shall be reviewed with NCDOT to determine its appropriateness for use or reference in the final design noise analysis.

8.7 Defining a Noise Study Area (NSA) and Included Receptors

An NSA may contain only receptors within a certain Activity Category (such as residences) or it may contain receptors that represent several types of activity land uses (such as residences, schools, daycare facilities, offices, etc.). At the project limits (limits of the proposed project roadway construction or reconstruction), receptors could exist that may be potentially impacted by the project. The analyst shall never assume that the noise impacts are limited to the physical limits of the construction of a project. These potentially impacted receptors should be included in the NSA that exists near the limits (i.e. termini) of the project, even if that causes the NSA boundaries to extend past the limit of work associated with the highway improvement project. Based upon the results of feasibility and reasonableness evaluations for noise abatement measures, it may be necessary to ultimately extend the noise study limits to incorporate required noise abatement for any impacted receptors in these areas. The focus of any extension of noise study limits should strictly be on incorporating any abatement for these impacted receptors and not in increasing the number of benefited receptors.

The first step in determining the impacted area is the analyst should extend the modeling limits at a minimum distance based on the roadway functional classification (see Table 8.1 below) or to a logical termini point greater than the minimum distance from the end of physical construction. This logical termini point for the noise analysis might be a roadway crossing or change in land use that is beyond the minimum distance from the end of physical construction. Next, the analyst should determine if the project's impacts extend beyond this point. If impacts do exist, the analyst should extend the modeling further away from the project terminus to a point where the future build condition noise levels do not create a substantial noise increase (10 dB(A)) over future no-build levels or cause receptors to approach or exceed the applicable NAC as a result of the project (future no-build vs. future build).

Table 8.1: Defining Noise Study Area Limits

Functional Class	Distance
Freeway/Expressway	800 feet
Arterial/Major Collector	500 feet
Minor Collector/Local	200 feet

These distances can also be used to determine the noise study area limits extending outward (or laterally) from the sides of a project. The key consideration is that the NSA must be adequately sized such that all impacts due to the project have been identified.

The mapped receptors and associated narrative should clearly indicate that the analysis has gone far enough to demonstrate that receptors are neither experiencing a 10 dB(A) or greater increase nor are they approaching or exceeding applicable NAC for the future build vs. future no-build year conditions as a result of the project.

Once the limits of the noise analysis have been determined, continue the analysis to determine impacts (comparison of the existing condition with the future build) and abatement.

8.8 Ambient Noise Measurements

Ambient noise measurements shall be conducted following NCDOT approval of the Noise Analysis Work Plan. Field personnel shall obtain an NCDOT right-of-entry letter prior to entering private property for the purposes of data collection. For projects on new alignment, the purpose of the measurement program is to determine existing ambient noise levels. For roadway improvement projects, the primary purposes of the measurement program (along with the collection of concurrent traffic data) are to help determine worst noise hour(s), and to serve as the foundation for the creation of a validated TNM for modeling existing and future noise levels.

Noise measurements may also be required during the construction phase of the project to address complaints or to validate any prescribed construction noise abatement.

- Ambient noise measurement locations shall be selected to provide a suitable foundation for accurately predicting existing and design-year traffic noise levels at identified receptor locations.
- A TNM model can be validated only as far from the existing roadway noise source(s) as the farthest existing noise measurement location. While the collection of existing noise measurement data for receptors located at distances beyond the probable limits of traffic noise impact occurrence is encouraged, such measurements are not required if no sensitive receptors exist or are planned and permitted, since impacts are only defined for receptors. In addition, measurement of noise at a receptor where there is clearly no exterior area of frequent human use is not required unless the site is an Activity Category D land use and an assessment of interior noise impacts is necessary.
- Collection of existing noise measurement data for the purposes of evaluating traffic noise levels, and for the formation of a validated TNM model, will require sufficient measurement sites to represent sound level attenuation at exterior areas of frequent human use associated with receptors located at increasing distance(s) from the roadway. If no noise sensitive receptors exist beyond a front row measurement site, then no other sites need to be modeled. If receptors exist beyond the front row, additional sites will be required. Focus should be placed upon locating noise meters for ambient noise measurements data collection at discernible sites, rather than at nominal distances from the subject roadway.
- To reemphasize the point made in the previous bullet, noise measurement data should not be obtained at locations that are not, or will not, be representative of actual noise sensitive receptors (e.g., collection of ambient noise measurement data within the existing

right-of-way of a proposed interstate highway widening project or collection of data behind a front row receptor when no other receptors exist behind that receptor).

Figure 8.1: Ambient Noise Measurement Locations

Figure 8.1 Notes: The sound level meters shown in the background and foreground of Figure 8.1 represent the 2nd and 3rd row receptors, respectively, in the array. The meters are located at future deck areas of single-family homes with approved building permits. The 1st-row receptor was located near the roadway beyond the forested area in the background of the figure.

Examples of appropriate placement of sound level meters for other exterior areas of frequent human use are shown below:

8.1.1 Sound Level Meter Placed Near Apartment Balcony

8.1.2 Sound Level Meter Placed Near Hole on Golf Course

8.1.3 Sound Level Meter Placed in a Park Near a Picnic Table

8.1.4 Sound Level Meter Placed at a Daycare Center Playground

8.1.5 Array of 3 Sound Level Meters in an Open Play Field

- Sound level meters used for ambient noise measurement data collection should be placed at locations easily identified on project plans or photography, since measuring distances from existing or proposed roadway alignments to the far-field locations necessary to create a correctly validated TNM model will be difficult, if not impossible. For example, in Figure 8.1, the 2nd row receptor was placed at a slope break line conspicuous in the elevation contour data. The 3rd row receptor was placed at a survey stake marking the corner of a residential lot, also clearly identified in the electronic survey data.

- Simultaneous measurements may need to be conducted in front of and behind study area features such as privacy fences, privacy walls, and other noise blocking features that affect existing noise levels and / or for purposes of accurately validating a noise model. Such fences typically have gaps that let a substantial amount of noise through. Based on data obtained from these simultaneous measurements, the privacy fences may be able to be modeled as building rows, with their coverage percent established based on the simultaneous measurements. Privacy fences are only to be included if needed for TNM model validation and are not to be included in design year TNM data files.

- ANSI S1.4-1983, TYPE I or TYPE II logging sound level meters shall be used to collect existing ambient noise level data. All meters must be calibrated by an appropriately accredited laboratory within 2 years of use on any project. All meters shall be field-calibrated at the beginning of every noise measurement session and when batteries are changed (either during a short-term or long-term noise measurement session).

- Sound level meters shall be set to the slow response setting for traffic noise measurement.
- For construction noise monitoring set the sound level meter response rate based on the construction noise source. Use a fast response rate for impulse noise sources (e.g. jackhammer, impact pile driver, mounted impact hammer) and a slow response rate for other sources.
- If possible, sound level meters shall be set to capture the L_{eq}, L_{max}, L10, and L90 sound level metrics. Minimally, sound level meters shall capture L_{eq} and L_{max}.
- Short-term ambient noise level data collection measurement sessions shall have a minimum duration of 20 minutes. Short-term ambient noise measurement in rural areas, or in the vicinity of low traffic-volume roadways may require longer measurement periods (e.g., 60 minutes or more) to attain desirable statistical accuracy. Table 8.2 presents suggested measurement sampling periods based on the temporal nature and the range in sound level fluctuations of the noise source.

Table 8.2 Measurement Durations

Temporal Nature	Greatest Anticipated Range		
	10 dB	10-30 dB	>30 dB
Steady	2 minutes[1]	N/A	N/A
Nonsteady fluctuating	5 minutes[1]	15 minutes[1]	30 minutes
Nonsteady intermittent	For at least 10 events	For at least 10 events	For at least 10 events

Source: Adapted from Table 5 in FHWA's *Measurement of Highway-Related Noise*

[1] Note the NCDOT requires a minimum measurement period of 20 minutes.

- Noise measurement data shall be obtained in increments of not more than one minute (i.e. a 20-minute short-term noise measurement session shall be comprised of at least 20 data points; a 24-hour long-term noise measurement session shall be comprised of at least 1,440 data points).

- Long-term noise measurements may be appropriate at multiple locations and on both sides of a highway in order to ascertain the influence of directional flow on the worst noise hour(s), realizing that different worst noise hours may exist for different NSAs. Such long-term measurement periods should encompass up to 24-hours, and include at least the typical or known loudest worst traffic noise and highest traffic noise hours of the day. A minimum time period of 5:00 am to 8:00 pm should be anticipated. Worst noise hour determinations cannot typically be determined from short term measurements, since short term measurements are usually taken at different times, at different locations, and at different distances from the roadway. The need for, and locations of, long-term measurements will be determined on a case-by-case basis and included in the Noise Analysis Work Plan.

- An event log shall be created for all attended/manned noise measurement sessions. The event log does not need to be included in the report; however, it shall be available as a reference to document the existing noise environment, justify despiking of aberrant noise events from data sets, defend TNM model validation, etc.

- Sound level meters shall never be turned off during a noise measurement session as a means to eliminate the effects of aberrant noise events (traffic or otherwise). However, if an aberrant noise source can be identified prior to it affecting a noise reading (such as a distant police siren approaching the measurement site), pausing the meter is acceptable as long as the time of the pause is noted. When appropriate, justified, and documented in an event log, removing affected data points from the noise measurement data set, or despiking, is encouraged. Whether the meter is paused or the data is de-spiked depends on a variety of factors including the relationship of sound level meters to each other, the relationship of each meter to the adherent noise source, and how many meters a particular person much simultaneously operate. Either technique may be employed.

- Traffic counts collected in each direction of travel concurrent with noise measurements shall be made in accordance with the five vehicle classification types employed by the TNM model. Corresponding to the 13 FHWA vehicle classifications, the TNM model defines vehicles as Autos (FHWA vehicle classifications 2 & 3), Medium Trucks (FHWA vehicle classification 5), Heavy Trucks (FHWA vehicle classifications 6 through 13), Buses (FHWA vehicle classification 4), and Motorcycles (FHWA vehicle classification 1). All two-axle, four wheel vehicles – including pickups – shall be counted as Autos. Only two-axle, six-wheel trucks (e.g. delivery trucks and small box trucks) shall be counted as Medium Trucks. All types of buses (e.g. school buses, inter-city buses, and intra-city buses) shall be counted as Buses. All other trucks shall be counted as Heavy Trucks.

8.9 TNM Validation

Title 23 CFR 772.11(d)(2) requires that, for projects on new or existing alignments, the analyses of traffic noise impacts validate predicted noise levels through comparison between measured and predicted levels. A TNM model is considered validated if it is a reasonable representation of the existing noise study area and/or project area, *and* the TNM- predicted noise levels are within the acceptable FHWA tolerance value of +/- 3.0 dB(A) as compared to the noise level data obtained in the field at noise measurement locations. Arbitrary TNM models shall not be considered for TNM validation. Acceptable TNM models represent actual existing conditions at receptors within the project study area. Refer to Section 8.10 for guidance on TNM modeling.

Although the FHWA-accepted tolerance for TNM model validation is ±3.0 dB(A), it is desirable to strive for a closer tolerance, if such can be achieved by the application of consistent and justifiable modeling inputs. However, in no instance should noise analysts add additional input that may not be appropriate or modify input parameters in an inappropriate manner in an attempt to either meet or improve upon the ±3 dB(A) tolerance value. On occasion, acceptable model validation may not be obtainable at a site because of unusual events or circumstances. If necessary, such locations may be re-measured. At a minimum, the reason for a site not validating should be noted in the validation tables.

Validation of a TNM is only possible if there are sources of traffic noise that are the predominant contributors to noise in an area. As such, most TNM validations are conducted for roadway widening and reconstruction projects or where a new feature, such as a new interchange or new intersection is being added to an existing facility. Therefore, TNM cannot normally be validated for projects on new alignment where no traffic noise sources exist. At best, validation could be performed for parallel or cross roads, if they exist within the project area.

Use the existing pavement as the pavement type in TNM for validation purposes only (if use of existing pavement is needed to validate) and note any pavement defects or unusual texturing observed during a measurement in the field notes.

8.10 TNM Modeling

The most recent version (currently Version 2.5) of the FHWA Traffic Noise Model (TNM) Report No. FHWA-PD-96-010 is the only approved tool for predicting traffic noise levels, for assessing traffic noise impacts, and for determining abatement measure effectiveness. The Reference Energy Mean Emission Level (REMEL) data and the predictive algorithm of the TNM software are FHWA approved and must not be altered. All traffic noise analyses, assessments of impact, and evaluations of potential abatement effectiveness shall be performed by means of appropriate application of the TNM software. Refer to *Traffic Noise Model: Frequently Asked Questions (FAQs)*:

http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_faqs/faq00.cfm .

All reasonable efforts must be made to appropriately represent the project study area(s) for the purpose of accurately assessing existing and design year traffic noise levels and identifying all traffic noise impacts. Acoustically-relevant features including, but not limited to, existing roadways, elevation contour changes, structures, areas of dense forestation, and all receptor locations should be modeled. If sufficient data is not available in customary formats such as electronic drawing files, external resources should be examined (e.g. web-accessible county GIS data, Google Maps™, Google Earth™, Microsoft® Bing® maps, etc.). Detailed modeling – even for preliminary traffic noise analyses – is critical to limiting inaccurate results and misleading recommendations, and to optimizing the overall efficiency of the expenditure of resources in maintaining compliance with the requirements of 23 CFR 772. The Run Identification input shall be complete and accurate for all TNM models created in conjunction with NCDOT preliminary and final design noise analyses. Unless specified, the modeling guidance applies to both the TNR and DNR.

In performing TNM noise analyses, the guidance provided within the TNM Users Guide and the TNM Technical Manual should be utilized. Some additional guidance is provided in the following discussions, including some best modeling practices guidance from recently completed research efforts. Collaboration with NCDOT Traffic Noise and Air Quality Group staff is encouraged for the resolution of anomalous TNM results and/or complex modeling scenarios such as interchanges with flyover ramps, overpasses, barriers on structures, retaining walls, median barriers, superelevated highways, etc.

8.10.1 Roadway Elements

In modeling roadway elements, noise analysts should refer to the latest version of the FHWA Traffic Noise Model (TNM) Release Notes, and FHWA TNM FAQs (http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_faqs/faq06.cfm#miroadways1), and the following general guidance. Unless specified, the following modeling guidance applies to both the TNR and DNR:

- Roadway elements should not represent more than two (2) travel lanes for preliminary design traffic noise analyses. Model each direction of travel with a separate TNM roadway(s). For final design traffic noise analyses, lane-by-lane modeling is required. NOTE: secondary roadways with low traffic volumes (less than 500 ADT, may be represented with a single TNM roadway with the width set to match the entire paved surface).
- Average pavement type must be used for prediction of all noise levels unless NCDOT obtains FHWA approval to use a different pavement type.
- For Existing, Design Year No Build and Design Year Build studies the vehicle speed in the TNM model shall be the posted speed plus five (5) miles per hour, not to exceed the design speed. Where the design speed is unknown, such as might be the case with cross

streets or other minor roads, the posted speed may be used. For validation models, the vehicle speed in the TNM model shall be the speed observed during validation measurements and concurrent traffic counts.

- Roadway widths should be set to ensure overlapping between adjacent roadway elements, and so that no horizontal gaps occur. Avoid exactly matching the edges of roadways. For final design traffic noise analyses, provide travel lane overlap distances between one (1) and ten (10) feet. For preliminary design noise analyses, there is no maximum overlap distance for travel lanes.

- When possible, local roadways (particularly local streets within noise-sensitive neighborhoods) should be modeled for all projects.

- Unless specific data is available for each travel lane or each TNM roadway, TNM roadways should be modeled as flat and at-grade, such that all modeled lanes of a roadway section are modeled at the same elevation. (Note that flat applies to the roadway section; it means that, unless lane-by-lane elevation data is available, super-elevations should not be modeled into the TNM roadway elements. The term at-grade applies to the roadway profile; it means that roadway grade elevations should be modeled into the TNM roadway elements.) Super-elevations are applicable for final design noise analyses only.

- If a roadway is in a cut- or fill-section, then the appropriate terrain line(s) must be included in the TNM model.

- Roadway segment lengths should be established to accurately represent horizontal and vertical changes in the roadway alignment. While NCDOT encourages modeling TNM roadway element vertices at increments of no more than 200 feet (two 100-foot survey stations), modeling of segment lengths of 100 feet and 50 feet may be justified in order to accurately represent roadway horizontal and vertical alignment and to maintain the essential relationship of roadways and noise barriers. See Section 8.10.4 for further discussion.

- Standard NCDOT survey stations are in increments of 100 feet.

- Roadway vertical coordinates should be established to a resolution of at least 0.5-feet in the vertical direction. A greater degree of resolution in the vertical plane is acceptable, but not necessary.

- Roadway elements on structure should be appropriately bordered with applicable traffic barriers. Shielding for traffic barrier segments for roadways on structure must be correctly designated for applicable roadway segments.

- TNM traffic control devices should be designated as appropriate for ramps and intersections (particularly for on-ramps adjacent to the modeled study area). See Section 8.10.8 for additional guidance. See Appendix I for guidance on modeling interchanges, intersections, and roundabouts.

- Although the TNM modeling functionality will not exactly replicate emission levels and frequency spectra, NCDOT recommends modeling off-ramp deceleration by reducing vehicle speeds throughout the modeled off-ramp roadway segments. For cases in which off-ramp traffic is the dominant noise source, employing this practice will produce more accurate results than otherwise. For cases in which off-ramp traffic is not the dominant noise source, then the effects of reducing vehicle speeds for the modeled off-ramp roadway segments will be inconsequential.

- There is no off-ramp control device feature in TNM (TNM does not have a function to model true deceleration, and inputting a speed constraint that is higher than the travel speed does not cause a reduction in traffic noise levels consistent with deceleration). For first-row receptors for which ramp traffic is the primary noise source, the difference between 65 miles per hour and 35 miles per hour can be as much as 6 dB(A), as illustrated below:

  For a receptor located 200 feet horizontally distant from the centerline of a single lane ramp, with an unimpeded view, and with 1,000 vehicles per hour (2% medium trucks, 3% heavy trucks), the TNM-predicted traffic noise level at 65 miles per hour is 62 dB(A). At 35 miles per hour, the TNM-predicted traffic noise level is 56 dB(A).

