COLORADO DEPARTMENT OF TRANSPORTATION

NOISE ANALYSIS AND ABATEMENT GUIDELINES

DECEMBER 1, 2002

COLORADO DEPARTMENT OF TRANSPORTATION

REGION 1	**AURORA**
REGION 2	**PUEBLO**
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1. Introduction

Pursuant to requirements set forth by the Federal Highway Administration (FHWA), the Colorado Department of Transportation (CDOT) Noise Analysis and Abatement Guidelines provide the procedural and technical requirements for the evaluation of highway project traffic noise and consideration of noise mitigation alternatives where noise impacts are identified. The resultant goal of these guidelines is to provide the citizens of the State of Colorado with as compatible a relationship as possible between highway improvements and noise sensitive land uses. CDOT understands the importance of the issue of highway traffic noise and is committed to evaluating traffic noise impacts during the planning, design, and construction of highways and transportation improvements.

The following guidelines are intended to provide a consistent, equitable approach in addressing highway traffic noise and to foster a rational abatement decision-making process for highway projects within the State of Colorado. In addition, the guidelines include the protocol for providing thorough documentation of these activities in technical noise study reports as a part of National Environmental Policy Act (NEPA) documents.

This document supersedes the February 1, 1995 *CDOT Noise Analysis and Abatement Guidelines* for all projects initiated on or after December 1, 2002. Projects initiated prior to December 1, 2002 will remain under the authority of the 1995 guidelines.

These guidelines are based on currently accepted practices and procedures used by Federal and state transportation agencies and will be subject to review every three years. Interim amendments to these guidelines will be made on an as needed basis and will be considered, when approved, to be an integral part of these guidelines. An addendum to these guidelines will subsequently be prepared to document the changes.

2. Applicability and Scope

2.1 Federal Requirements

The 1969 National Environmental Policy Act process provides broad authority and responsibility for evaluating and mitigating adverse environmental effects of transportation projects, including highway traffic noise, but it was not until the Federal-Aid Highway Act of 1970 that FHWA was mandated to develop noise standards for the mitigation of highway traffic noise.

The regulations that govern highway traffic noise for Federal-aid projects are contained in Part 772 of Title 23 of the Code of Federal Regulations (23CFR772). 23CFR772 describes the methods that must be followed in the evaluation and mitigation of highway traffic noise in Federal-aid highway projects. FHWA will not approve the plans and specifications for any federally aided highway project unless the project includes noise abatement measures that are deemed to be feasible

and reasonable to adequately reduce noise impacts. When warranted, noise mitigation is to be considered as an integral component of the total project development process and incorporated as such.

The FHWA document, *Highway Traffic Noise Analysis and Abatement: Policy and Guidance* (1995), calls for each state highway agency to prepare and adopt written guidelines specific to that state which must demonstrate compliance with 23CFR772. State highway agencies are allowed flexibility to establish their own definitions and quantifications of different criteria and decision items that are used in the guidelines to make noise abatement determinations. All highway projects that are developed in conformance with the CDOT guidelines will be deemed to be in conformance with the Federal regulations and with FHWA noise standards.

2.2 State Requirements

In addition to the Federal regulatory requirements, the CDOT guidelines are also required to be in accordance with CDOT Policy Directive 1601, Interchange Approval Process. The 1601 process applies to governmental and quasi-governmental (i.e. E-470, etc.) entity projects which require a new interchange on the system or major modifications to an existing interchange. Included in this process is the provision that potential environmental impacts must be evaluated, including those from projected traffic noise. This requirement broadens the general definition of Type I projects to include not only Federal-aid projects, but also state, local, and public-private partnership projects overseen by CDOT and requiring CDOT approval. The 1601 process also requires compliance with NEPA.