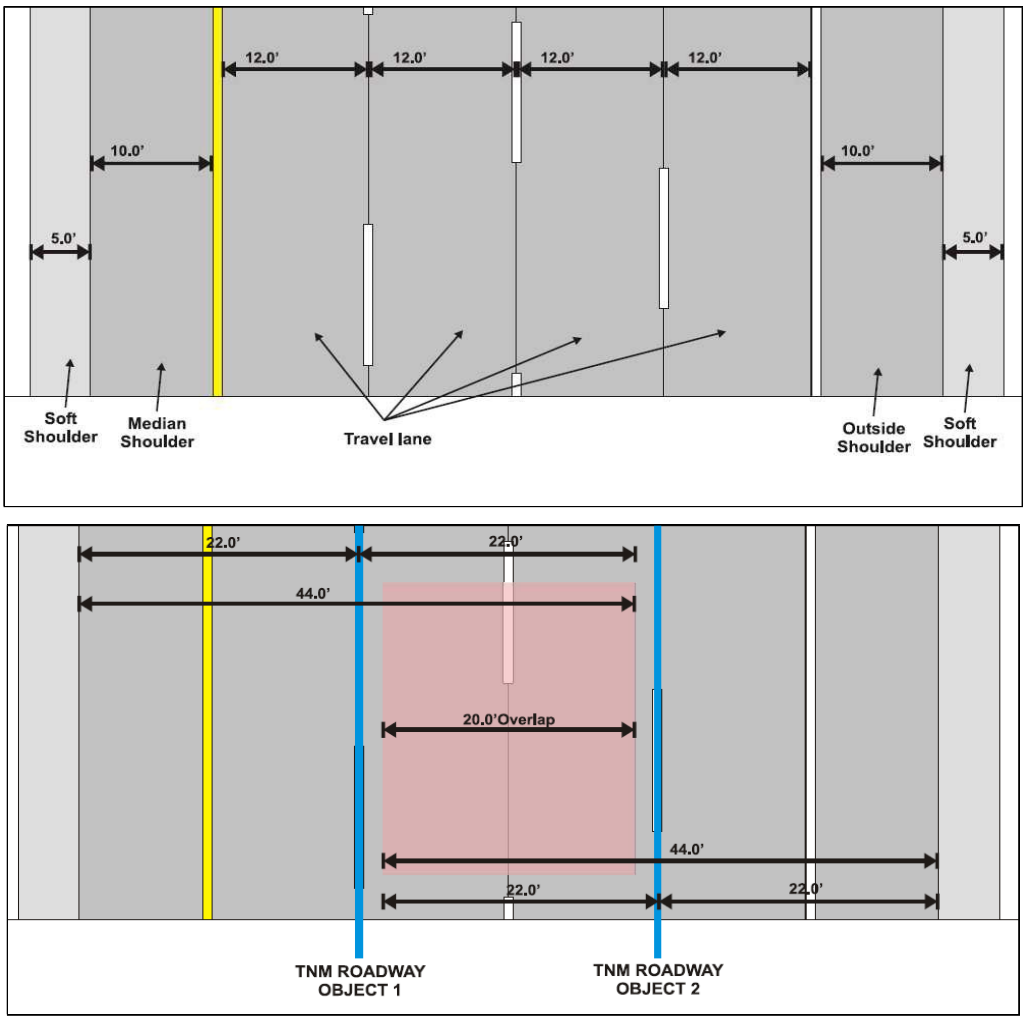
- For preliminary design traffic noise analyses, an acceptable methodology is to use a sufficiently wide TNM roadway to include the edge of inside and outside shoulders.

- For final design traffic noise analysis, use the Dummy Lane [shoulder modeled as a roadway with no traffic] technique to model shoulders, especially outside shoulders. It presents less potential for "illegal intersection" errors within FHWA TNM than using a ground zone to represent a shoulder, and may not require the addition of a contour line that is definitely required with the Ground Zone technique. It also allows for a smaller lane overlap than that resulting from use of the Adjacent Lane Width technique and is more compatible with modeling super-elevated roadway sections. This approach is not meant to suggest that additional terrain lines or other ground zones should not be used in the TNM modeling process. If a wide area exists between the paved shoulder and a hinge point, this area will probably need to be modeled using an appropriate intervening ground zone and a terrain line at the hinge point. If the shoulder is represented by a ground zone and the intervening area is also represented by a ground zone, an "illegal intersection" error will occur if any point of one ground zone touches any point of the other ground zone.
- For preliminary design noise analyses where there is grouping of travel lanes, roadway segment horizontal coordinates should be selected so that the modeled traffic is at the horizontal center of the actual travel lane(s), (e.g., to model the 4- lane northbound direction of an interstate highway with 12-foot wide travel lanes and 10-foot wide inside and outside shoulders, an acceptable methodology would be to model one 44-foot wide roadway element at the center of lanes 1 and 2 and another 44-foot wide roadway element at the center of lanes 3 and 4. The result will be a cumulative width = 68-feet (10-foot shoulder + four x 12-foot travel lanes + 10-foot shoulder), with a 20-foot overlap. Refer to Figure 8.2).

Figure 8.2: Modeling 4-Lane Interstate Roadways (Two TNM Roadway Elements per Direction)

(Applies to Preliminary Design Traffic Noise Analyses)

Plan View – (Roadway Elements Shown in Blue for Northbound Roadways Only)



TNM Skew – Section View: Southbound Lanes on Left, Northbound Lanes on Right

Assuming that the PM directional flow of a highway is reversed from the AM directional flow, worst noise hour traffic data should be entered into the TNM with the peak direction traffic on the roadway closest to the NSA being evaluated. While this may result in relatively minor noise level differences, such differences could, under certain situations, result in a difference in noise impact determinations.

For a receptor located 200 feet horizontally distant from the centerline of a single lane ramp, with an unimpeded view, and with 1,000 vehicles per hour (2% medium trucks, 3% heavy trucks), the TNM-predicted traffic noise level at 65 miles per hour is 62 dB(A). At 35 miles per hour, the TNM-predicted traffic noise level is 56 dB(A).

8.10.2 TNM Receptors and Represented Receptors

In the TNM modeling process, receptors are used to represent exterior areas of frequent human use. A receptor is a discrete point where an exterior area of frequent human use occurs, and is typically defined as a specific location of outdoor activity (e.g. swimming pool, athletic field, etc.), or the corner of the representative structure (e.g. house, place of worship, school) nearest to the primary roadway noise source.

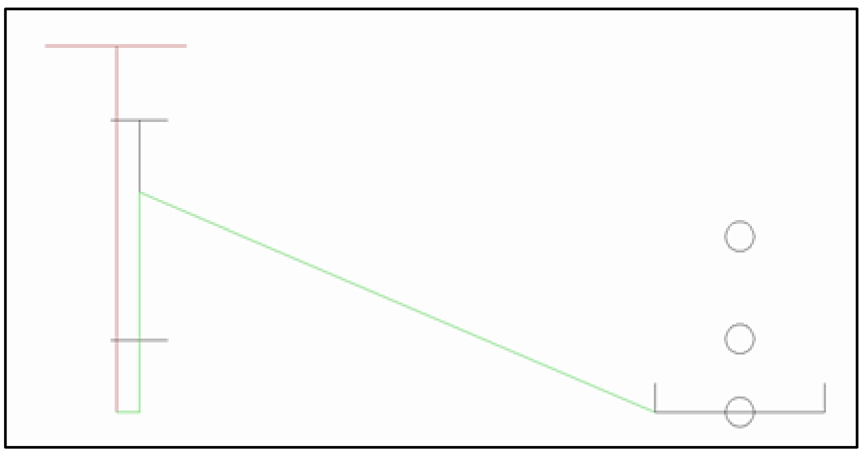
Receptors to be displaced due to project right-of-way acquisition should only be modeled for existing and no build conditions. For the build condition, displaced receptors do not require a noise analysis but should be shown on figures in the TNR and DNR using standard NCDOT symbology. NCDOT will provide relocation reports if available at the time of the noise analysis.

While sufficient TNM receptors should be modeled to represent the exterior areas of frequent human use of all receptors in the project study area, there is no set rule for modeling TNM receptors. For example, if a noise study area (NSA) contains single family residential structures that are spaced at distances of more than 100 feet, the exterior use area associated with each residential structure is represented by its own TNM receptor. In modeling receptors, the following guidance should be followed:

- TNM receptors should be set to the default height of 4.92 feet above ground level
- When modeling balconies, TNM receptors should be set at 4.92 feet above the floor level for multi-story areas of frequent human use (e.g. if the 4th story balcony of an apartment building is 30-feet above the adjacent ground level, then the representative receptor height should be 30 + 4.92 = 34.92-feet. Figure 8.3 shows the incorrect and correct approaches to receptor input.

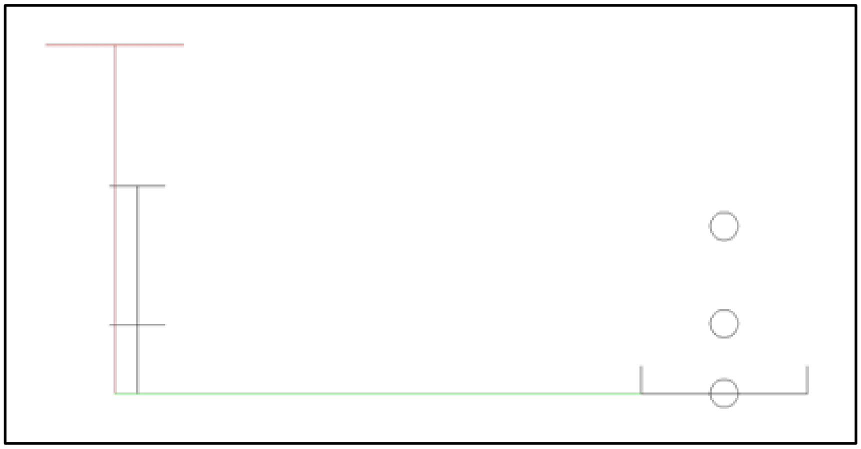
Figure 8.3: Modeling Multi-Story Areas of Frequent Human Use (2-Story Balconies)

TNM Skew – Section View
Incorrect Approach



Each receptor was entered with a height of 4.92' and the Z coordinate establishes the elevation of the receptor. Using this method, TNM draws a terrain line directly from the roadway to each receptor (NOTE: due to graphics limitations TNM only displays the terrain line between the source and the highest receptor when multiple receptors share the same X and Y coordinates). For the upper receptor TNM assumes the ground slopes upward from the roadway to the receptor and calculates accordingly when determining noise levels. This is not an accurate representation of the real world condition.

Correct Approach



In this case, the Z coordinate remains the same for each receptor and the difference in receptor elevation is established using the Height input in TNM. Using this approach, TNM retains the same ground elevation information when calculating noise levels for each receptor and provides the correct results for this case.

- NCDOT does not consider parking lots to be noise sensitive and therefore should not be considered for receptor placement.
- Although each TNM receptor defines the ground elevation at a specific point, TNM does not interpolate a ground line between two or more receptors. Do not model TNM receptors assuming that TNM will interpolate ground elevations between receptor points.
- Care should be taken when positioning TNM receptors to represent exterior areas of frequent human use outside of structures that totally shield the exterior use area from the highway. In no case should a receptor be placed within the boundary lines used to define a building structure.
- In verifying the extent of impacts associated with a highway project, sensitive receptors are often represented by TNM receptors located at varying distances from the highway project depending on a variety of project conditions, such as topography (see Table 8.1 for additional guidance). When positioning such receptors, noise analysts should keep in mind that, without a receptor, there cannot be a noise impact. Therefore, only place receptors at locations that represent sensitive receptors. As an example, if a single row of homes exists fronting a highway project and the land use behind the homes is farmland, industrial land, retail facilities, or some other Activity Category F or G land use,

placement of receptors in the area behind the homes is not necessary, regardless of the distance from the highway project.

- In establishing TNM receptor locations to model noise levels associated with a highway project, contributions from all highway noise sources are considered when determining noise impacts. At some distance from a highway project, the total noise levels often become more influenced by noise from other roadways or from other noise sources in the neighborhood than from the noise generated by the highway project. These factors should be considered in determining the limits of receptor placement necessary to evaluate the effects of the highway project on total noise levels.
- When modeling interior noise levels for Activity Category D land uses during a preliminary design noise analysis, noise analysts may collect field measurements or use the TNM to estimate exterior levels and apply exterior/interior noise reduction factors. In the absence of calculations or field measurements, noise analysts should compute the interior noise level by subtracting the noise reduction factor from the predicted exterior level for the building in question, using the information in Table 8.3. NCDOT assumes that windows will be closed in buildings with air conditioning. During final design noise analyses, noise analysts should take interior noise measurements as part of the abatement design. The FHWA publication titled Measurement of Highway-Related Noise provides procedures for measuring building noise reduction.
- The only time impacts are considered for Category C (that do not also appear on the Category D list) and Category E land uses is when there are exterior areas of frequent human use. Receptor locations coincide with the exterior areas of frequent human use associated with the land use.

Table 8.3: Building Noise Reduction Factors

Building Type	Window Condition	Noise Reduction Due to Exterior of the Structure
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
	Storm Windows	25 dB
Masonry	Single Glazed	25 dB
	Double Glazed	35 dB
*The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.		

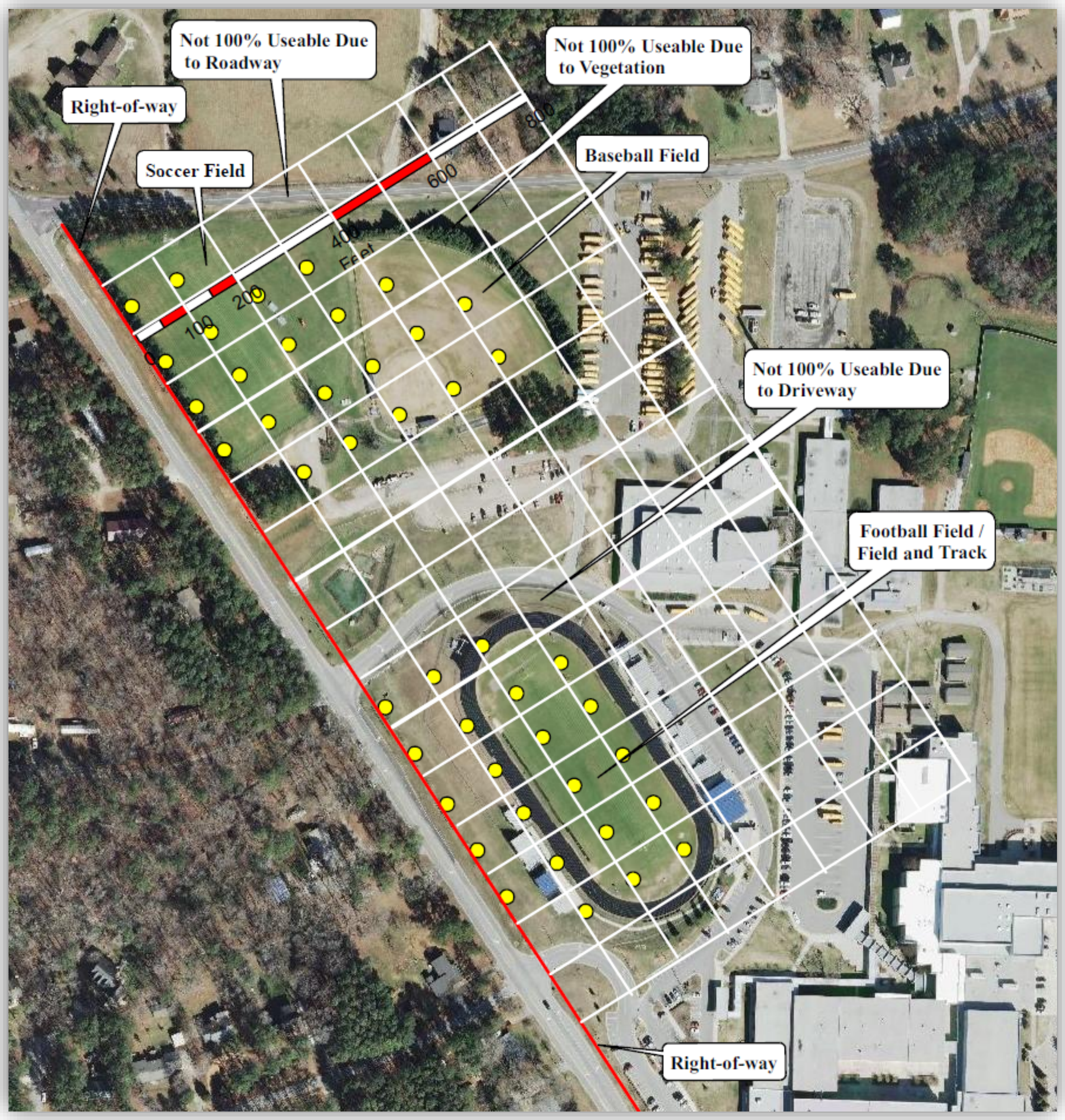
FHWA-PD-96-046, Measurement of Highway-Related Noise, Final Report, May 1996 provides procedures to measure building noise reductions.

More than one receptor may be necessary to adequately model larger parcels of land, potential noise-sensitive land uses represented by more than one equivalent receptor (refer to Section 11.4), and/or parcels for which more than one project roadway noise source may be acoustically significant. In modeling existing and future noise levels, representation of non-residential land uses such as schools, places of worship, parks, etc., with multiple receptors or a grid-type array of receptor may be appropriate. Figure 8.4 shows a park with multiple recreational activities that are represented by a grid of equally-spaced receptors. (See Section 11.4 for more information regarding equivalent receptors.) The park is represented by a grid of receptor points (or equivalent receptors (ERs)) that have ER values based on the usage of that area. Figure 8.5 illustrates how ER points are to be distributed to represent walking trails. On this figure, a grid of ER points at approximately a 100-foot spacing is used to represent a walking trail. Figure 8.6 shows ER points for exterior areas of frequent human use of an apartment complex with a swimming pool, playground, volleyball court, basketball court and tennis court. It should be noted that a small usage area, such as an outdoor dining area associated with a hotel, gets at least one receptor point in TNM. For all special use areas, the ER values are distributed equally across the individual receptor points in TNM. For example, an athletic field with 10 modeled receptor points and five ERs would feature a value of 0.5 ERs per receptor point. A motel with one modeled receptor point in TNM to represent an outdoor dining area and two ERs for that same dining area would feature a value of two ERs for the receptor point. Refer to the distances in Table 8.1 to determine the distance to extend the grid from the highway.

For cemeteries, one receptor must be counted for each area of a formalized memorial gathering facility. Individual gravesites, access ways and informal activity areas are not considered individually sensitive receptors; however, each section of the cemetery, as defined through consultation with the operator, that may have informal gathering areas must be assigned a receptor. When no noise analysis is necessary for a site because there is no exterior area with frequent human use, this finding must be documented in the Traffic Noise Report or Design Noise Report.

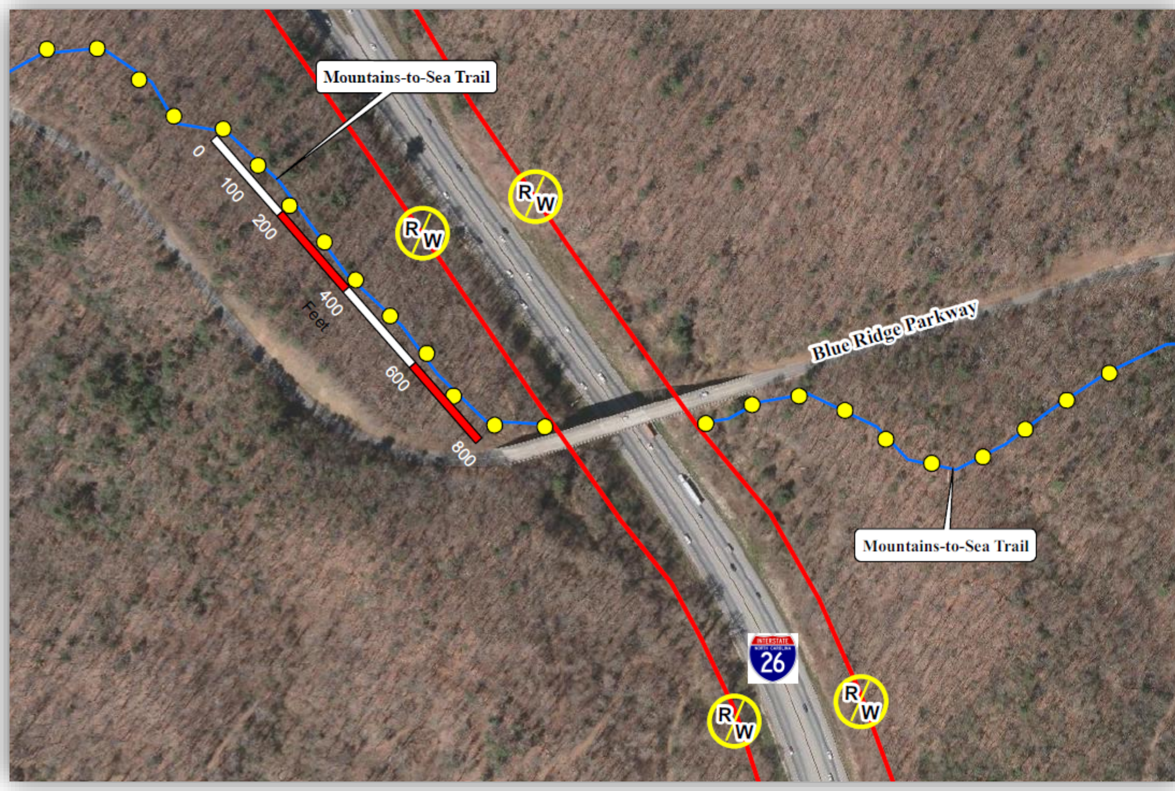
NCDOT will verify the approach for treatment of non-residential land uses pursuant to the noise policy and manual.

Figure 8.4: Nodal Array Receptor Modeling Showing Various Activities Related to a Park and How They are Represented by Equivalent Receptors



100-foot grid starts at the roadway right of way. If the roadway is curved, start grid at the right-of-way point closest to the activity area. Receptor points are placed within each grid at the center point closest to the roadway.

Figure 8.5: Receptor Modeling for Walking Trails



Walking trails should be plotted approximately every 100 feet starting at the right of way and continuing until there are no further impacts or benefits, whichever is greater.

Figure 8.6: Receptor Modeling at an Apartment Complex with Multiple Exterior Areas of Frequent Human Use

Plot TNM Receptors at the closest point to the roadway project for each exterior area of frequent human use. Each TNM Receptor represents all equivalent receptors for its respective activity. Refer to the NCDOT Equivalent Receptor Calculation Table: Tab M1 for additional information.

8.10.3 Terrain Lines

TNM terrain lines shall be modeled as necessary to represent acoustically significant elevation changes between the most-distant roadway edge of pavement (EOP) and the most- distant receptor(s). TNM terrain lines should be modeled in consideration of the latest version of the TNM User's Manual, the TNM Technical Manual, TNM Release Notes, and TNM

Frequently Asked Questions.

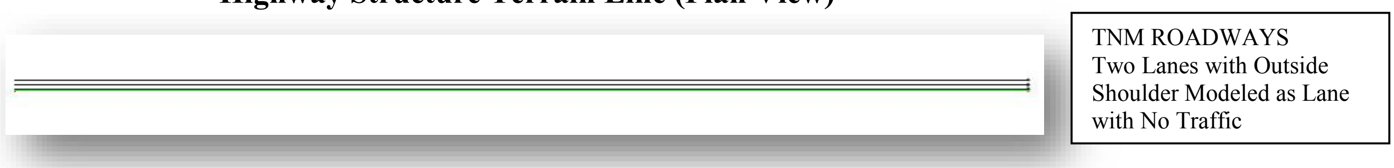
http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_faqs/faq07.cfm#miterlines1.

- All roadway median and shoulder ditches should be modeled.
- All defining grade changes such as top-of-cut sections and bottom-of-fill sections should be modeled (i.e. model any intervening C/F line(s) between roadway(s) and receptors).
- When possible, terrain lines should be modeled generally parallel to the primary roadway (terrain lines modeled at skewed or perpendicular angles to the roadway can result in anomalous TNM-predicted noise levels).
- Modeling the right-of-way line(s), cut-lines, and fill-lines as terrain lines is highly recommended.
- While a noise barrier defines the ground elevations along its horizontal alignment in the TNM model, the build no-barrier ground elevation at the location of a noise barrier horizontal alignment may not be the same as the base elevation that will exist at that same location in the with-barrier case. As such, different terrain lines may be necessary to accurately define topography for the no-barrier and with-barrier conditions. Care should be taken not to automatically assume that the no barrier values reported in a TNM output table (based on a zero-height barrier) represent the true no-barrier noise levels. It is highly recommended that no-barrier and with-barrier values be determined from separate TNM runs, and compared using spreadsheets.
- Sufficient space (generally five (5) to 10 feet of level terrain) is required behind noise barriers to allow access by maintenance crews. This should be considered when defining terrain in TNM.
- Terrain line vertices should be added where terrain lines are modeled in close proximity to receptors so that the terrain line does not create anomalous vertical elevation changes in the source-to- receptor path(s).
- Terrain lines should be modeled just outside the horizontal limits of roadways on structure, so as to define the depressed ground elevation under the structure. Otherwise,

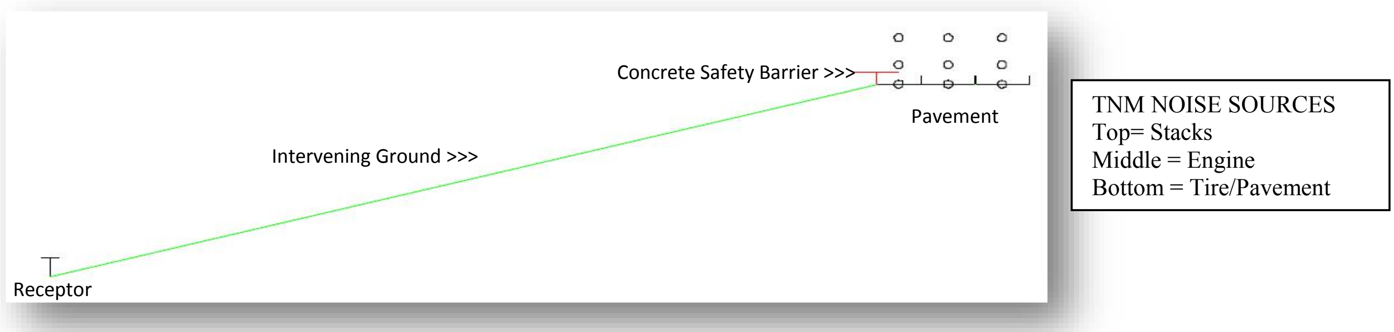
TNM will interpret the ground elevation immediately adjacent to the structure as the roadway elevation, even though the roadway is on structure. This is applicable to highways on bridges. Proper modeling of a retaining wall establishes the correct ground elevation at the base of a retaining wall, therefore eliminating the need to place a terrain line at that location.

Figure 8.7: Terrain Lines Adjacent to Highways on Structure

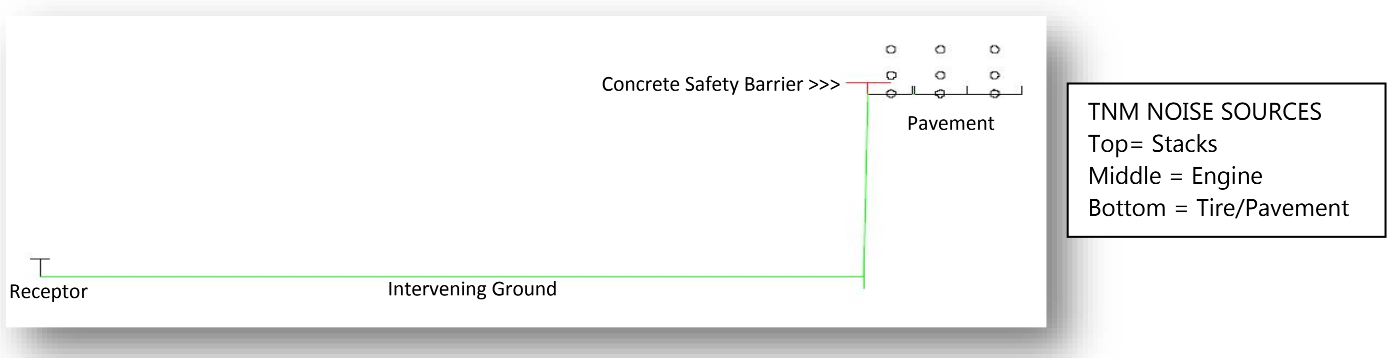
Highway Structure Terrain Line (Plan View)



Incorrect Highway Structure Terrain Line (Skew Section)

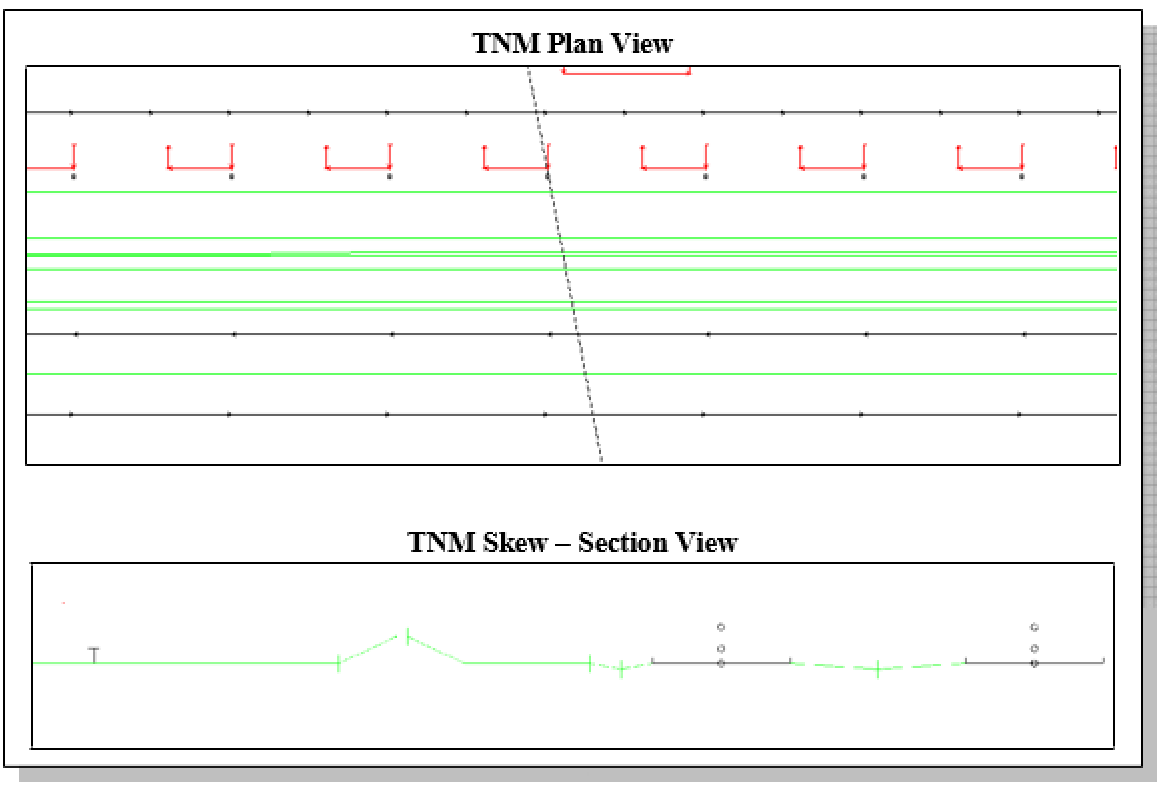


Correct Highway Structure Terrain Line (Skew Section)



- Terrain lines should be modeled at the top and bottom of retaining walls, with a minimal horizontal distance between the two, so that TNM perceives the surface between the top and bottom of the retaining wall to be nearly vertical.
- Since TNM does not interpolate ground elevations between the point locations of two or more receptors, a terrain line should be modeled just in front of any row or array of receptors.
- Terrain lines should not be directly copied into TNM from exported design exchange formatted (.dxf) elements because the large number of vertices (points) in the .dxf elements will dramatically increase the number of calculations necessary to complete the running of the TNM model. Rather than converting .dxf elements into TNM terrain lines, create TNM terrain lines by snapping as few vertices as possible to appropriately represent the terrain feature.

Figure 8.8: Terrain Line Modeling (General) (Median Ditch, Shoulder Ditch, Community Berm)



Recent research related to the modeling of topography is documented in Chapter 8 of *NCHRP Report 791, Supplemental Guidance on the Application of FHWA's Traffic Noise Model (TNM).* The findings of this report support many of the general guidance items listed above and provides additional guidance on minimum terrain line spacing, vertical positioning of terrain lines, and flat top berm modeling.

8.10.4 Noise Barriers

TNM noise barriers should be modeled as the basis for potential noise barrier design (refer to Section 10). An adequate level of detail is important in TNM noise barrier modeling to determine an appropriate barrier design that avoids unnecessarily long or high barriers, aesthetically unpleasing barriers (jagged, notched, and/or undulating top of barrier vertical profiles) that meets reasonableness and feasibility criteria. Common consequences of coarse TNM noise barrier element input considerations are unnecessarily large barriers (length and / or segment heights), aesthetically unpleasing barriers (jagged, notched, and / or undulating top-of-barrier vertical profiles), recommendations to build inappropriately justified barriers, and recommendations to not build barriers when justifiable.

During Preliminary Design Noise Analyses

During a preliminary design noise analysis, identification of one predicted preliminarily feasible and reasonable noise barrier will be satisfactory to justify a recommendation for further study. General guidance for modeling barriers during this phase of project development is included below.

- The resolution of modeled noise barriers in the horizontal plane is equally important as the resolution in the vertical plane. Barrier segment lengths should be established to accurately represent horizontal and vertical changes in the barrier alignment, modeling TNM barrier points opposite TNM roadway points at increments of no more than two (2) survey stations (English units). Standard NCDOT survey stations are in increments of 100 feet. The importance of this is stated in the TNM Users Guide, which stresses the importance of preserving the relative horizontal and vertical relationship between roadways and barriers and indicates that noise analysts should try to match the barrier segments with the adjacent roadway segments.

- While previous NCDOT direction stated that "noise barriers should be modeled as equally spaced segments of logical lengths of 120-feet or less (60-foot foot segments are optimal to coincide with multiples of 10-foot, 12-foot, and 15-foot constructed panel lengths)", maintaining the relationship of barriers to roadways is felt to be more important than the actual segment length. While it is possible to model barrier segments of 120 feet (maximum) or 60 feet (optimal), to meet the above desires, most often roadway data (plan, profile, and most importantly cross-section data) is provided by stations (50 feet or 100 feet increments as noted above). A barrier with 50-foot stationing is indicated in Figure 10.1. This guidance in the manual is based on language in Section 8.5.1 of the TNM Users Guide, which states: "Barrier XY Coordinates. When digitizing barriers that lie along roadways, try to match the straight-line segments you used for roadway digitizing. In this manner, you will preserve the relative horizontal distance between roadway and barriers, which is important to calculations [emphasis added here]. Try to maintain the relative roadway/barrier distance to within approximately 10 percent. With no nearby roadways or receivers, you may relax this barrier XY precision."

- Roadway segment lengths must be established in order to adequately define the roadway geometry and taking into consideration the potential for a noise barrier being evaluated parallel to the roadway. To do this and also to meet the optimal and maximum barrier segment lengths suggested in the second bullet, roadway and barrier segment length of less than 200 feet (e.g. 50 feet and 100 feet roadway and barrier segment lengths) could be required if dictated by roadway or barrier geometrics, topography, intervening features, etc. A barrier with 50-foot stationing is indicated in Figure 10.1.

- Modeling of noise barrier vertical profiles should be performed using vertical height perturbations of not more than two feet. Shorter horizontal segments may be required to accomplish this.

- A barrier envelope drawing is not required at this stage.

During Final Design Noise Analyses

- Beginning a final design noise analysis with a noise barrier top-of-barrier input profile that is generally a vertical projection of the roadway profile is highly recommended.
- Where final design horizontal and vertical data and information are of sufficient detail and where other engineering features (utilities, overhead signs, access requirements, maintenance requirement, etc.) do not preclude, noise barriers should be modeled as equally spaced segments. The guidance and direction regarding roadway and barrier segment lengths provided above for the preliminary design noise analysis phase should be followed.
- Baseline, or TNM input height noise barriers should be modeled with a level top, with a consistent top-of-barrier grade, or with a convex top-of-barrier vertical profile. Focus should be placed upon consistent top-of-barrier elevations and uniform barrier segment elevation changes without notches, undulations, or concavities in the overall top-of-barrier profile.
- Modeling barriers and/or barrier segments with nominal heights (e.g. 14.0 feet, 16.0 feet, 18.0 feet, etc.) should be avoided unless the barrier is immediately adjacent to the roadway edge of pavement.
- Modeling barriers with specific segment heights to achieve nominal top-of-barrier segment elevations is highly recommended (e.g. if a barrier segment has a ground elevation of 320.63 feet, model the segment height at 24.37 feet for a nominal top-of-barrier segment elevation of 325.00 feet).
- Final optimization of noise barrier vertical profiles should be performed to a resolution of 1.0-foot segment perturbations.
- NCDOT's desire is for the final recommended noise barrier's top of barrier profile to consist of extended lengths with consistent vertical grades.
- To determine applicable height limitations on existing and/or proposed bridges, coordination with NCDOT shall occur prior to noise barrier modeling. There is no

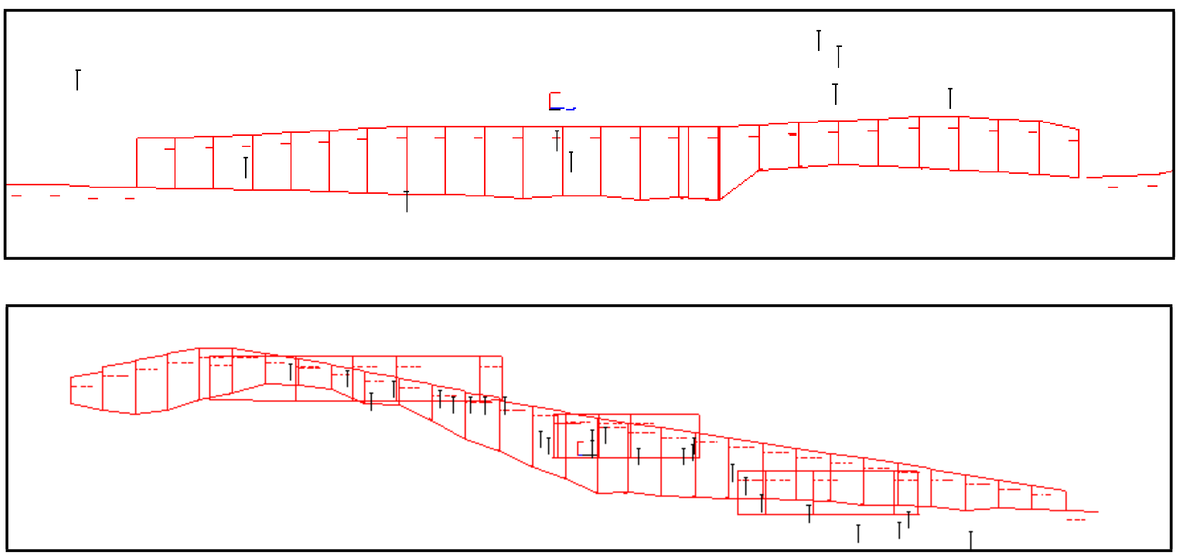
standard height limit that can be uniformly applied to bridges. Height limits for noise walls on bridges, if allowed, shall be determined on a case-by-case basis.