2.3 Project Classification

The following discussion describes which CDOT highway projects require a noise analysis:

2.3.1 Type I Projects

Under 23CFR772, it is mandatory for all states to comply with the regulations for projects that are classified as Type I projects. A Type I project is a project that consists of a **proposed Federal or Federal-aid highway project for the construction of a highway on a new location or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignment or increases the number of through traffic lanes.**

The CDOT guidelines are applicable to all Type I projects. Type I projects include, but are not limited to, the following activities:

- Addition of through-travel lane(s) to an existing highway.
- Addition to a highway of continuous acceleration/deceleration lanes that exceed 0.5 miles in total length. This requirement also applies to auxiliary and climbing lanes.

- Additions of new interchanges or alterations of existing interchanges.
- Addition of high-occupancy vehicle (HOV) lanes to existing highways.
- A project which consists of a change in vertical profile of 5 feet or more.
- Alteration of highways such that the horizontal distance between the nearest through centerline of travel and existing sensitive receivers is approximately halved.

In general, actions such as the above are considered to be Type I projects due to capacity increases or alignment changes. In all cases in which a project is identified as Type I, a noise analysis study is required if noise sensitive receivers are present within the project study zone. This study zone is defined as a 500-foot distance in all directions from the proposed edge of traveled way throughout the extents of the project. This 500-foot "halo" defines the extents for the noise analysis and shall include receivers on all sides of the highway.

2.3.2 Type II Projects

CDOT does not currently separately fund a Type II noise program, which is defined in 23CFR772 as projects that provide noise abatement on existing highways, essentially a "retrofit" noise barrier in a location where there will not be any new highway construction.

2.3.3 Other Projects

Additionally, a project that does not meet the Type I project definition must also undergo a noise analysis if there are noise sensitive receivers present and the project itself, through major alteration of the existing terrain, is expected to create a noise impact. An example of this would be a case where, to improve sight distance on a highway, an existing earth berm is flattened, resulting in a direct line-of-sight between the highway and an existing residence. These cases are extremely rare and shall be dealt with on a case-by-case basis.

2.3.4 Non-applicable Projects

Other than the example illustrated above, projects that do not meet the Type I project criteria are not required to undergo noise analysis. Projects and activities such as these include maintenance operations, minor safety improvements, resurfacing or whitetopping projects, and traffic-based operations such as modification of speed limits or traffic control devices.

2.4 Noise Sensitive Receivers

A noise sensitive receiver is any location where highway traffic noise may be detrimental to the enjoyment and functional use of the property. The primary consideration is normally residential areas, however, frequent human use areas such as schools, parks, hotels, and commercial centers are also considered for evaluation.

Normally, these properties are in existence at the time of the project construction, but special provisions apply to undeveloped lands if applicable.

2.4.1 Currently Developed Lands

All existing properties within the study zone are to be considered as existing receivers in the noise analysis. These properties must be classified as to the type of land use and the extent of the activity. As mentioned above, all receivers present within the defined study zone must be included in the analysis.

2.4.2 Planned, Designed, and Programmed Development

Normally, the noise analysis does not consider lands that are not developed, however, noise analysis is required for undeveloped lands for which development is "planned, designed, and programmed" at the time of the analysis (i.e., the noise analyses for the draft NEPA document [EA or draft EIS] and the final NEPA document [CE, FONSI, or final EIS],). This indicates that a definite commitment, with official public knowledge, has been made to develop the property in question and has reached a point where the developer's plans can no longer be changed in a practical manner. Any area which falls under this category must be dealt with in the noise analysis as though the development has already been constructed. The State of Colorado will consider a proposed development as being "planned, designed, and programmed" when a formal building permit has been issued to the developer by the local agency of authority.

2.5 Project Timing

Each state highway agency is required to identify when the public is officially notified of the adoption of a location of a proposed highway project. CDOT, within the scope of these guidelines, defines the "date of public knowledge" as the date in which the final environmental project document (Categorical Exclusion, Finding of No Significant Impact, or Record of Decision) is approved. After this date, CDOT will be responsible for analyzing changes in traffic noise impacts, but will not be required to provide noise abatement for new development which occurs adjacent to the proposed highway project. Decisions concerning such noise abatement are left to the local government agencies and private developers. See Section 7.2 for further discussion concerning noise-compatible land use development.