- Noise walls on existing retaining walls are discouraged. Coordination with NCDOT shall occur prior to noise wall modeling on existing retaining walls.
- For noise walls adjacent to proposed retaining walls, a six (6)-foot minimum horizontal separation shall be provided between the noise wall and retaining wall. See standard drawing in Appendix J.
- Noise wall offsets on roadway shoulders should not reduce the usable shoulder width and should be wide enough to provide for full paved shoulder widths plus placement of a protective barrier (guardrail, single faced barrier, etc.) in front of the noise wall. There should be two to three feet of offset behind the noise wall to the shoulder break point. If drainage accommodations are needed behind the noise wall, offsets will need to be greater.
- Noise wall offsets at the top of cut sections should be sufficient for the noise wall to be placed outside the clear zone on the roadway side and five (5) to 10 feet from the right of way on the property owner side.
- Noise walls must be designed with existing and proposed utilities in mind. For underground utilities, noise wall posts should be placed at least 10 feet horizontally from the utility. Noise walls should provide at least 17.5 feet of vertical clearance beneath the lowest sag point of an overhead powerline. Noise walls should be located at least 50 feet from the outermost overhead powerline where the noise wall is parallel to the powerline.
- A minimum six (6)-inch embedment of the bottom noise wall panel is required.
- All potentially feasible and reasonable noise barrier horizontal alignments should be evaluated and optimized as part of a final design noise analysis. Optimization of a single noise barrier horizontal alignment is not sufficient justification to recommend that specific noise barrier for construction. While noise analysts may develop an acoustical profile for each potentially feasible and reasonable noise barrier to aid in the barrier selection process, such a profile is only required for the recommended barrier.

- The acoustical profile will provide the basis for the development of any noise barrier envelope drawing prepared by the designers for the recommended barrier. Noise barriers for which barrier envelope drawings are developed will have their own independent stationing. An envelope drawing is required only for a recommended barrier.
- The development of an envelope drawing may be waived if it is known that the contractor will be developing shop drawings that will be reviewed and approved by NCDOT and/or may have the option of redesigning the barrier as part of a design-build or value engineering process. In this instance, the contractor will be provided with an acoustical profile that must be adhered to as well as a performance specification that details the minimum design and acoustical requirements of the finalized noise barrier.

Figure 8.9: Final Recommended Noise Barrier Top of Wall Profiles

TNM Noise Barrier Analysis Elevation Views



(Note townhouses modeled as noise barriers in background)

Barrier Design Guidance for All Design Phases

- When using stepped rectangular noise wall panels, step panels in a uniform manner. For rectangular noise wall panels, keep steps at a maximum of one (1) foot unless deemed impractical due to topography.
- Concrete safety barriers along the outside of a roadway are modeled in TNM as fixed height noise barriers. These safety barriers abate traffic noise to a varying degree, dependent upon the relationship of the highway to adjacent receptors. This abatement is typically more for receptors located at lower elevations than the highway, but can also be important to consider for receptors that are near the elevation of the highway. The horizontal relationship of receptors to the roadway can also affect the abatement provided by such safety barriers. Outside safety barriers also can reflect noise. However, usually such reflections are not sufficient to adversely affect noise levels to receptors on the opposite side of the roadway.
- Median barriers also abate and reflect traffic noise. While TNM can predict the abatement of noise by median barriers, it cannot currently predict the effect of noise reflecting off of median barriers. Recent research related to the modeling of median barriers is documented in Chapter 5 of the previously referenced NCHRP Report 791. This report presents several techniques for estimated the effects of such reflected noise and presents some guidelines for modeling median barriers, as summarized in Table 8.10.5:

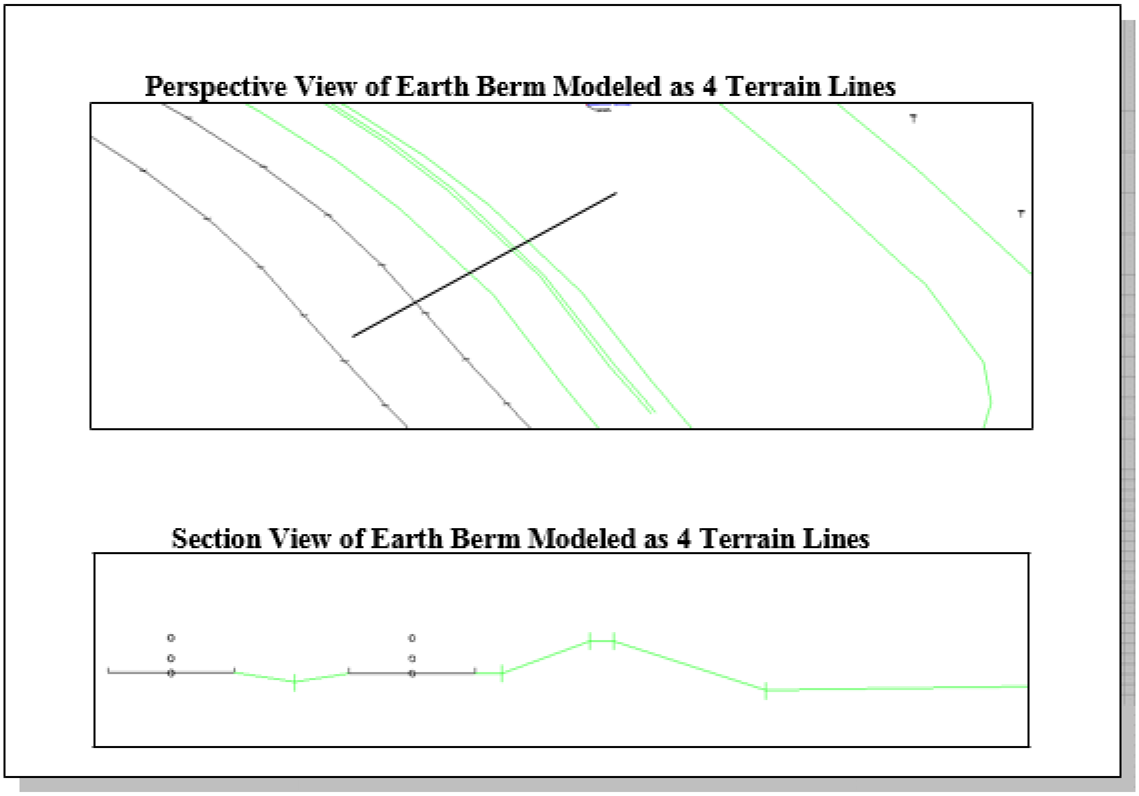
Table 8.10.5: Median Barrier Modeling Guidance

<table>
<tr><th>Distance to Receptor from Middle of Near Travel Lane (Feet)</th><th>Receptor Below to 6 Feet Above Roadway</th><th>Receptor More Than 6 Feet Above Roadway</th></tr>
<tr><td>50</td><td rowspan="4">Model Median Barrier and Ignore Reflections</td><td rowspan="5">Model Median Barrier and Consider Reflections</td></tr>
<tr><td>100</td></tr>
<tr><td>200</td></tr>
<tr><td>500</td></tr>
<tr><td>1000</td><td>Model Median Barrier and Consider Reflections</td></tr>
</table>

- Elevated roadway sections should be modeled with traffic barriers, as applicable.
- Shielding for traffic barrier segments for roadways on structure must be correctly designated for applicable roadway segments.
- Model acoustically significant structures such as existing noise barriers, apartment buildings, commercial buildings, townhouse clusters, and individual residences as individual non-perturbable barriers.
- Houses should be represented by three-sided barriers. The house shape is outlined and then lifted above the ground elevations on the surface. Sometimes, roof elevations (if definitive information is available) can be used to help define the height. The primary interest is in modeling the most massive part of the structure (below the roof line) to be conservative, as opposed to modeling a sloped roof. Receptors should be placed in the gap spaces between the houses for greatest exposure to the modeled traffic noise.

Prior to recommendation in a Design Noise Report, the acoustic effectiveness of berm noise barriers shall be proven in a TNM model(s). Berm noise barriers will be considered only if adequate right-of-way is available, enough waste material is available, and no drainage issues exist. Berm noise barriers shall be modeled as four or more terrain line TNM elements that represent the bottom of berm (roadway side), top of berm (roadway side), top of berm (receptor side), and bottom of berm (receptor side). Guidance on such modeling is provided in Chapter 8 of the previously referenced NCHRP Report 791.

Figure 8.10: Modeling TNM Earth Berm Noise Barriers



8.10.5 Tree Zones

TNM tree zones should be modeled to represent existing forested areas as necessary to accurately predict traffic noise levels. Tree zones consist of long, wide regions of heavy, non-deciduous woods and undergrowth (not just individual trees or several rows of trees) that intervene between roadway and receptors, thereby reducing noise levels. The trees and undergrowth should obstruct vision of the traffic. Potential modeled tree zones should initially be presented in the Work Plan following field reconnaissance. Final NCDOT approval to model tree zones for the build alternative(s) should be provided concurrently with the approval of model validation efforts.

- Although the widely-accepted criteria for sound attenuation is that an area of dense forestation must be 100-feet thick for it to reduce noise levels by ~5 decibels, inclusion of much thinner TNM tree zones has been shown to appreciably affect TNM-predicted traffic noise levels. Inclusion of actual forested areas less than 100 feet wide into TNM models will be considered acceptable if all other features have been modeled (e.g. terrain lines, structures, ground zones, etc.) and the modeled tree zone appreciably improves the predictive accuracy of the validation model.

- TNM computes tree attenuation per the International Standards Organization. This standard requires that trees be sufficiently dense to completely block the view along the propagation path. This requires dense undergrowth as well as dense treetop foliage. According to FHWA, tree zones should not be modeled unless they have this vegetative density. NCDOT approval, typically considered during review of the Noise Analysis Work Plan, is required prior to including tree zones when modeling existing and future noise levels.
- TNM tree zones should be limited to the area beyond the limit of disturbance. If the limit of disturbance is unknown, include the tree zones that exist beyond the right-of-way line.
- Chapter 10 of the previously referenced NCHRP Report 791 recently concluded "No overlaid ground zone of any type is needed for TNM input to properly compute tree attenuation. However, it is important to use default ground type or a ground zone type for the tree zone that is consistent with the actual ground present under the vegetation." Therefore, if a default ground zone of pavement was specified in TNM, then a tree zone should be overlaid with a field grass or lawn ground zone. The referenced Chapter provides additional guidance on modeling tree zones.

8.10.6 Ground Zones

TNM ground zones should be modeled to represent existing and/or proposed areas of acoustically significant ground surface conditions, including transitions between two or more different types of surfaces, and the representation of oddly-shaped hard or reflective surface areas such as parking lots, highway exit ramp gore areas, paved medians, and bodies of water, etc. Chapter 9 of the previously referenced NCHRP Report 791 states that

- Ground zones are not needed for small patches of non-default ground such as suburban sidewalks and driveways. In general, a ground zone must cover about 20% of the source-receptor distance to have more than a one (1) dB effect.
- It is not necessary to be precise when entering X and Y coordinates for ground zones. Ground zone effects are very insensitive to the precise size and location of the zone. For example, it might take a change in width of 30 feet to cause a one (1) dB(A) change in the ground zone's effect, and even then the change might only occur under the most critical input geometry.
- Ground zones are needed more toward the middle of the propagation path, generally in the area where the sound ray bounces off the ground toward the receptors. In general, ground zones are needed in this central area as long as they cover more than 10 to 20% of the source- receptor distance. If in doubt, it is best to include them to determine their effect.

The listed Chapter also includes an expanded set of effective flow resistivity (EFR) values that can be entered into TNM as custom values.

8.10.7 Structure-Reflected Noise and Expansion Joint Noise

When modeling noise levels at receptors located adjacent to an elevated roadway on a structure (bridge), TNM is capable of predicting the noise generated by vehicles traveling on the highway structure, taking into account direct noise paths and diffracted noise influences of any noise blocking features (parapets, noise barriers, etc.). However, TNM does not currently enable the direct modeling of the following:

- Noise reflected off of barriers or retaining walls on the opposite side of road
- Noise reflected off of the underside of the structure itself
- Noise radiated from the underside of a bridge superstructure associated with vibrations of the superstructure created by vehicles traveling on the structure
- Noise created by vehicles traveling over bridge expansion joints

With regard to the first bulleted item, future enhancements to TNM are expected to enable the incorporation of single reflections off vertical and near vertical surfaces.

In many instances, the structure-related noise conditions listed in bullets 2, 3, and 4 occur simultaneously, and their individual noise level contributions cannot be easily segregated. In addition, the observed influences of these structure-related noise sources on total noise levels are most noticeable at receptors located fairly close to the roadway (usually within 50 to 100 feet from the structure), and dissipate fairly rapidly with distance. In an attempt to address these issues, several best modeling practices for the development of adjustments to the basic TNM predictions were developed to account for these structure-reflected and structure-radiated noise conditions that cannot be modeled directly. These practices are contained in Chapter 1 of NCHRP Report 791, and include:

- a computational method based on image sources to calculate noise reflected off of the underside of a structure
- a process involving noise measurement comparisons to determine noise reflected off of the underside of a structure

- a computational method to convert noise measurements of structure-related noise taken below the drip edge of an elevated structure to structure-related noise levels at receptors located at various distances from the structure.
- This methodology is most applicable to roadway reconstruction/improvement projects and should be instituted for any location adjacent to a bridge structure that does not validate to within ±3 dB(A) of the measured level.

8.10.8 Signalized Interchanges, Intersections, and Roundabouts

Correct TNM modeling of traffic on ramps, intersections, local cross roads, and roundabouts is essential where receptors exist in proximity to these noise sources. This requirement pertains to both signalized and unsignalized intersections and ramp termini. While vehicles accelerating on roadway segments are often the most predominant noise sources in the vicinity of intersections and ramps, vehicles operating on free-flow roadway segments and on decelerating segments approaching ramp termini or intersections also require consideration. Also essential is the manner in which accelerating ramps are modeled when they tie into the mainline roadways. Chapter 3 of the NCHRP Report 791 provides guidance on modeling the decelerating, accelerating, and free flow operations for:

- a normal signalized diamond’s entrance and exit ramps
- a folded diamond signalized interchange’s entrance loop ramp, entrance diamond ramp, exit loop ramp, and exit diamond ramp
- full and partial modeling of a single-point signalized urban interchange’s exit ramps, entrance ramps, and crossing road
- unsignalized intersections with two-way and four-way stops and signalized intersections with one-way and two-way roadways
- roundabouts with one-lane and two-lane circulatory roads

Appendix I contains modeling guidance for interchanges, intersections and roundabouts.

8.10.9 Area Sources

Chapter 4 of the NCHRP Report 791 provides guidance on modeling special types of area noise sources where idling, stop-and-go, and/or slow-moving vehicle operations occur. Such operating conditions are typically associated with weigh stations, park-and-ride lots, toll facilities, and service plazas. Because of the uniqueness and limited number of these types of facilities in relation to other roadway-related noise sources, consultation with NCDOT is required prior to performing any noise analyses related to these area sources. Should such analyses be required, the Report 791 best modeling practices should be considered. They include several procedures to use and/or adapt TNM to model idling trucks, stop-and go traffic, accelerating traffic, and decelerating traffic associated with such area sources.

8.10.10 Parallel Barriers

Chapter 12 of the NCHRP Report 791 provides additional guidance to that included in the TNM Users Guide regarding the modeling of parallel barriers. Evaluation of parallel barriers is performed by TNM by a separate Parallel Barrier Module that runs outside of the main TNM program. It provides an indication of the degradation of a noise wall's effectiveness created by the presence of a parallel barrier (which could be another noise wall or a retaining wall). Rather than being used to adjust the noise wall insertion loss values predicted by the main TNM program, the Module should be used to identify the need for absorptive treatment on one or both of the parallel noise walls necessary to essentially eliminate the degradation. A parallel barrier analysis shall be performed for all instances where there are parallel reflective surfaces (either noise walls, retaining walls, or any combination thereof) on both sides of a roadway that meet the following conditions:

- Both surfaces are at least six (6) feet high
- The ratio of the distance between each reflective surface and the average of the heights of both reflective surfaces is less than 10:1 for a preliminary design noise analysis
- The ratio of the distance between each reflective surface and the average of the heights of both reflective surfaces is 20:1 or less for a final design noise analysis

Such analyses must be conducted for receptors behind both reflective surfaces, even in situations where a new noise wall is being designed opposite of a previously constructed noise wall. Absorptive surface materials shall be considered for noise walls or other reflective surfaces in accordance with Section 10.3.

8.10.11 Tunnel Openings

Occasionally, noise analysts may be required to model noise levels at receptors located in proximity to tunnel openings. While TNM does not have a routine to directly model such a situation, techniques have been developed to approximate the tunnel noise by representing the noise sources in the tunnel as TNM roadways with tall, parallel noise barriers representing the outside tunnel walls. Such a technique is described in Chapter 13 of the NCHRP Report 791. Because of the uniqueness and limited number of these types of facilities in relation to other roadway-related noise sources, consultation with NCDOT is required prior to performing any noise analyses related to tunnels.

8.10.12 Wind and Temperature Gradients

TNM predictions included in NCDOT noise studies assume neutral atmospheric conditions and low wind speeds. Chapter 11 of the NCHRP Report 791 provides information regarding the effects of wind and temperature gradients on noise levels. While this information is sometimes useful in explaining the effects of wind and temperature changes on sound paths, it should not be used to adjust any TNM noise levels.

8.10.13 Predicted Noise Levels and Traffic Noise Level Contours

All predicted existing and future noise levels will be generated by validated TNM models (refer to Section 8.5) for projects on existing alignment. It is not possible in some cases to develop validated models for new alignment projects since TNM does not account for non-road noise sources. Noise analysts should incorporate recommendations for model validation of projects on new alignment in the Noise Analysis Work Plan. Interpolation between two or more receptors, and/or extrapolation outside of two or more modeled receptors will not be an acceptable means of estimating, assuming, or predicting traffic noise levels at noise-sensitive receptors.

Per 23 CFR 772.7(9)(c), noise level contours may be used for project alternative screening or for land use planning to comply with 23 CFR 772.17; however, noise level contours shall not be used for determination of highway traffic noise impacts. Determination of noise level contours shall be made by screening the build-condition TNM models of the actual project for receptor locations at which the requisite contour noise levels are predicted to occur. Utilization of arbitrary TNM models, not representative of the actual project, is not an acceptable methodology to assess project traffic noise level contours.

8.11 Analysis Requirements for NEPA as Compared to 23 CFR 772 Requirements

While the above-discussed techniques for performing a noise analysis meet the requirements of 23 CFR 772, there is a major difference between NEPA and 23 CFR 772 requirements for determining highway traffic noise impacts.

As discussed in Chapter 9.0, 23 CFR 772 defines highway traffic noise impacts as occurring when a build alternative's predicted noise level approaches or exceeds the NAC, or represents a substantial increase over existing noise levels. Even if predicted noise levels decrease in the future as a result of the project, e.g. from 72 dB(A) to 69 dB(A) at a Category B site, there is still a highway traffic noise impact under 23 CFR 772, and abatement must be considered.

It is FHWA's view that the noise analysis performed to satisfy the requirements of 23 CFR 772 generally satisfies the requirements under NEPA. Under NEPA, a proposed alternative is compared with a baseline (the design year no-build alternative) to determine whether highway traffic noise impacts will occur, and the proposed project itself must create the traffic noise impact. 23 CFR 772 ignores the no-build alternative because absent a project, there is no requirement for abatement. To satisfy NEPA requirements, NCDOT traffic noise analyses for roadway widening projects will include noise levels for the design year no-build alternative. An analysis of the future no build alternative is useful to compare future no build and future build noise levels because there are circumstances where project construction reduces future noise levels. For example, if a project's purpose is to straighten out a curve, in which the alignment moves away from sensitive receptors, comparing the future build to future no-build could potentially show reductions in noise levels due to the project.

8.12 Analysis Requirements for Section 4(f) Resources

The requirements of Section 4(f) of the DOT Act of 1966 are separate from 23 CFR 772, but may also call for consideration of noise impacts to lands subject to Section 4(f). A noise impact does not necessarily constitute a Section 4(f) use. However, even when noise increases do not constitute a Section 4(f) use, noise impacts may still require consideration for abatement under 23 CFR 772. Abatement measures may result in additional impacts that require consideration under Section 4(f), NEPA, Section 106, or as visual impacts.

Section 23 CFR 774.15 of FHWA's regulations governing implementation of Section 4(f) include specific discussion to aid in assessing whether noise impacts would constitute a constructive use and require a Section 4(f) evaluation. In general, a constructive use occurs when "The projected noise level increase attributable to the project substantially interferes with the use and enjoyment of a noise-sensitive facility of a property protected by Section 4(f)". Examples include, hearing performances at an outdoor amphitheater, sleeping in a campground, visiting a historic site where a quiet setting is related to the site's significance, enjoying an urban park where serenity and quiet are significant attributes, or viewing wildlife in an area of a refuge intended for such viewing.

According to 23 CFR 774.15(f), there is no constructive use impact from predicted traffic noise levels of the proposed highway project on a noise-sensitive activity unless noise levels exceed the FHWA noise abatement criteria or the increase in the predicted noise levels of the proposed project is greater than (3 dB(A).

Noise levels and any proposed abatement for Section 4(f) lands will be identified in Traffic Noise Reports and Design Noise Reports. As necessary, the NCDOT Project Planning Engineer will use this information for further coordination with FHWA on whether noise levels and any proposed abatement constitute a use in the context of Section 4(f).

8.13 Analysis Requirements for Section 106 Resources

As with Section 4(f), the consideration of historic properties under Section 106 of the National Historic Preservation Act is a separate requirement, but may be related to the assessment of noise impacts under 23 CFR 772. There is no metric for analyzing when a change in noise constitutes an effect under the regulations implementing Section 106 (36 CFR Part 800), since that will be dependent on the contributing characteristics and use of the historic resource. Some properties, such as designed or cultural landscapes where the landscape itself is the significant feature or where the setting is especially important, may be extremely sensitive to any change that can be perceived by the human ear. In such cases FHWA considers anything above three (3) db(A) to be a change that should be considered an effect. These cases should be assessed to determine whether it could adversely affect the contributing characteristics of the property. Other historic properties, such as historic transportation facilities, could be relatively unaffected by noise. It depends on the resource as to when noise impacts may diminish the integrity of a property's significant historic features, including a change in character of the property's setting or use [see 36 CFR 800.5(a)(1) and (2)]. Mitigation to address impacts of noise to a historic property is a separate matter from any abatement determined justified under 23 CFR 772, and as with Section 4(f) properties, the abatement measures may present additional impacts to be considered.

Noise levels and any proposed abatement for historic properties under Section 106 will be identified in Traffic Noise Reports and Design Noise Reports. As necessary, the NCDOT Project Planning Engineer will use this information for further coordination with FHWA and the North Carolina State Historic Preservation Office (NC-HPO) for an effects finding (no effect, no adverse effect, or adverse effect).

9.0 PROJECT NOISE IMPACT ASSESSMENT

Highway noise impacts generally occur as either traffic noise impacts and/or construction noise impacts. When traffic noise and construction noise impacts are identified, abatement must be assessed, and if possible, implemented.

9.1 Traffic Noise Impacts

Traffic noise impacts occur when predicted design year build condition worst hour noise levels either approach or exceed the FHWA noise abatement criteria, and/or when the predicted design year build condition worst hour noise levels substantially exceed the existing worst hour noise levels. Noise abatement shall be considered for all traffic noise impacts. Regarding the determination of noise impacts, it is important to emphasize the following points:

- Consistent with FHWA's position contained in the 23 CFR 772 Final Rule's Supplementary Information and FHWA guidance contained in the FHWA Analysis and Abatement Guidance document, "an effective noise analysis should consider major noise sources in the environment including transportation, industry, and background noise." This means that in identifying both existing and future worst hour noise levels, the total noise level must be considered. This total noise includes not just the modeled noise from an existing or proposed highway, but also noise from the "combination of natural and mechanical sources and human activity usually present in a particular area." In determining worst hour noise impacts associated with the design year build condition, the total noise level associated with the design year build condition is compared with the appropriate NAC level as well as with the total worst hour existing noise level.
- By definition, the noise abatement criteria (NAC) are associated solely with build condition noise levels, not with existing or no-build noise conditions. This is further emphasized in the Final Rule and the FHWA guidance document, both of which state that "without a project, noise levels may exist that exceed the noise abatement criteria (NAC), but there are no impacts without a project."

- As discussed in Section 8.11 and as stated in FHWA's Frequently Asked Questions, "There is a major difference between NEPA and 23 CFR 772 requirements for determining traffic noise impacts. NEPA requires comparison of a proposed alternative with a baseline (the no-build alternative or no action alternative, in the design year) to determine whether traffic noise impacts will occur. The proposed project itself must create the traffic noise impact. However, 23 CFR 772 utilizes the opportunity provided by a proposed project to consider abating current as well as future noise problems. Therefore, under 23 CFR 772, if the predicted noise level approaches or exceeds the Noise Abatement Criteria, there is a traffic noise impact regardless of whether or not the proposed project is the cause. Even if noise levels decrease in the future, e.g. from 72 dB(A) to 69 dB(A) at a Category B site, there is still a traffic noise impact, and noise abatement must be considered." Thus, while 23 CFR 772 does not require that a build versus no-build comparison be made to satisfy the noise regulation, it may be appropriate and necessary to determine the no-build alternative noise levels and to compare them to the build alternative noise levels to adequately address NEPA requirements. Projects that widen existing roadways will include no-build alternative noise levels. The need for no-build noise levels for projects on new location will be made by NCDOT on a project-by-project basis. As with 23 CFR 772, there cannot be a traffic noise impact for existing and no-build alternatives under NEPA since only a project can create an impact.
- Approaching or exceeding the NAC requires the consideration of noise abatement and the construction of abatement features determined to be both feasible and reasonable. This means that, while it is appropriate to compare existing noise levels and no-build future noise levels with build condition noise levels, it is not appropriate to compare them with NAC values, since this could be interpreted as requiring the consideration of noise abatement for existing or no-build conditions where the NAC value is approached or exceeded. In other words, existing and no-build noise levels should not be designated as impacts to meet the requirements of 23 CFR 772.
- While results of noise analyses are summarized in NEPA environmental documents, NEPA itself does not specifically require the comparison of noise levels with the NAC or the increase over existing criteria.

A sample summary table for the identification of traffic noise impacts along the project is shown below.

Table 9.1: Traffic Noise Impact Summary for Build Condition

DETAILED STUDY ALTERNATIVE	REASON FOR NOISE IMPACT	SUMMARY OF IMPACTED RECEPTORS[7] BY ACTIVITY CATEGORY							
		A	B	C	D	E	F[5]	G[6]	ALL ACTIVITY CATEGORIES
1	Based on NAC Criteria Only[1]	0	14	3	2	2			21
	Based on Substantial Increase Criteria Only[2]	1	11	1	1	0			14
	Based on Both Criteria[3]	0	10	1	0	0			11
	TOTAL DSA IMPACTS[4]	1	25	4	3	2			35
2	Based on NAC Criteria Only[1]	0	19	2	0	0			21
	Based on Substantial Increase Criteria Only[2]	0	2	0	1	1			4
	Based on Both Criteria[3]	0	10	0	0	0			10
	TOTAL DSA IMPACTS[4]	0	21	2	1	1			25
3	Based on NAC Criteria Only[1]	0	17	1	2	1			21
	Based on Substantial Increase Criteria Only[2]	0	2	1	1	0			4
	Based on Both Criteria[3]	0	10	1	0	0			11
	TOTAL DSA IMPACTS[4]	0	19	2	3	1			25
4	Based on NAC Criteria Only[1]	0	10	3	1	0			14
	Based on Substantial Increase Criteria Only[2]	0	5	1	3	0			9
	Based on Both Criteria[3]	0	2	0	0	0			2
	TOTAL DSA IMPACTS[4]	0	15	4	4	0			23

Note 1: Predicted traffic noise level impacts due to design year worst hour build-condition noise levels approaching or exceeding the NCDOT Noise Abatement Criteria (NAC)

Note 2: Predicted design year worst hour noise levels exceeding existing worst hour noise levels by 10 dB(A) or greater. (NCDOT Substantial Increase Criteria).

Note 3: Predicted traffic noise level impacts due to both 1 and 2 above.

Note 4: Only one of the Note 1 and Note 2 conditions must be met for an impact to exist.

Note 5: There are no impact criteria for land use facilities in this activity category and no analysis of noise impacts is required.

Note 6: There are no impact criteria for undeveloped lands but some noise levels may need to be provided to local officials to aid them in future land use planning efforts.

Note 7: Values noted for Activity Category C, D, and E represent Equivalent Receptor values for these non-residential land uses.

Table 9.2 lists the FHWA Noise Abatement Criteria (NAC) land use activity categories, and the noise levels that, when approached or exceeded with the project build condition, constitute an impact. NCDOT defines approach as reaching one decibel less than the applicable FHWA NAC L_{eq}(h) values below. As an example, NCDOT considers a TNM model value of 65.5 dB(A) or greater (rounded to 66 dB(A)) to approach the FHWA Activity Category B or C Criteria and therefore constitute a noise impact. Other activity category criteria values are treated similarly.

Table 9.2: Noise Abatement Criteria

Hourly Equivalent A-Weighted Sound Level (decibels (dB(A))

Activity Category	Activity Criteria[1] $L_{eq(h)}$ [2]	Evaluation Location	Activity Description
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 [3]	67	Exterior	Residential
C [3]	67	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, daycare centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section4(f) sites, schools, television studios, trails, and trail crossings
D	52	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E [3]	72	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F
F	--	--	Agriculture, airports, bus yards, emergency services, industrial, logging maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	--	--	Undeveloped lands that are not permitted

1 The $L_{eq(h)}$ Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.

2 The equivalent steady-state sound level which, in a stated period of time, contains the same acoustic energy as the time-varying sound level during the same time period, with $L_{eq(h)}$ being the hourly value of L_{eq}.

3 Includes undeveloped lands permitted for this activity category

Noise impacts can also result from predicted design year build condition worst hour equivalent noise levels increasing substantially over existing worst hour equivalent noise levels. NCDOT defines substantial to be 10 dB(A) or greater. Therefore, if the existing worst hour rounded noise level is 60 dB(A) and the predicted design year worst hour rounded noise level is 70 dB(A), then a noise impact exists (increase over existing = 10 dB(A)).

9.2 Construction Noise Impacts

Per 23 CFR 772.19, NCDOT shall perform the following tasks to assess, and if possible, minimize the effects of construction noise for all Type I and other State-Funded projects requiring a noise analysis:

- In all noise reports (TNR and DNR), identify land uses or activities that may be affected by noise from construction of the project.
- Determine the measures that are needed in the plans and specifications to minimize or eliminate adverse construction noise impacts to the community. This determination shall consider the benefits achieved and the overall social, economic, and environmental effects and costs of the abatement measures.
- Consider construction techniques and scheduling to reduce construction noise impacts to nearby receptors and incorporate the needed abatement measures in the project plans and specifications.

The assessment of highway construction noise impacts and potential abatement options is not an arbitrary or superfluous task. It is a requirement of 23 CFR 772, and shall be completed in a comprehensive manner for all Type I projects. Refer to Table 9.4 for typical construction equipment noise level emissions. Common factors of project construction noise that should be addressed as part of all traffic noise analyses include, but are not limited to:

- Proximity of project construction activities to noise sensitive receptors
- Schedule of project construction activities in the context of localized land use(s), both in terms of the hour(s) of the day (e.g. daytime, evening, nighttime), and in terms of the

number and type(s) of days, weeks or months specific activities might occur (e.g. weekday, weekend, holiday, season, etc.).

- Likelihood of any severe construction noise emissions, particularly from impact-type equipment, that might occur in the vicinity of noise sensitive receptors.
- The following text is a general example of acceptable construction noise impact evaluation and abatement assessment documentation. It should not be considered boilerplate or universally acceptable for all traffic noise analyses. To fulfill the requirement of 23 CFR 772.19, the evaluation of construction noise impacts and assessment of construction noise abatement shall be performed on a project-by-project basis.

Example: Construction Noise Sample Text:

"The predominant construction activities associated with this project are expected to be earth removal, hauling, grading, and paving. Temporary and localized construction noise impacts will likely occur as a result of these activities. During daytime hours, the predicted effects of these impacts will be temporary speech interference for passers-by and those individuals living or working near the project. During evening and nighttime hours, steady-state construction noise emissions such as from paving operations will be audible, and may cause impacts to activities such as sleep. Sporadic evening and nighttime construction equipment noise emissions such as from backup alarms, lift gate closures ("slamming" of dump truck gates), etc., will be perceived as distinctly louder than the steady-state acoustic environment, and will likely cause impacts to the general peace and usage of noise- sensitive receptors – particularly residences, hospitals, and hotels. Extremely loud construction noise activities such as usage of pile-drivers and impact-hammers (jack hammer, hoe-ram) will cause temporary, sporadic, and acute construction noise impacts in isolated areas.

Generally, low-cost and easy-to-implement construction noise control measures should be incorporated into the project plans and specifications (e.g. work-hour limits, equipment exhaust muffler requirements, haul-road locations, elimination of "tail gate *banging", ambient-sensitive backup alarms, construction noise complaint mechanisms, and consistent and transparent community communication and rapport).*

While discrete construction noise level prediction is difficult for a particular receptor or group of receptors, it can be assessed in a general capacity with respect to distance from known or likely project activities. For this project, earth removal, grading, hauling, and paving is anticipated to occur in the near vicinity of three residential neighborhoods, two schools, and one commercial area (shopping center). Additionally, impact hammer and pile-driving activities are anticipated to occur in the near vicinity of one school as part of the removal and replacement of the "US 1234 – SR 5678" interchange. Although construction noise impact abatement should not place an undue burden upon the financial cost of the project or the project construction schedule, pursuant to the requirements of 23 CFR 772.19, it is the recommendation of this traffic noise report that:

1) *Earth removal, grading, hauling, and paving activities in the vicinity of the three residential neighborhoods (provide neighborhood names and project station limits, if known) should be limited to weekday daytime hours.*

2) *Earth removal, grading, hauling, and paving activities in the vicinity of the two schools (provide names of schools and project station limits, if known) should be performed during evening and nighttime hours, or any hours during weekends and/or holidays.* (Note: Address appropriate construction activity scheduling recommendations per project-specific noise sensitive land uses in this section).

3) *If meeting the project schedule requires that earth removal, grading, hauling and/or paving must occur during nighttime hours in the vicinity of one or more of the three nearby residential neighborhoods (provide neighborhood names and project station limits, if known), the Contractor shall notify NCDOT as soon as possible. In such instance(s), all reasonable attempts shall be made to notify and to make appropriate arrangements for the abatement of the predicted construction noise impacts upon the affected property owners and residents.*

4) *If construction noise activities must occur during context-sensitive hours in the vicinity of noise-sensitive areas, discrete construction noise abatement measures*

including, but not limited to portable noise barriers and other equipment-quieting devices shall be considered.

For additional information on construction noise, please refer to the FHWA Construction Noise Handbook (FHWA-HEP-06-015) and the Roadway Construction Noise Model (RCNM), available online at: *http://www.fhwa.dot.gov/environment/noise/cnstr_ns.htm*.

Table 9.3: Construction Equipment Typical Noise Level Emissions[1]

	Noise Level Emissions (dB(A)) at 50 Feet From Equipment[2]				
	70	**80**	**90**	**100**	
Pile Driver[3]					
Jack Hammer					
Tractor					
Road Grader					
Backhoe					
Truck					
Paver					
Pneumatic Wrench					
Crane					
Concrete Mixer					
Compressor					
Front-End Loader					
Generator					
Saws					
Roller (Compactor					

1. Adapted from Noise Construction Equipment and Operations, Building Equipment, and Home Appliances. U.S. Environmental Protection Agency. Washington D.C. 1971.
2. Cited noise level ranges are typical for the respective equipment. For point sources such as the construction equipment listed above, noise levels generally dissipate at a rate of -6 dB(A) for every doubling of distance over a hard surface or through the air. For example, if the noise level from a pile driver at a distance of 50 feet = 100 decibels (dB(A)), then at 400 feet, it will generally be 82 decibels (dB(A)) or less.
3. Due to project safety and potential construction noise concerns, pile driving activities are typically limited to daytime hours

10.0 NOISE BARRIER DESIGN CONSIDERATIONS

The following are noise barrier design considerations that are generally accepted by NCDOT, grouped in acoustical; engineering and maintenance; and aesthetic categories. Certain factors related to a barrier design relate to a combination of these considerations and may contain considerations that fit into several categories, an example being the design of a barrier's acoustical profile, which should consider both aesthetic and acoustical factors.

10.1 Acoustical Considerations (including feasibility and reasonableness)

As a starting point in a noise barrier design process, noise barrier termini should extend beyond the last benefited receptor in an NSA by four (4) times the perpendicular distance from the last benefited receptor to the barrier. As the barrier design progresses, factors may lead to a longer extension, a shorter extension, or possibly no extension at all. Determinations of barrier termini points should not be arbitrarily established, since they are greatly influenced by many factors, including the horizontal and vertical relationships of receptors to roadways and barriers, intervening topography, and the geometric configuration of the highway.

For example, a *shorter* extension may be justified if:

1) the horizontal curvature of the highway away from the receptor allows a shorter barrier to adequately block flanking noise, or
2) the grade of the highway results in it descending in elevation as it extends further from the receptor (if the grade is sufficient enough, no extension at all may be required), or
3) the topography allows the construction of a barrier that wraps in at its end in order to adequately block flanking noise.

A *longer* barrier extension may be necessary if:

1) the horizontal curvature of the highway inward towards the receptor requires a longer barrier to adequately block flanking noise, or
2) the grade of the highway results in it ascending in elevation as it extends further from the receptor (no barrier extension at all may be justified if the extended barrier length does not adequately block the flanking line-of-sight between vehicles on the roadway(s) and the receptor.

- In analyzing receptors within an NSA located at or beyond a project's construction termini, abatement must be considered for all impacted receptors within that NSA, even if such receptors are located beyond the project termini. In addition, all benefited receptors within such an NSA must be identified and considered in feasibility and reasonableness evaluations. If, as the result of a barrier extension to adequately protect impacted receptors within such an NSA, benefits are obtained for additional receptors outside of the NSA these additional receptors may be included in feasibility and reasonableness evaluations. However, these added benefited receptors shall not be considered in selecting one barrier option over another. In addition, any extension of a barrier beyond what is required to abate noise for impacted receptors within the NSA itself is not permitted.

- Noise barriers function by extending the noise transmission path length. The most efficient noise barriers are often, but not always, horizontally located near a roadway or near a receptor. The barrier location should take advantage of local terrain conditions to benefit from higher elevations; however, a higher barrier elevation does not always result in greater traffic noise attenuation. Priority should be given to overall noise barrier performance.