3. Noise Fundamentals and Traffic Noise Impact Criteria

Sound can be defined as mechanical energy generated by movement or vibration from a source that can be sensed by the ear. Noise, generally, is defined simply as unwanted sound, and is the description usually given to sound that emanates from highway traffic. Each sound (noise) can be expressed in terms of three characteristics: magnitude, frequency, and time element.

The magnitude of a sound event can be measured in terms of its acoustic pressure. Since the range of absolute pressure values can vary over several orders of magnitude, the unit

typically used to describe sound levels is the decibel (dB), which is a relation of the sound pressure level to a standard reference pressure. This ratio is then converted to a more compact logarithmic scale.

Since sound travels in waves, there are also varying frequencies associated with each sound event. The human ear does not respond equally to all frequencies, however, and filtering of these frequencies must be done in order to obtain accurate measurements and descriptions of highway traffic noise, as this noise is comprised of many frequencies. The filtering (weighting of frequencies) of the "A" scale on sound-level meters most closely approximates the average frequency response of the human ear, and is the scale that is used for traffic noise analyses. Decibel units described in this manner are referred to as "A-weighted decibels", or "dBA".

As sound intensity tends to fluctuate with time, a method is required to describe a noise source, such as a highway, in a steady state condition. The descriptor most commonly used in environmental noise analysis is the equivalent steady state sound level, or L_{eq}. This value is representative of the same amount of acoustic energy that is contained in a time-varying sound measurement over a specified period. If that time period is one hour, the value then reflects the hourly equivalent sound level, or $L_{eq}(h)$.

For highway projects that require noise analyses in Colorado, the accepted noise descriptor is the worst-hour $L_{eq}(h)$ for determining existing and future noise levels and impacts. The worst-hour is specified and defined as such to reflect the conditions that will produce the worst traffic noise. In general, this is highest traffic volume traveling at the highest possible speed and reflects Level of Service (LOS) C conditions. If traffic volume continues to increase past these conditions, the traffic is forced to slow down, which in turn decreases the noise levels generated.

A traffic noise impact is considered to occur when any noise sensitive receiver is subjected to either 1) existing or future noise levels that approach or exceed the noise abatement criteria (NAC), or 2) future noise levels that substantially exceed the existing noise levels. Both of the above must be analyzed to adequately assess the noise impact of a proposed project.

When noise sensitive receivers are present and are found, during the course of the analysis, to be impacted under either case, noise mitigation must be considered and evaluated for those receivers under the feasibility and reasonableness factors.

3.1 Approach or Exceed Noise Abatement Criteria

The noise abatement criteria (NAC) are noise levels which are compared to existing or future levels to determine absolute impact. The levels that are specified are based on the certain types of existing activities that are present.

CDOT defines "approach" as noise levels that are 1 dBA less than the NAC specified in 23CFR772. The values shown in Table 1 reflect the values that CDOT considers when evaluating noise levels for each corresponding land use category.

Any receiver that is subjected to noise levels that either currently reach or are predicted to reach the values stated on Table 1 are considered to be impacted by noise. It is important to note that these values do not have to be exceeded to result in an impact, and there is no difference in the severity of the impacts in either case.

Table 1
CDOT Noise Abatement Criteria (NAC)
Based on FHWA Noise Abatement Criteria, 23CFR772

Category	L_{eq}(h), dBA*	Description of Activity Category
A	**56 (Exterior)**	Lands on which **serenity and quiet** are of extraordinary significance and serve an important **public** need and where preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	**66 (Exterior)**	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C	**71 (Exterior)**	Developed lands, properties, or activities not included in Categories A or B above
D	**--**	Undeveloped Lands
E	**51 (Interior)**	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

*Hourly A-Weighted Sound Level in Decibels, Reflecting a 1 dBA "Approach" Value Below 23CFR772 Values

The above criteria strikes a balance between noise levels that are desirable and those that are feasible. Numerous approaches were considered in establishing the criteria, to include hearing impairment, annoyance, sleep interference, and speech communication interference. Highway traffic noise levels do not normally reach the levels that result in hearing damage, and what constitutes an "annoyance" or hindrance to sleep is very difficult to quantify on a large scale. Speech impairment, however, was usefully applied as a condition that reflects a compromise between noise levels that are desirable and those that are achievable and was found not to be arbitrary or capricious.

It is very important to understand that the above noise levels are impact criteria only; the absolute threshold levels for which mitigation consideration must take place. There is not a specific absolute noise level that must be mitigated to. When evaluating mitigation, the NAC values are not to be considered as desirable levels for which mitigation must be designed. The overall goal of mitigation is to obtain a substantial noise reduction, which may or may not result in noise levels below the NAC levels.

Most sensitive receivers that will be encountered on highway traffic noise analysis efforts will be categorized as category "B" receivers and are subject to the 66 dBA approach criterion. Category "C" receivers include most commercial and industrial areas, and category "D" describes lands that are undeveloped and development is not planned, designed, and programmed. Category "D" receivers are not subject to an NAC value.

Classification of category "A" receivers should be extremely rare and apply only to extraordinary special public needs where the existing environment is of a serene nature that needs to be preserved to allow the area to continue to serve its purpose. Determination of whether or not a specific receiver qualifies as a category "A" will be made on a case-by-case basis.

When determining impacts, primary consideration is to be given to exterior areas of frequent human use where a lowered noise level will be of benefit. In those cases where there are no exterior activities to be affected by highway traffic noise or where exterior activities are far from or physically shielded from the roadway in a manner that prevents an impact on exterior activities, the interior criterion (category "E") may be used. CDOT will consider interior noise abatement only for severe traffic noise impacts (see Section 5.6) or public-use or non-profit institutional structures (see Section 5.7).

3.2 Substantial Increase over Existing Noise Levels

The second manner in which a noise sensitive receiver can be impacted by highway traffic noise is to be subjected to a substantial increase of the existing noise environment due to a highway project.

CDOT defines that a noise impact occurs if a receiver is to receive an increase in noise levels of at least 10 dBA. This impact criterion takes effect regardless of the absolute noise levels. For example, an increase of noise from 45 to 57 dBA for a category "B" receiver will result in a noise impact, as the noise increase of 12 dBA is greater than the 10 dBA threshold.

A change in noise levels from 62 to 69 dBA would not be an impact under the substantial increase criteria, but would still result in an impact as the approach criteria has been met.

As long as one of the impact criteria is met for a receiver, mitigation must be considered for that receiver. No subjective descriptor terms are used to describe traffic noise impacts, with the exception of a "severe" impact, which is described below.

3.3 Severe Traffic Noise Impacts

A severe noise impact is defined to occur when a receiver is either exposed to absolute exterior noise levels of 75 dBA or greater, or a projected increase of 30 dBA or more over the existing noise levels. Situations such as these are reflective of a condition in which receivers are affected by highway traffic noise to a much greater degree. Special provisions apply to the mitigation considerations for these receivers, which are described in section 5.6.

4. Highway Traffic Noise Analysis

The main purpose of the highway traffic noise analysis is to identify noise sensitive receivers that will be subjected to traffic noise impacts. Any and all receivers that are

identified as impacted must be considered for noise mitigation. The mitigation alternatives must be evaluated under the feasibility and reasonableness criteria. The noise analysis technical report serves as proof that the analysis was performed and provides all necessary documentation as required by the regulations.