- An optimal noise barrier process strives to develop a barrier that breaks the line-of-sight between receptors and the roadway noise sources. Noise analysts should use the TNM line-of-sight check tool to design noise barriers that break the line-of-sight for as many receptors as possible while conforming to other acoustical and engineering criteria. While breaking line-of-sight to all roadway traffic noise sources for all benefited receptors is desirable, it is not an absolute requirement for barrier design. Use the TNM default values for subsource height and a distance limit equal to eight times the distance to the furthest impacted receptor. Analysts should limit the line of site check to a single barrier or barrier system designed to protect a single NSA and the adjacent highway.

- It is required that exterior noise levels be reduced by at least 5 dB(A) for at least two (2) impacted receptors to meet the NCDOT feasibility criteria.
- It is required that exterior noise levels be reduced by at least 7 dB(A) for at least one (1) benefited receptor to meet the NCDOT reasonableness criteria.
- In accordance with 23 CFR 771.11(c)(2)(iv), interior noise analyses for Activity Category D land use facilities shall only be conducted after exhausting all outdoor analysis options and only after outdoor abatement options have been determined to be not feasible or not reasonable. If conditions warrant the evaluation of interior noise levels at an Activity Category D land use facility, the facility shall be represented by an analysis point or points having an equivalent receptor value(s) as determined by the procedures described in Section 11.3. It is required that interior noise levels be reduced by at least 7 dB(A) for at least one of the facility's analysis points.

10.2 Engineering and Maintenance Considerations

Noise barriers should not be designed with any segment heights greater than 25 feet above the proposed ground line, without explicit NCDOT approval (note that barrier segment height refers to the height of all horizontal locations throughout the segment – not just at the segment termini).

- Noise barriers must not be considered where they create a safety hazard, such as blocking safe vehicle line-of-sight distances.
- Combining the barrier with natural terrain features and structures (e.g., berms and retaining walls), particularly at the barrier termini, can reduce required barrier length and/or area.

- Grade cut-fill transitions do not universally require noise barrier horizontal alignment shift to/from the edge of pavement to/from the right of way limits. Optimal noise barrier designs utilize the most cost-effective application of all roadway design elements (e.g., grading, drainage, utilities, etc.) resulting in the greatest reduction in traffic noise.
- NCDOT does not generally construct maintenance openings in noise barriers. For instances in which special project conditions necessitate noise barrier maintenance openings, they will be considered on a case-by-case basis. It is much more preferable to provide doorways or other closable openings at locations where through-wall access is desirable. For such approved cases, maintenance gaps shall be flanked by overlapping noise wall sections at least four times the gap width in length (i.e., for a 10-foot wide gap, the noise wall should have panels that overlap at least 40-feet), the noise wall top profile elevation(s) shall be maintained on both sides of the opening, and the overlapping panels shall be oriented as parallel to the roadway as possible to minimize the potential for roadway traffic noise reflections.
- Noise barrier vertical profile segment elevations shall be clearly marked on the appropriate design plan sheet(s).
- In designing noise barriers, be considerate of secondary effects of a noise barrier that could relate to aesthetic factors, drainage and utility conflicts, structural implications, and safety factors. Refer to Chapters 6 through 9, respectively, of the FHWA Highway Noise Barrier Design Handbook for guidance.
- Where necessary, NCDOT will consider providing access to fire hydrants or other sources of water and coordinate the design and implementation of related features with the appropriate jurisdictional entity.

10.3 Absorptive Noise Walls

An absorptive noise wall surface may be recommended to optimize the benefits of the proposed traffic noise abatement. NCDOT requires that absorptive noise walls provide a minimum Noise Reduction Coefficient of 0.7. Cases where it may be appropriate to consider noise wall panels with absorptive surface(s) include:

- a parallel noise wall system
- where there is a retaining wall with a reflective surface on the other side of the highway from a proposed reflective-surface noise wall
- when there are impacted receptors on the other side of the highway for whom a noise wall on their side was determined not to be feasible and reasonable.

The following guidelines should be followed on all projects where absorptive-faced noise walls are being considered. The decision on the application of absorptive treatments will be made during the final design noise analysis process.

- Absorptive-faced noise walls will be analyzed for a single wall configuration (a noise wall on only one side of the highway) where there are impacted noise-sensitive receptors on the opposite side of the highway that are not receiving a noise wall and at a distance no greater than 10 times the proposed noise wall height
- Absorptive-faced noise walls will be analyzed where the parallel barrier analysis shows that the noise reduction degradation results in noise levels and/or insertion loss values that cause the noise wall not to be feasible and reasonable.
- Absorptive-faced noise walls will be analyzed where the parallel barrier analysis results in impacted receptors no longer being benefited.

Documentation of the parallel barrier analysis should include a discussion of methodology and results, including a table showing the noise level increase associated with the parallel reflective barriers at receptors studied in the cross section analysis. This table should include the prediction of results for a reflective and an absorptive wall. A statement should be included that the final determination on absorptive treatment will be made during final design.

10.4 Aesthetic Considerations

- Noise barriers should be designed with linear or convex top-of-wall or top-of-berm vertical profiles. Design focus should be placed upon top-of-wall segment or top-of-berm profile elevations, not heights. While jagged undulations, notches, and concavities in the top-of-wall or top-of-berm vertical profiles are aesthetic considerations, they also are acoustical considerations, since they can allow traffic noise to more easily reach noise-sensitive receptors – reducing the overall effectiveness and efficiency of the noise barrier.

- Default TNM noise barrier analysis orthogonal views can be misleading with respect to the representation of noise barrier top-of-wall profiles. All recommended noise barriers must be supported by TNM-predicted noise levels; however, the NCDOT Traffic Noise and Air Quality Group encourages the use of spreadsheets and/or other computational tools outside of TNM model(s) as an intermediate step to derive the basis for the assessment and of acoustically efficient and cost-effective – optimal – noise barriers (refer to Figure 10.1).

Figure 10.1: Use of a Spreadsheet for Noise Barrier Profile Optimization

		TNM		Optimized		RECOMMENDED		
STA	Length	Top El.	% Grade	Top El.	% Grade	Input Ht	Area	Length
392+00.00	49.26	649.20	3.3%	650	4.1%	12.8	664	49
392+50.00	49.32	650.85	5.4%	652	4.1%	14.15	731	49
393+00.00	52.33	653.50	2.4%	654	1.9%	15.5	831	52
393+50.00	52.26	654.75	2.4%	655	1.9%	16.25	869	52
011+00.00	50.91	656.00	1.2%	656	2.0%	17	901	21
011+50.00	50.69	656.00	-0.8%	657	0.0%	18.4	943	21
012+00.00	98.83	656.20	-0.2%	657	-1.0%	18.8	1,818	99
013.00.00	101.42	656.00	0.0%	656	0.0%	18	1,876	101
014+00.00	99.89	656.00	-1.0%	656	-1.0%	19	1,898	100
015+00.00	99.72	655.00	0.1%	655	0.0%	19	1,940	100
016+00.00	100.61	655.10	-2.4%	655	-2.0%	19.9	2,022	101
017+00.00	98.73	652.70	-3.3%	653	-3.0%	20.3	2,019	99
018+00.00	98.90	649.40	-3.7%	650	-3.0%	20.6	2,070	99
019+00.00	101.01	645.70	-1.9%	647	-3.0%	21.3	2,096	101
020+00.00	100.16	643.80	-2.3%	644	-3.0%	20.2	1,938	100

Note: The Optimized % Grade changes represent a more consistently convex shape – a more optimal top-of-wall-profile – than the TNM % Grade changes.

11.0 FEASIBILITY AND REASONABLENESS OF NOISE ABATEMENT

Title 23 CFR 772.13(d) requires the examination and evaluation of feasible and reasonable noise abatement measures for reducing the noise impacts. Since FHWA and NCDOT require any noise abatement measure to be both feasible and reasonable, reasonableness evaluations are not performed for noise abatement measures that have been clearly determined not to be feasible.

Noise abatement shall be designed to benefit impacted receptors only, although it is recognized that in doing so there will sometimes be non-impacted benefits provided by an abatement measure.

11.1 Feasibility

Determination of feasibility is the combination of acoustical and engineering factors considered in the evaluation of a noise abatement measure. The following factors apply to the determination of feasibility:

- Any receptor that receives a minimum noise level reduction of 5 dB(A) due to noise abatement measures shall be considered a benefited receptor. A noise reduction of 5 dB(A) must be achieved for at least two impacted receptors.
- Engineering feasibility of the noise abatement measure(s) shall consider adverse impacts created by or upon property access, drainage, topography, utilities, safety, and maintenance requirements. Reference Section 15.3 for a listing of factors that can affect noise barrier constructability.
- The effects of secondary traffic noise (e.g., non-project traffic noise) and non-traffic noise sources on attainable Noise Level Reduction shall be considered when developing effective noise abatement measures.
- Although projects with full control of access are typically optimal for the design of traffic noise abatement measures, noise abatement occasionally meets feasibility requirements on uncontrolled access and partial access control of access roadway

facilities. A comprehensive examination of possible traffic noise abatement measures shall be conducted for the benefit of all predicted traffic noise impacts – regardless of project roadway access.

- If the results of feasibility evaluations determine that the acoustical requirements associated with a noise abatement measure are clearly not met, then no evaluation of its reasonableness is required, since any constructed barrier must be both feasible and reasonable. Similarly, if the evaluation of engineering or safety factors clearly indicate that a barrier is not feasible, then no evaluation of an abatement measure's reasonableness is required, even if the measure is acoustically feasible. In some cases, particularly during a preliminary design noise analysis process, the degree of detail related to the project may not be sufficient to make a determination of an abatement measure's feasibility, or such details may only be sufficient to make a preliminary determination of feasibility. In that case, reasonableness evaluations are conducted.

11.2 Constructability

NCDOT practices a comprehensive approach to traffic noise analysis and design that includes the constructability of recommended noise walls. Solutions to project-specific constructability issues shall be explored on an as-needed basis.

NCDOT 's approach includes, but is not limited to, the following items:

- Lateral clearance
- Drainage
- Maintenance access
- Noise wall installation on existing structures
- Wind and earth loads
- Foundation design
- Construction specifications
- Utilities
- Roadside hazard and crash protection
- Safe sight distances for stopping and merging

11.3 Reasonableness

Determination of reasonableness includes the combination of social, economic, and environmental factors considered in the evaluation of a noise abatement measure. Per NCDOT Traffic Noise Policy, noise abatement reasonableness determination is based upon the following factors:

11.3.1 Preferences of Property Owners and Tenants

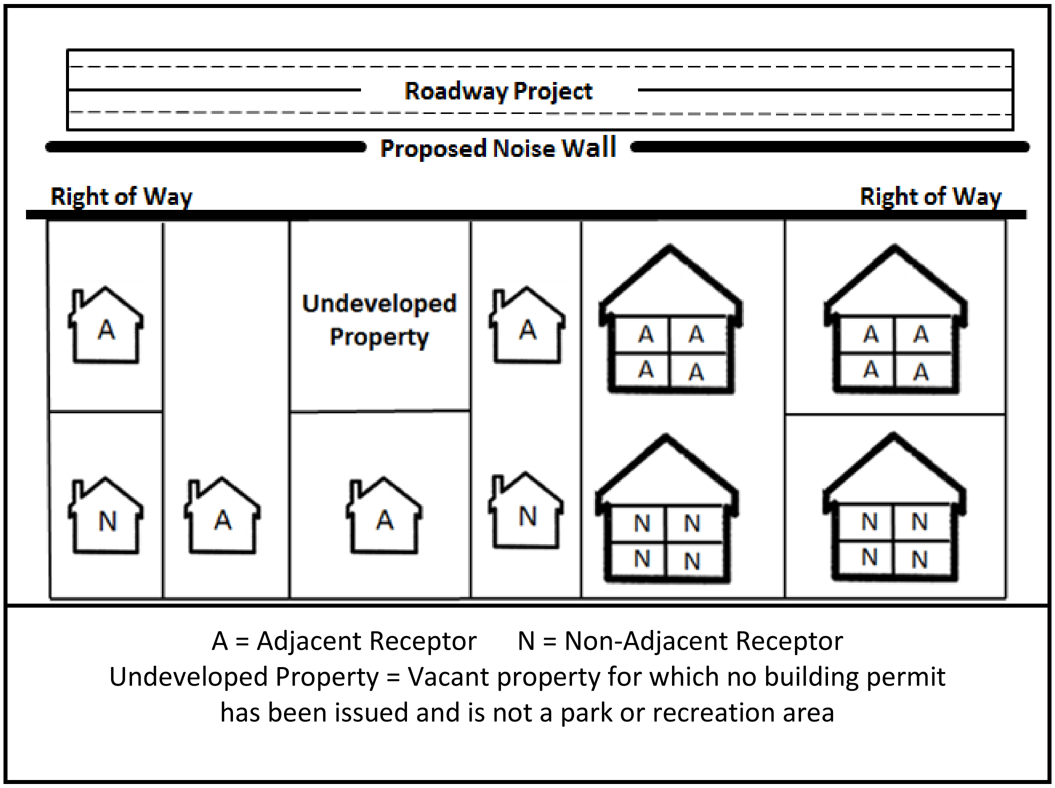
During the final design noise analysis process, the preferences of the property owners and tenants of all benefited receptors (including properties represented by equivalent receptors) shall be solicited. One ballot will be provided to the owner of each Activity Category A, B, C, D, and E receptor and one ballot will be provided to the tenant (occupant) of each Category B residential dwelling unit. No tenant ballots are distributed for vacant rental property. Points per ballot shall be distributed in the following weighted manner:

- 5 points/ballot for adjacent property owners who reside at property
- 4 points/ballot for adjacent property owners who rent property to others
- 3 points/ballot for all non-adjacent property owners who reside at property
- 2 points/ballot for all non-adjacent property owners who rent property to others
- 1 point/ballot vote for all tenants of rental property

An Adjacent Receptor is a benefited receptor that 1) represents a property that abuts the highway right of way or 2) has no benefited receptor between it and the highway. Where multiple buildings containing benefited receptors are on the same property, such as an apartment or condominium complex, only the building closest to the highway is an adjacent receptor. Adjacent receptors will most often, but not always, be part of the front row of benefited receptors. Figure 11.1 below provides graphic examples of Adjacent Receptors. For commercial properties (Activity Category E) distribute all points to the property owner. See the NCDOT Equivalent Receptor Calculation Table Tabs M4 and M6 for examples.

Owners of multi-unit rental locations will receive the applicable number of owner points for each individual benefited receptor (rental unit) owned.

Figure 11.1: Examples of Adjacent Receptors



Appendix N contains a spreadsheet showing how voting points can be determined for benefited receptors of both property owners and tenants.

11.3.2 Cost-Reasonableness of Abatement Measures

NCDOT evaluates the square feet of barrier per benefited receptor (SF/BR) value in determining the cost-reasonableness of an abatement measure. The following table shows the allowable quantities per benefited receptor that are used to determine this value and a barrier's cost-reasonableness. It should be noted that while NCDOT primarily constructs noise barriers for abatement of traffic noise, berms and buffer zones may also be considered in the rare situation where they would provide a more cost effective abatement solution than would be provided by a wall. The allowable SF/BR base quantities shown in Table 11.1 are normally determined for each noise wall.

Table 11.1: Allowable Noise Abatement Base Quantities

Maximum Allowable Base Quantity	Noise Level Consideration	Noise Wall	Berm	Buffer Zone/Noise Insulation
		1,500 ft^2	4,200 yd^3	$22,500
Average dB(A) Increase Between Existing and Future Build for All Impacted Receptors	< 5 dB(A)	+ 0 ft^2	+ 0 yd^3	+ $0
	5-10 dB(A)	+ 500 ft^2	+ 1,400 yd^3	+ $7,500
	> 10 dB(A)	+ 1,000 ft^2	+ 2,800 yd^3	+ $15,000
Average Exposure to Absolute Noise Levels for All Impacted Receptors	5-10 dB(A) Over NAC Activity Category	+ 500 ft^2	+ 1,400 yd^3	+ $7,500
	> 10 dB(A) Over NAC Activity Category	+ 1,000 ft^2	+ 2,800 yd^3	+ $15,000

NOTE: The incremental increases to the base quantity are cumulative when both criteria (average increase and average exposure) apply. The incremental increase is based on impacted receptors regardless of whether such impacted receptors are benefited or not.

- The maximum allowable base quantity of noise walls and/or earthen berms per benefited receptor shall not exceed 1,500 ft^2 and 4,200 yd^3, respectively. Additionally, an incremental increase of up to 2,000 ft^2 for noise walls and 5,600 yd^3 for earthen berms shall be added to the base quantity to reflect the average degree of increase in dB(A) between existing and predicted exterior noise levels of all impacted receptors within each noise study area (NSA), which is defined as a geographically limited area in which noise sensitive land uses exist that are, or may be exposed to, similar noise sources.
- The amount of any additional increase shall be proportional to the amount of the build alternative's future noise level increase over existing noise levels. Impacted receptors subject to an average increase over existing levels of less than 5 dB(A) will receive no additional abatement credit. For those receptors subject to an average noise level increase over existing ranging from 5 to 10 dB(A), 500 ft^2 will be added to the base value for noise walls and 1,400 yd^3 for berms. For those receptors subject to an average noise level

increase over existing of more than 10 dB(A), 1,000 ft^2 will be added to the base value for noise walls and 2,800 yd^3 for berms.

- In addition to the adjustments to the base square feet values associated with average increases of existing levels, the build alternative's absolute noise level for impacted receptors can also result in adjustments to the base square feet value. If the build alternative's average absolute noise level for impacted receptors is predicted to be 5 dB(A) or more above the Noise Abatement Criteria (NAC) level, 500 ft^2 will be added to the base square feet value for noise walls and 1,400 yd^3 for berms. If the build alternative's average absolute noise level for impacted receptors is predicted to be more than 10 dB(A) above the Noise Abatement Criteria (NAC) level, 1,000 ft^2 will be added to the base square feet value for noise walls and 2,800 yd^3 for berms. For purpose of calculating the additional square feet / cubic yards credits, the NAC values for Activity Categories A, B, C, D, and E are assumed to be 57 dB(A), 67 dB(A), 67 dB(A), 52 dB(A), and 72 dB(A), respectively. Note that these NAC values represent the values listed in Table 9.2 as opposed to the NCDOT approach values used in impact determinations.
- If the build alternative's average noise level is predicted to be 5 dB(A) or more above the existing level, $7,500 will be added to the $22,500 base dollar value listed above for buffer zones and noise insulation. If the build alternative's average noise level is predicted to be more than 10 dB(A) above the existing level, $15,000 will be added to the base dollar value.
- When considering the cost reasonableness of buffer zones and noise insulation, if the build alternative's average absolute noise level is predicted to be 5 dB(A) or more above the appropriate NAC level, $7,500 (500 SF/BR times $15/SF) will be added to the base dollar value for a total of $30,000 per benefited receptor. If the build alternative's average absolute noise level is predicted to be more than 10 dB(A) above the NAC level, $15,000 (1,000 SF/BR times $15/SF) will be added to the base dollar value, resulting in a total value of $37,500 per benefited receptor. The increases may be applied in addition to the increases associated with build alternative increases over NAC levels. The maximum allowable dollar value of $52,500 per benefited receptor for buffer zones and noise

insulation would occur if both the NAC value is exceeded and the increase over existing value exceeds 10 dB(A).

11.3.3 Noise Reduction Design Goal

In accordance with 23 CFR 772, NCDOT has established a noise reduction design goal of 7 dB(A). A noise reduction design goal (NRDG) of at least 7 dB(A) must be evaluated for all benefited receptors. At least one benefited receptor must achieve the NRDG of 7 dB(A) to indicate the proposed noise abatement measure effectively reduces traffic noise.