As early as is reasonably possible in the process, an initial assessment must be made to determine as to whether or not the project will require a detailed noise analysis. This is best done in conjunction with the environmental scoping of the project.

The analysis consists of two major parts. The first consists of identification of noise sensitive receivers, assessment of the noise levels that these receivers are currently experiencing and are predicted to experience, and a determination of whether or not traffic noise impacts exist. If no traffic noise impacts are found, the analysis is then considered to be complete with no further evaluation required. If traffic noise impacts are expected, then the second part of the analysis, mitigation consideration and evaluation, must be performed. The requirements for the first part of the analysis will be described below, while the mitigation consideration protocol will be discussed in section 5.

Common misunderstandings arise when the subject and requirements of performing noise analyses are discussed. The requirement to perform a noise analysis, in and of itself, does not imply that any other future actions are inevitable. The analysis will identify any noise impacts, which will then be considered for noise mitigation. Noise mitigation will be provided if it is determined to be both feasible and reasonable.

4.1 Identification of Land Uses

The proper identification and quantification of the noise sensitive receivers adjacent to a highway improvement project is essential to the success of the analysis. Each receiver that is present within the extents of the project must be accounted for in accordance with the regulations.

Obviously, a project that does not border any existing or planned, designed, and programmed noise sensitive land use area will not require a noise analysis, nor will any receivers that are outside of the study zone (500 foot “halo” around the extents of work) for the individual project need to be considered.

In general, the primary consideration when considering the presence of noise sensitive receivers are the exterior areas of frequent human use that are adjacent to the individual properties. For single-family residential areas, the consideration point will be the outside area that is immediately facing the highway, which in most cases will be either the front or back yard or porch area. This also applies to special-use and non-residential areas, such as a park playground area or an outdoor restaurant seating area.

When first assessing the site for possible receivers, the different land use categories that are adjacent to the project must be identified. Sites directly adjacent to the highway are considered “first-row” receivers, and will be the main receivers of

interest in the noise analysis. This first row of receivers will be determined by drawing an imaginary line connecting each receiver with direct sight to the highway. Second- and third-row receivers, those which are directly beyond the first row, may also be determined as well, although this may not be necessary in all cases. Receivers beyond the third row are usually not considered, with possible exceptions being any receivers located along the end of a row, to evaluate the end areas of a potential barrier, or a receiver which is located beyond the second row where there are large gaps between structures in the first two rows.

To summarize the land-use activities that are present, list each type and number of receivers identified. This would include the number of existing or planned, designed, and programmed single-family residences, number of multi-family dwellings (i.e. apartment complex units), businesses, and if any other special use buildings or areas exist, such as parks, motels/hotels, or churches. These will be the areas that will be considered in the following phases of the analysis.

For noise modeling purposes in multi-family dwellings, each dwelling (unit) shall be considered as well as any common outdoor use areas. Areas above the ground level, however, are typically not feasible or reasonable to mitigate due to the inability to provide effective and reasonable noise mitigation at those locations. This is primarily due to the excessive barrier heights that will likely be required for mitigation.

4.2 Determination of Existing Noise Levels

The next step in the analysis is to quantify the existing noise environment by determining the noise levels that the identified receivers are currently experiencing. Determination of existing noise levels shall be made by field measurement and use of the Colorado version of the STAMINA 2.0 noise prediction model. Noise modeling of existing conditions is not possible and thus not performed in the case where the project involves the construction of a new highway in a new location, as there is no existing highway contribution to the noise environment.

4.2.1 Field Measurements and Model Validation

The purpose for taking field measurements is to gather data that is used to develop a comparison between those measurements and results obtained with the noise prediction model. This exercise is performed to validate the model so that it can be used with confidence to determine the worst-hour existing noise levels and predict the future noise levels.