11.4 Noise Level Reduction at Impacted Receptors

The emphasis of NCDOT traffic noise abatement is on the impacted receptors. Although designing noise abatement for impacted receptors may result in non-impacted receptors being benefited, the focus of abatement design should not be on maximizing benefits. It is also not necessary to maximum noise level reduction at impacted receptors, as long as the 5 dB(A) reduction for benefited receptors and the 7 dB(A) reduction design goal have been met.

11.5 Equivalent Receptor (ER) Values for Land Uses Other Than Single Family Dwelling Units

Representation of several types of land uses as more (or less) than one receptor is appropriate in some cases. These receptors typically include active sports areas, playgrounds, schools, pre- school and daycare facilities; places of worship, hospitals, retirement homes; parks, trails, campgrounds, cemeteries, and other exterior areas of frequent human use for the land uses found in the NAC Activity Categories A, C, D, and E. In addition, exterior activities associated with walking paths, pools, basketball courts, ball fields, etc. may occur on common use areas of Activity Category B lands (multi-family land uses being an example).

For some exterior activities associated with the above-listed land uses, a grid- or nodal-type array of receptors based on a 100-foot grid spacing is modeled to accurately assess the extent of impacts occurring over larger areas and to ensure adequate noise abatement design (refer to Section 8.10.2). While noise abatement must be considered for all modeled receptors within such a grid- or nodal-type array for which impacts are predicted, other grid points are also modeled for purposes of identifying receptors benefited by noise abatement. NCDOT must approve both the equivalent receptor calculations and the locations of the receptors modeled throughout the grid- or nodal-type array prior to beginning noise abatement design.

To determine the effectiveness of the noise barrier, an ER value is determined by calculating the person-hours of use per year associated with each of the activities listed above and comparing that value with the average available person-hours of use associated with a residential dwelling unit in North Carolina. In general, the ER value is calculated using the following formula:

Equivalent Receptor = (Person-hours per Year Associated with the Land Use) /
(Person-hours per Year Associated with a Single Family Residence)

In the calculation of the denominator in the above equation, NCDOT assumes that the average family in North Carolina is comprised of three (3) people and that homes are available for use at all times.

The following tables are included in Appendix M:

Table M1 – An apartment complex with a pool (Activity Category B)
Table M2 – A park / recreation area (Activity Category C)
Table M3 – A trail (Activity Category C)
Table M4 – Exterior and interior activities at a daycare center (Activity Categories C and D)
Table M5 – Interior activities at a school (Activity Category D)
Table M6 – A motel with an outside use area (Activity Category E)

These tables illustrate and perform several functions related to the above-listed land uses:

- The tables list example cases of various land uses and illustrate how an ER value is to be calculated by using a spreadsheet tailored to each land use activity. Case examples and input values are presented for illustrative purposes only.

- The tables also provide guidance regarding the distribution of the ER value throughout a land use in cases where multiple receptors are used to model activities associated with the land use. The spreadsheet nature of the tables enables calculation of the distributed values.
- Also calculated in each spreadsheet is the appropriate value to be applied to the land use during the voting process when assessing viewpoints regarding the desire for a noise barrier. As noted in Section 11.2.1, only the owners of non-residential land uses may cast a ballot indicating their desire for, or opposition to, a noise barrier.
- Tables M4 and M5 illustrate under what conditions interior noise abatement might be evaluated and provide procedures to calculate the appropriate ER value.

It is essential that calculated ER values be appropriately applied in the determination of impacts and benefits and in feasibility and reasonableness determinations. In all cases, such values should be ultimately applied to all impacted receptors and to all benefited receptors. For example, in the instance where an ER value is calculated for the interior uses in a school, this value should be representative of only the interior portions of the school (usually areas that face the highway) that are predicted to be impacted and/or benefited.

11.6 Noise Barrier Feasibility and Reasonableness Worksheet

The NCDOT Traffic Noise and Air Quality Group has developed a worksheet to assist with the assessment of noise abatement feasibility and reasonableness (see Appendix C). A completed worksheet is required to accompany each individual noise abatement measure investigated, including those determined not to be feasible and/or reasonable, during the noise analysis process.

12.0 REPORTING

Although consistency in reporting and report formatting is desirable, NCDOT does not intend to dictate the exact content and formatting of Traffic Noise Reports or Design Noise Reports. All NCDOT traffic noise reports should be written in a manner necessary to adequately and appropriately document:

- the relevant noise conditions (traffic and otherwise),
- the assessment of traffic noise impacts
- the assessment of construction noise effects,
- the analysis of feasibility of all potential traffic noise abatement measures
- the analysis of reasonableness of all feasible noise abatement measures
- locations where noise abatement was determined not to be feasible or reasonable
- all recommendations for feasible and reasonable abatement, and
- other information pertinent to traffic noise in the context of the subject project(s).

With the exception of TNM model validation and parallel barrier degradation values, all noise levels shall be rounded to the nearest whole decibel prior to conducting traffic noise impact assessment and insertion loss/noise level reduction calculations. Unless explicitly requested otherwise, all other noise levels shall be stated in units of whole decibels in all NCDOT traffic noise reports. All noise level descriptors such as metric, time, and spatial references (e.g., $L_{eq(h)}$) shall be included as appropriate. NCDOT shall consider the qualification of one or more noise level descriptors for the ease of reporting. For example, L_{eq} may be qualified to represent $L_{eq(h)}$ throughout an entire report.

The guidance provided in this section is intended to be comprehensive; however, specific features of individual projects will dictate the requirements of each traffic noise report that must be fulfilled to satisfy 23 CFR 772.

12.1 Executive Summary

a) The Executive Summary should contain the following information:

b) General project description

c) Date of Public Knowledge (if known)

d) The number, type, and general location of any predicted traffic noise impacts

e) The location of any recommended noise barriers

f) The general, summarized conclusion/recommendation

12.2 Table of Contents

The Table of Contents shall contain the following information:

a) Section and subsection numbers, titles, and pages

b) Appendix titles

c) List of Tables, with table numbers, titles, and pages

d) List of Figures, with figure numbers, titles, and pages

12.3 Project Location, Description, and Background

The project location, description, and background should expand upon the general description found in the Executive Summary and include:

a) a detailed project description, including the project location, TIP number, length, posted/design speeds, and design year,

b) a description of existing land uses and proposed land uses (if known),

c) a description of and location map showing each noise study area (NSA),

d) a discussion of all previous traffic noise analyses for the project,

e) the phase of the project (e.g., preliminary design or final design),

f) the type of project (e.g., widening, reconstruction, new highway construction), and

g) any other unique information related to the project and/or the project area.

12.4 Procedure

Briefly state that the noise analyses reported herein were performed:

a) using noise measurement procedures that considered the methodologies contained in FHWA publication titled Measurement of Highway Noise [NOTE: Do not say "in conformance with" since rarely do States have the time or budget to conduct measurements that strictly conform to the procedures in the document.] If applicable, note that these measurements assisted in validating the project's prediction model.

b) using Version 2.5 of the FHWA Traffic Noise Model® (TNM) described in FHWA Traffic Noise Model® Users Guide to model existing, no-build (if needed), and build condition noise levels; to help determine noise impacts; and to help evaluate noise abatement feasibility and reasonableness.

c) applying NCDOT Noise Abatement Criteria (NAC) and increase over existing criteria to evaluate potential noise impacts applying NCDOT criteria to evaluate the feasibility and reasonableness of potential noise abatement measures.

d) using the FHWA Roadway Construction Noise Model (RCNM) or other means to evaluate project-related construction noise.

Reference the sections of the report where the detailed results of these procedures are contained.

12.5 Characteristics of Noise

An informative description of the characteristics of noise shall be included in all NCDOT traffic noise reports (includes TNR and DNR).

12.6 Noise Abatement Criteria

An informative description of NCDOT noise policy and criteria for the assessment of traffic and construction noise impacts and impact related abatement measures shall be included in all NCDOT traffic noise reports.

12.7 Ambient Noise Levels

An informative description of the ambient noise level data obtained as part of the field work shall be included in all NCDOT traffic noise reports. At a minimum, the description of ambient noise levels shall include the following information:

a) A general definition of ambient noise

b) An explanation of why measurements were taken (e.g. model validation; determining worst-hour noise levels; establishing existing levels; determining building attenuation; and/or determining abatement characteristics of existing features such as privacy fences, estate walls, etc.)

c) A general description of the ambient noise environment(s) in the vicinity of the project, including dominant and otherwise significant sources of existing noise

d) The number, general descriptions, and photographs of the locations of ambient noise level data collection

e) The range and general discussion of the noise levels obtained in the ambient noise level data collection

f) The range and general discussion of the noise levels obtained in the ambient measurement process, including short-term and long-term measurements

g) A description of traffic data collected simultaneously with short-term noise measurements and at any other times

h) A reference to the appendix citing the ambient noise levels measured (L_{eq}(h)) and/or predicted (L_{eq}(h)) for all receptors in the project area

12.8 Noise Model Validation

A discussion of how TNM was validated should be included in this section, and accompanied by appropriate table(s). Notes should be included to explain where model validation was beyond the 3 dB(A) tolerance level. The discussion should state that the validation process was the basis upon which the TNMs for predicting existing year and design year noise levels were built.

12.9 Procedure for Predicting Existing Noise Levels

This section should include an informative description of how and where existing noise levels were determined, a listing of the existing noise levels, and how worst-hour existing noise levels were determined. The descriptions, locations (addresses) and types (land use activity areas) of noise sensitive receptors can be identified in this section and located within the previously described NSAs.

12.10 Procedure for Predicting Future Noise Levels

This section should include an informative description of the TNM analysis process for predicting future noise levels associated with design year traffic for the build (and possibly the no-build) alternative(s).

12.11 Traffic Noise Impacts

This section should reiterate the definitions of a noise impact based on NCDOT criteria. Design year worst-hour noise levels should be compared with existing worst-hour noise levels and with the appropriate NAC level(s) with the location and number of noise impacted receptors identified via color-coding on plans and in tables.

12.12 Potential Traffic Noise Abatement Measures

As part of all NCDOT traffic noise reports, a comprehensive discussion of potential traffic noise abatement measures shall be provided, including, but not limited to, discussion of the following:

a) Highway alignment selection

b) Traffic system management measures

c) Buffer zones

d) Noise barriers (noise walls and earthen berms)

All traffic noise abatement measure assessments shall be described in detail, including the measures that do not meet feasibility and reasonableness criteria. Discussion and tables shall be included that document:

- the results of acoustical and engineering feasibility evaluations performed for all noise abatement measures,
- the results of reasonableness determinations for all noise abatement measures determined to be clearly feasible from both an acoustical and engineering standpoint, and
- the results of reasonableness determinations for noise abatement measures where it is not clear if the measure is feasible from either an acoustical or engineering standpoint.

12.13 Traffic Noise Levels for Undeveloped Lands Where No Building Permits Have Been Issued

For undeveloped lands where no building permits for development have been issued, noise level information shall be developed for use by public officials and others in future planning efforts. At a minimum, provide this information in tabular form. The report may also include contour maps as graphic presentation of future noise levels on undeveloped lands. 23 CFR 772(9)(c) infers that such information "may be used for project alternative screening or for land use planning to comply with § 772.17 of this part, but shall not be used for determining highway traffic noise impacts". Distances from the roadway centerline and interchange ramps and loops to where the 71 dB(A) and 66 dB(A) noise levels are predicted to occur shall be identified in the table. These levels are representative of where exterior noise level impacts occur for NAC B and C, and NAC E land uses, respectively. The basis for noise level contour prediction shall be worst-hour design year TNM-predicted noise levels at a grid of representative receptors modeled in one or more validated project TNM runs. Arbitrary or flat and level TNM models shall not be used to develop traffic noise level contours.

12.14 Construction Noise

All NCDOT traffic noise reports shall include a general discussion of construction noise, as well as a comprehensive discussion of the project- specific construction noise effects and recommended noise-control measures (refer to Section 9.2).

12.15 Conclusion

A conclusion shall be made as part of all NCDOT traffic noise r eports. The conclusion should cite the project name (including TIP number), the process/procedure by which traffic noise levels were determined, and how impacts were determined (e.g. ambient noise monitoring, TNM modeling, etc.), and make a recommendation regarding noise abatement (e.g. further study, recommendation of abatement measures, no further action, etc.). The recommendation should state whether it is likely or unlikely that noise abatement measures will be installed for each noise study area identified. Likely does not mean a firm commitment. The final decision on the installation of an abatement measure shall be made upon completion of the project design, the public involvement process, concurrence with the NCDOT Policy, and FHWA acceptance.

12.16 References

A list of applicable references shall be included as part of all NCDOT traffic noise reports.

12.17 Project Mapping

Project mapping shall include a representation of the entire project (study area) on one image, and detailed small-scale images as necessary to appropriately document receptor locations, traffic noise levels, impacts, and abatement. All project maps shall include a title block, a legend (as applicable), properly oriented north arrow, and map creation date. Additional graphics such as tables and figures are typically included in a noise report to supplement or expand upon information presented on maps.

- A Project Map uses aerial photogrammetry or other appropriate base mapping to display the entire project. It is defined by a logical scale or denoted as being not to scale.
- Detailed Study Area Maps use aerial photogrammetry to show the project and all noise receptors on one or more images, defined by a consistent logical scale based upon receptor density. All receptors shall be color-coded to indicate:
- Receptors indicating field measurement locations shall be shown with a solid white circle,
- Receptors located within proposed right of way limits or otherwise being displaced shall be shown with a white X,
- Receptors predicted to be impacted but not benefited shall be shown with a solid red circle,
- Receptors predicted to be impacted and benefited shall be shown with a solid blue circle,
- Receptors predicted to be benefited but not impacted shall be shown with a solid green circle, and
- Receptors predicted to be not impacted and not benefited shall be shown with a solid yellow circle.

Land use activities that are not noise sensitive and therefore do not require a noise analysis (Activity Category B, C, and E land uses with no exterior areas of frequent human use and Activity Category F) shall be shown with a solid black circle.

Related tables are often used to provide more details than can be displayed on plans or mapping. Color-coding is sometimes used to help highlight various information contained in tables, such as impacted and benefited receptors.

12.18 Appendices

The Appendices of all NCDOT traffic reports contain the details about measured noise levels, traffic noise model validation, predicted noise levels, noise level impacts, TNM noise barrier analyses, abatement recommendation(s), and other significant information including, but not limited to:

a) Ambient Noise Level Measurements: Information defining the time, duration, receptor number, land uses, equivalent sound levels, weather data, sound level meters (identified by meter manufacturer, model number, and serial number) shall be provided for each ambient noise level measurement location. Sound level meter calibration certificates (not the charts and graphs associated with laboratory backup data) shall be included. Table 12.1 is provided as a general reference; however, additional information may be required to describe the ambient noise level measurement data on a project-specific basis.

Table 12.1: Measured Ambient Equivalent Noise Levels, L_{eq} in dB(A)

Setup	Receptor	Land Use / Activity Category	Roadway Noise Source(s)[1]	Start/Stop Time	Measured L_{eq} (dB(A))
1	1.1	Residential/B	US 29	8:50 am – 9:10 am	73
	1.2	Residential/B	US 29		57
	1.3	Residential/B	US 29		47
2	2.1	Residential/B	US 29	9:50 am – 10:10 am	51
	2.2	Residential/B	US 29		54
3	3.1	Residential/B	US 29	10:30 am – 10:50 am	69
	3.2	Residential/B	US 29		66
	3.3	Residential/B	US 29		65
4	4.1	School/C	US 29	11:20 am – 11:40 am	57
	4.2	School/C	US 29		64
	4.3	School/C	US 29		57

1. For each setup, sound level meters were located at logical locations for the assessment of existing highway traffic noise.

b) Hourly Equivalent Traffic Noise Level Tables: Information defining all noise-sensitive receptors, noise-sensitive land uses (NAC category), number of dwelling units (equivalent receptors), property address, and predicted worst-hour equivalent noise levels (refer to Table 12.2).

Table 12.2: Insert Project Name, STIP #, NSA #, and DSA # or name Receptors, Noise Levels and Noise Impacts

Receptors					Predicted Noise Levels, $L_{eq(h)}$ (dB(A))			
Rec. No.	**Use**	**NAC**	**ERs**	**Address**	**Ex.**	**No-Build**	**Build**	**Change**
R-0909	Res	B	1	909 Fowler Rd	48[1]	49	60	12
R-0600	Res	B	1	600 Maple Hill Rd	48[1]	49	67	19
R-0516	Res	B	1	516 Maple Hill Rd	48[1]	48	66	18
R-2701	Worship	C/D	1	2701 Concord Hwy	64/39	65/40	72/47	8
R-2635	Res	B	1	2635 Concord Hwy	67	67	72	5
R-2629	Res	B	1	2629 Concord Hwy	67	68	72	5
R-0120	Res	B	1	120 Maple Hill Rd	56	56	59	3
R-2613A	Worship	C/D	1	2613 Concord Hwy	69/44	70/45	73/48	4
R-2613B	Res	B	1	2613 Concord Hwy	73	74	75	2
R-0714	Res	B	1	714 Fowler Rd	48[1]	59	71	23
R-0715	Res	B	1	715 Fowler Rd	48[1]	57	66	18
R-0713	Res	B	1	713 Fowler Rd	48[1]	54	64	16
R-0219	Res	B	1	219 Ridge Rd	48[1]	48	60	12
R-0709	Res	B	1	709 Fowler Rd	48[1]	58	63	15
R-2907	Res	B	1	2907 Concord Hwy	65	66	72	7
R-3613	Res	B	1	3613 Concord Hwy	70	71	70	0
R-0809	Res	B	0	809 Fowler Rd	48[1]	49	R/W	N/A
Predicted DSA 2 Design Year 2040 Traffic Noise Impacts[2]					**N/A**	**N/A**	**11[3]**	**6[4]**

Impact = [red] Right-of-Way Acquisition = [brown]

1. Existing ambient noise levels based on $L_{eq(20\text{-min})}$ = 48.1 dB(A) at #1204 Back Road, obtained 10:15 a.m. – 10:35 a.m. on June 15, 2015.
2. Total number of predicted traffic noise impacts under the DSA 2 Build alternative = 13. The number of predicted impacts is not duplicated if receptors are predicted to be impacted by more than one criterion (e.g., if a receptor is impacted by NAC criteria and also by Substantial Increase criteria, it is counted as only one impact).
3. Predicted traffic noise impact due to approaching or exceeding NAC (refer to Table 3, pg 6).
4. Predicted substantial increase traffic noise impact (refer to Table 4, pg 7).

Notes on table preparation: a) All receptors must be listed individually with street addresses; b) Where existing and no-build noise levels are identical, the columns may be combined; c) Use red to denote impacts. Do not use different colors to distinguish between an NAC impact and a Substantial Increase impact; d) Do not show existing and/or no build noise levels as impacts. This is because there must be a proposed highway improvement project for there to be a traffic noise impact; e) An explanation for any decreases in Build Condition traffic noise levels should be explained; and f) It is acceptable to use landscape orientation if needed to represent all data on one table.

c) Traffic Noise Models: Information pertaining to the input and implementation of all FHWA Traffic Noise Model (TNM) runs for the purpose of assessing project-related traffic noise levels. At a minimum, this information should include a general description of all modeled TNM elements (roadways, receptors, terrain lines, etc.), the validation process and accuracy (refer to Table 12.3), and a description of the modeling iterations by which traffic noise levels were assessed. All TNM data files associated with the traffic noise analyses must be included in electronic format as part of each draft and final report submission. NCDOT requires approval of the TNM validation model(s) prior to the initiation of TNM runs for existing, no-build (if appropriate), and build alternatives.