Measurements can be taken at any time; however, it is best to measure when traffic is relatively free flowing at or near the posted speed limit. For high-volume roads, a 10-minute sample is usually statistically accurate enough to obtain a good measurement, but sample times of 30 minutes or more may be needed for measurements along lower volume roads. All measurement procedures must be performed in accordance with report FHWA-PD-96-046, Measurement of Highway Related Noise. It is not required to perform

measurements at any or each individual receiver, however, enough representative measurement locations in the project area must be utilized in order to reasonably characterize conditions for the validation effort. Once these data have been collected, each of the locations is then input into the model for comparison purposes.

In order to arrive at a valid comparison between measured and modeled results, traffic and speed data must be collected at the measurement locations at the same time the noise measurements were taken. This will involve actual counting of vehicles, being sure that truck (heavy and light) counts are taken separately, and a determination of the approximate speed that the vehicles were traveling. This speed can be determined by either driving a test vehicle through the traffic stream or by use of a radar gun. Once this data has been collected and normalized to an hourly basis, it is input into the computer model. The collection of relevant data will allow the modeling of the same conditions as was observed during the measurement exercise and does not require the analyst to attempt to measure during the "worst" noise hour. This effort is to be thoroughly documented within the noise study report.

The acceptable range between the actual noise measurements and the modeling results is 3 dBA. If the difference between the measured and predicted levels is not within 3 dBA, an examination of the measured and modeled data shall be performed to determine the reason for the difference. This may require that a second measurement be taken in some instances.

4.2.2 Noise Modeling for Existing Conditions

Unless the project involves the construction of a new highway on a new location, the worst-hour noise levels are determined by the validated computer model.

In selecting model locations, each individual receiver does not have to be modeled separately. A modeling location can be chosen that represents several actual receivers. This is acceptable as long as all the identified sensitive receivers are represented in the analysis. The number of the actual modeling points that are used will vary depending on the nuances of the individual project. For each modeled location, a table that shows the location identification and exactly how many receivers are being represented by that location must be included in the noise study report. These locations are then modeled at a height of 5 feet (1.5 meters) above the ground level elevation to approximate the height of the average human ear. For analysis of areas above the ground level, those locations shall be modeled at a height 5 feet above the elevation level of the use area.

To perform the noise modeling for the existing conditions, the following input data are required:

- Current roadway alignment for all roadways in the immediate area which may contribute to the noise environment.

- Existing traffic volumes, which include a breakdown of numbers of automobiles, medium trucks (2-axle, 6-tire), and heavy trucks (3+ axles) for all roadways.
- Current posted speed limit for all roadways.
- Alpha factors for ground attenuation affects (0.0 for hard ground, 0.5 for soft ground).
- Receiver locations.
- Terrain features, such as natural berms.
- Other features which result in a shielding effect (i.e. buildings).
- Any existing noise barriers present.

To model the worst hour existing condition, the traffic data that shall be used is the highest volume of traffic that can travel at the highest possible speed for the particular roadway, reflecting LOS "C" conditions. This is normally the Design Hour Volume (DHV) of the roadway modeled at the posted speed limit. If the projected traffic volume is less than the LOS "C" volume, those lesser volumes are to be used. Proper documentation of the source of the traffic volumes is required to be included in the noise study.

To provide for a detailed and thorough review of all noise modeling efforts, to include those done to predict the future noise levels as described in section 4.3, the noise study must either include a disk with an electronic copy of the data files or a computer printout of all data generated during the modeling analysis.

4.2.3 Locations With Existing Noise Barriers and Privacy Fences

The situation in which a noise barrier is currently present can create confusion. If a barrier is currently in place, the existing noise model, in order to reflect the existing noise environment, must be made with the barrier in place. This, however, must be a solid barrier designed specifically to abate noise. The noise levels that are then used to depict the existing conditions are those that are generated through the noise analysis with the barrier location included in the model.