Table 12.3: TNM Validation Table

Measurement Location	Measured L_{eq} dB(A)[1]	TNM-Predicted $L_{eq(h)}$ dB(A)[1]	Validation Delta (Pred. – Meas.)[1]
M-	62.1	62.2	+0.
M-	62.4	63.2	+0.
M-	61.8	61.9	+0.
M-	83.1	79.2	-
M-	70.9	72.0	+1.
M-	64.2	63.3	-
M-	67.1	66.9	-
M-	61.9	62.4	+0.
M-	55.4	51.9	-

1. Hourly equivalent noise levels, $L_{eq(h)}$, are expressed to the nearest one-tenth decibels to ensure that TNM-predicted noise levels validate to within ±3.0 dB(A) of measured noise levels without the benefits of rounding.
2. The 1st-row noise measurement location M-2.1 is approximately 50' E of the existing roadway, and is not indicative of a noise-sensitive land use in the vicinity of the project.
3. The 3rd-row noise measurement location M-3.3 is approximately 400' SE of the adjacent ramp, and it is approximately 50' higher in elevation. Ramp vehicle traffic was audible during the short-term noise measurement session; however, local community non-traffic-related noise sources (e.g. air conditioning units) were perceived to be dominant. Given that the 1st- and 2nd-row receptors M-3.1 and M-3.2 validated to a high degree of tolerance to the monitored noise levels (-0.2 and +0.5 dB(A), respectively), and that the TNM-predicted noise levels at M-3.3 are *lower* than the field-monitored noise levels, traffic noise is considered to be an insignificant component of worst-hour noise levels at the M-3.3 location.

d) Noise Barrier Analyses: As applicable, a generalized or detailed summary of the assessment of noise barrier feasibility and reasonableness is required in all traffic noise reports. This may be provided in text or tabular form (see Table 12.4 below); however, it should include mapping of the noise study area and barrier location(s), the logical description (e.g. neighborhood and/or local street name(s)), noise barrier length, number of impacts, number of benefits, the allowable quantity per benefit, and the quantity per benefit of the abatement measure (noise wall and/or earthen berm). Noise barrier analyses should be provided for all optimized barriers – including optimized barriers that do not meet feasibility and reasonableness criteria. Additional discussion and tables may be included in the appendix to supplement (but not repeat) information presented in Section 12.12. Include a NCDOT Noise Barrier Feasibility and Reasonableness Worksheet (see Appendix C) for each considered noise barrier.

Noise Wall 7A (-NW7A-):

Location: Adjacent to the westbound lanes of the Insert Roadway Name mainline in the vicinity of Insert Roadway Name

-NW7A- does NOT preliminarily meet NCDOT feasibility and reasonableness criteria due to Area / Benefit exceeding the Allowable Area / Benefit.

-NW7A- is NOT likely to be incorporated into the project.

TNM Run: 4 BLD07.1 NW7A r1.5 SBA: NW7A r1.5 LTSD

Table 12.4: Noise Barrier Performance Table

-NW7A- Acoustical Performance Summary	
Impacts: 8	Benefited Receptors @ ≥ 7 dB(A) NLR: 1
Impacted Receptors Benefited: 2	Total Benefits: 2
Non-Impacted Receptors Benefited: 0	

-NW7A- Parameters	
Terminus (Northwest): -NW7A- Sta. 10+00.00 / -L- Sta. 610+60.00 61.00′ LT	
Terminus (Southeast): -NW7A- Sta. 14+80.00 / -L- Sta. 615+40.00 61.00′ LT	
Length: 480 ft	Area / Benefit: 3,165 ft^2
Average Height: 13.2 ft.	Allowable Area / Benefit: 2,750 ft^2
Area 6,330 ft^2	

Receptors					**Noise Wall Performance**		
Rec. No.	**Use**	**NAC**	**E.R.s**	**Address**	**Build**	**With Wall**	**NLR**
R-3211	Res	B	1	3211 Poplin Rd	68	68	0
R-1418	Res	B	1	1418 Clear Creek Drive	68	68	0
R-1404	Res	B	1	1404 Clear Creek Drive	59	59	0
R-1419	Res	B	1	1419 Clear Creek Drive	75	67	8
R-1415	Res	B	1	1415 Clear Creek Drive	69	64	5
R-3017	Res	B	1	3017 Poplin Rd	68	68	0
R-3101	Res	B	1	3101 Poplin Rd	66	66	0
R-3010	Res	B	1	3010 Poplin Rd	65	65	0
R-3008	Res	B	1	3008 Poplin Rd	66	66	0
R-1418	Res	B	1	1418 Roanoke Church Road	62	62	0
-NW7A- Predicted Build Condition With-Wall Benefits[1]							**2**

Impact = [red]   5 to 6 dB(A) NLR = [blue]   ≥ 7dB(A) NLR = [green]

1. A receptor is considered benefited if the predicted Noise Level Reduction (NLR) is at least 5 dB(A).

e) Recommended Noise Barrier Envelope Drawings: Scale plan and profile drawings consistent with NCDOT CADD standards shall be provided for all barriers recommended in Design Noise Reports. Although one or both noise wall and/or earth berm termini or other significant barrier points may be defined in reference to the alignment and project survey stationing of the adjacent roadway, all recommended noise walls and/or earth berms shall have distinct horizontal alignments (e.g. -NW-A-) and stationing. The envelope drawings should also include a logical description of noise barrier segment top elevations, either by wall segment numbers or wall segment lengths. The emphasis here is that an envelope drawing is only required for the recommended barrier(s). Envelope drawings shall be prepared using MicroStation and GEOPAK software.

f) Predicted Traffic Volumes: The base year, predicted design year no-build, and predicted design year build-condition traffic volume diagrams for all detailed study alternatives. Base year traffic volumes shall be assessed as the greater of base year Design Hour Volumes (DHV) or traffic counted in the field during ambient noise level measurements.

e) North Carolina Department of Transportation Traffic Noise Policy: Do not include a copy of the NCDOT Traffic Noise Manual

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13.0 PUBLIC INVOLVEMENT

13.1 Communication and Public Hearings / Public Meetings

Communication with the community regarding noise impacts and possible noise abatement shall occur early in the project development process and continue beyond the project public hearing. NCDOT will communicate with citizens to present information on the nature of highway traffic noise, and discuss the types and effects of noise abatement measures that may be considered. As needed, public outreach may include smaller-scale meetings with individual communities and neighborhoods, as well as project-wide workshops and hearings. Educational materials pertaining to traffic noise will be presented and distributed at public meetings. A detailed traffic noise analysis will be conducted for the detailed study alternatives based upon preliminary project design. The results of this preliminary design noise analysis will be included in the project environmental document. Noise study areas, if any, will be shown for all alternatives on the maps displayed at public hearings/meetings and/or will be defined in the environmental document.

The recommended location(s) of any noise abatement measures found to be preliminarily feasible and reasonable in the preliminary design noise analyses will not be shown on maps displayed at public hearings/meetings. The location(s) and design of such measures may change due to changes in the noise environment, the project design, and/or to findings in the detailed Design Noise Report prepared during the final design noise analysis process. The intent of not showing proposed noise abatement locations on maps displayed at public hearings/meetings is to minimize public confusion should the measures be modified or eliminated during the final design noise analyses and preparation of the Design Noise Report.

The definition and discussion of the Date of Public Knowledge is included in Traffic Noise Reports that NCDOT provides to local governments. The Date of Public Knowledge is not included in TNRs since they are completed prior to approval of the final environmental document, but DNRs normally do include the Date of Public Knowledge since they are typically approved after the final environmental document is completed. This notice shall include applicable specific language from the NCDOT Traffic Noise Policy regarding the use of local government authority to regulate land development, planning, design, and construction in such a way that noise impacts are minimized.

13.2 Public Documents

NCDOT environmental documents shall identify the following prior to CE approval or issuance of a FONSI or ROD:

a) Noise abatement measures that have been preliminarily determined to be feasible and reasonable;

b) Noise impacts for which no abatement measures have been preliminarily determined to be feasible and reasonable;

c) Locations where noise impacts have been predicted to occur, locations where noise abatement has been preliminarily determined to be feasible and reasonable, and locations for which no abatement measures have been preliminarily determined to be feasible and reasonable; and

d) NCDOT is committed to the construction of feasible and reasonable highway traffic noise abatement measures at the noise-impacted locations identified in (table, figure, chart, etc.) contingent upon the following conditions: 1) detailed noise analyses during the final design phase; 2) determination of the feasibility and reasonableness of highway traffic noise abatement measures evaluated during final design; and 3) input from benefited receptors regarding desires for a noise abatement measure. Feasible and reasonable noise abatement measures will be constructed contingent upon the above factors and conditions. Final recommendations on the construction of any noise abatement measure(s) will be determined following the completion of the DNR.

e) Noise study areas showing "likely" noise barriers and/or proposed locations of any "recommended" noise barriers will be presented and discussed when holding Public Hearings and Public Meetings. Likely noise barriers are based on preliminary design traffic noise analyses and are described in environmental documents. Recommended noise barriers are based on final design noise analyses and are usually identified after the environmental document is completed. Property owners and tenants who are being balloted for a recommended noise barrier will be provided a visual of the noise barrier location prior to their casting a ballot.

13.3 Final Determination

The final decision on the installation of traffic noise abatement measures shall be made upon completion of the project's final design, the acceptance of the Design Noise Report by the NCDOT and the FHWA, and the completion of the noise-related public involvement process. This decision will be based upon the feasibility and reasonableness criteria established in the NCDOT Traffic Noise Policy. The reasonableness criteria include the solicitation of viewpoints from property owners and tenants of all traffic noise receptors predicted to be benefited by proposed noise abatement measures along the project. The NCDOT Traffic Noise and Air Quality Group will prepare a memorandum to NCDOT Roadway Design Unit that summarizes the solicitation process and the balloting results. It is in this memorandum that a final determination of feasibility and reasonableness is made. A copy of this memorandum will also be distributed to the FHWA and the NCDOT Division Office. The property owners and tenants that were involved in the solicitation process will also be notified of the final results of the balloting process.

13.4 Public Involvement Process

The following describes public involvement during the project development process and during the design process:

<u>Project Development Process</u>

1. Attend Public Meetings as needed to discuss Noise Study Areas and general traffic noise topics

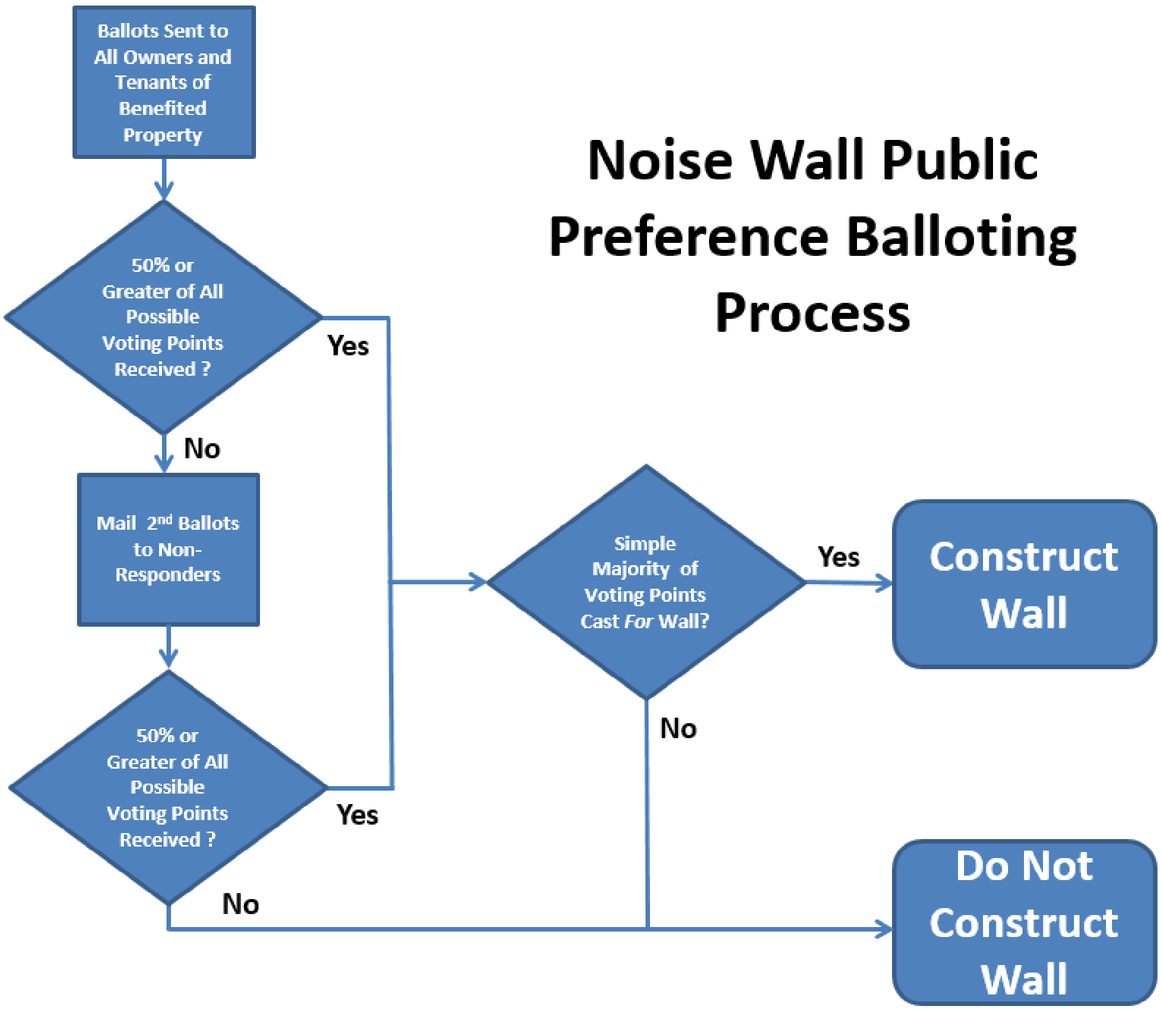
2. Complete Traffic Noise Report to identify all traffic noise impacted receptors, preliminary feasible and reasonable noise barriers and preliminary benefited receptors for all project alternatives
3. Attend Public Hearings to provide all available traffic noise information

Design Process

Complete Design Noise Report using final project design files to determine feasible and reasonable noise barriers and determine all benefited receptors

1. Develop initial Benefited Receptor Mailing List
    a. Tax records
    b. Multi-unit residential and commercial management companies
    c. Local Homeowners' Associations
    d. Local government records
2. Mail notice of upcoming ballot and/or public noise meeting to all benefited receptors and local government
    a. Letter explaining the purpose of ballot and balloting process
    b. Residency postcard
3. Validate / Revise Benefited Receptor Mailing List
4. Hold Public Noise Barrier Meeting, if applicable
5. Solicit corrections to Benefited Receptor Mailing List at meeting
6. Mail ballots
    a. Explanation letter with contacts for additional information
    b. Aerial photography indicating proposed barrier location(s)
    c. Noise barrier visualization
    d. Noise barrier ballot (pre-stamped and addressed postcard)
7. Determine public preference for or against proposed noise barriers using Noise Barrier Public Preference Balloting Process
8. Validate balloting process
9. Finalize and distribute noise barrier ballot results

For design build projects, NCDOT typically provides a Design Noise Report during the procurement process and prior to project letting. For design build projects, NCDOT will conduct balloting after project award and upon completion of the Design Noise Report or hydraulic design, whichever comes later.



14.0 DESIGN BUILD PROJECTS

For design-build projects, the FHWA noise regulation 23 CFR 772 requires that "the preliminary technical noise study shall document all considered and proposed noise abatement measures for inclusion in the NEPA document, and that the final design of design-build noise abatement measures shall be based on the preliminary noise abatement design developed in the technical noise analysis". The regulation also requires that "noise abatement measures shall be considered, developed, and constructed in accordance with this standard and in conformance with the provisions of 40 CFR 1506.5(c)" [which relates to the preparation of environmental impact statements by contractors in a manner that avoids conflicts of interest], "and 23 CFR 636.109" [which addresses how the NEPA process relates to the design-build procurement process]. It is important to note that 23 CFR 636.109(b)(6) states that "the design-builder must not prepare the NEPA document or have any decision making responsibility with respect to the NEPA process."

In addition, in its 23 CFR 772 Final Rule Supplementary Information, FHWA encourages States to "consider developing performance based specifications within their noise policies that apply to design build project[s] to accommodate the project flexibility inherent in the design build process and ensure constructed noise abatement is effective."

In consideration of the above FHWA requirements and suggestions, NCDOT will require that any design-build team be provided with a copy of the NCDOT's approved Design Noise Report and will be required to meet the requirements contained in a design build noise specification. Contents of such a specification include, but are not limited to, the following:

- General section describing the applicable NCDOT standards, policies, and criteria
- A listing of the required acoustical expertise of those performing noise analyses
- NCDOT requirements for the noise barrier system(s) associated with the engineering, acoustical, and aesthetic design requirements established by NCDOT

Three important requirements detailed in any performance specification will be:

The Design Build team shall design the highway and construct noise barrier system(s) generally conforming to the plans developed in the preliminary engineering phase of this project and documented in the Design Noise Report. The Design Build team may modify the horizontal and/or vertical configuration of the noise barrier system(s) PROVIDED THAT:

a) The line of sight break provided by highway cross section and the noise barrier system(s) for any impacted and benefited receptor is not reduced from that provided by the preliminarily feasible and reasonable noise barrier system(s) identified in the Design Noise Report provided to the Design Build team by NCDOT, and

b) The abated noise level provided by the above highway design and/or noise barrier system(s) at any impacted and benefited receptor is not increased from that provided by the preliminarily feasible and reasonable noise barrier system(s) identified in the Design Noise Report provided to the Design Build team by NCDOT.

c) The Design Build team's design does not result in an impact to any receptor that was previously reported as non-impacted in the Design Noise Report provided by NCDOT.

d) The contractor must verify that the modified design is in conformance with the acoustical requirements detailed in the Design Noise Report.

The Design Build team must address the implications of all proposed changes to the noise barrier system(s) as they relate to NCDOT noise policies and procedures.

15.0 MISCELLANEOUS

15.1 Noise Abatement Measure Standards

To provide standard structural design criteria for the preparation of noise barrier plans and specifications, the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures developed "Guide Specifications for Structural Design of Sound Barriers", which was published in 1989 and amended in 1992 and 2002. These specifications allow for more consistency and less conservatism in barrier design. FHWA encourages highway agencies to apply realistic noise barrier structural design practices and to avoid overly conservative design procedures, especially those related to wind load criteria. Also, the AASTHO Green Book is recommended for site design requirements. Finally, noise barrier material types should be selected based on economics, effectiveness, and aesthetic considerations.

15.2 Aesthetics

NCDOT has initiated a program for the improvement of noise wall aesthetics. Good engineering, architectural, and aesthetic judgment shall be applied toward context-sensitive noise wall design. The standard noise wall architectural treatment, as defined below, will apply to all projects regardless of the Date of Public Knowledge.

The standard noise wall architectural treatment consists of:

a) Concrete columns; steel piles may be used when necessary to address site conditions adverse to the use of concrete columns;

b) Precast concrete panels textured on both sides;

c) No texture on the uppermost foot of each wall segment;

d) A single color of stain in brown or gray tones applied to both sides of textured panels;

e) No stain applied to the uppermost foot of each wall segment and the concrete columns.

All enhancements to this standard noise wall must be paid for in accordance with the Third-Party Participation provisions in this policy.

NCDOT Division Engineers are responsible for determining noise wall textures and colors in their respective Divisions. Noise wall textures and stains are included in Appendix M.