Wooden privacy fences, which are not normally constructed to abate noise, are not to be modeled as noise barriers, since they generally do not provide an appreciable amount of noise reduction. These fences cannot normally be considered as noise barriers in that they contain many gaps, each of which results in additional transmission of noise, and are not sufficiently dense to provide negligible noise transmission through them.

When considerations for privacy and other development-related fences are made, consideration shall be given as to whether or not the fence will remain in good condition over the life of the project (20 years for projected future noise levels). If there is a question as to the durability of the fence, it should not be used.

4.3 Prediction of Future Noise Levels

Once the existing noise levels have been determined, the future design-year noise levels for each receiver are calculated. The future model shall reflect conditions 20 years into the future (traffic counts and speeds, roadway alignments, changes to terrain) for the worst-hour noise condition and should include all alternative alignments being considered for the project, to include the "no-action" alternative. For minor projects, there will likely only be one alternative, but in the cases of projects which are either part of an EA or EIS, there may be several alternatives to consider and for which to provide analysis.

The traffic projections that are used must be consistent with the applicable adopted long-range plan traffic model, if available. When a long-range plan traffic study is not available, the best available data shall be used. The traffic volumes used shall be the 20-year design volume at the design speed reflecting up to LOS "C" conditions for the new highway design (similar to the procedure used for modeling existing traffic conditions as per section 4.2.2).

The same traffic noise prediction model that was used in the determination of the existing conditions shall also be used for the future model, with the modeled receivers in the same locations as they were for the existing model, as appropriate. Receivers which are identified as potential ROW takes will not normally need to be included in the future modeling, but do need to be included in the "no-action" case. As was the case in the existing condition evaluation, if a noise barrier is currently present it must also be included in the analysis of the future conditions.

4.4 Determination of Traffic Noise Impacts

The final step in the first part of the noise study is to compare the future predicted noise levels to the applicable noise abatement criteria and to the existing noise levels to determine traffic noise impacts. As discussed earlier, any receiver which either approaches or exceeds the noise abatement criteria under the existing or future conditions or is subjected to a substantial increase in noise levels is considered to be impacted by highway traffic noise. This is to be done for each alternative, including the no-action alternative.

It is important to remember that the determination of traffic impacts only results in consideration of mitigation, which will be performed in the next part of the analysis. It is not a guarantee that mitigation will be provided.

If no traffic noise impacts are identified under the future conditions for any of the proposed alternatives, as defined by the provisions set in these guidelines, the analysis is considered complete and further consideration of mitigation is not required. This determination, if applicable, shall be stated as such in the final noise study report.

5. Evaluation of Highway Traffic Noise Abatement

Any and all receivers which were determined to be impacted in the analysis are evaluated for traffic noise mitigation. This requires that the overall social, economic, and environmental effects of the mitigation be evaluated against the benefits. When determining abatement measures, primary consideration is to be given to exterior areas surrounding residential areas or areas of frequent human use for other uses such as parks and commercial districts where a reduced noise level would be of benefit. All feasible and reasonable mitigation measures are required to be included in the highway project.

It is required that any potential noise abatement measure under consideration is one that provides a substantial reduction of noise levels. This, at the absolute minimum, is a noise reduction of no less than 5 decibels for at least one receiver. It is not considered to be a prudent investment of public funds to consider construction of a noise barrier that will not result in at least a readily perceptible noise reduction.

5.1 Mitigation Options

The following are mitigation measures that may be incorporated in highway projects to reduce traffic noise impacts. Each of these shall be considered and discussed in the noise study report.

- Traffic management measures, such as lane-use restrictions, designated truck routes, and speed limit reductions. Measures such as these may or may not be beneficial or possible given the constraints of the project and the immediate area. While lesser speeds do decrease noise levels, it generally will take a reduction of speed of approximately 20 miles per hour to achieve a readily perceptible (5 dBA) reduction of noise at its source.
- Alteration of horizontal and vertical alignments to reduce noise impacts, where practical.
- Acquisition of undeveloped land for buffer zone creation. While buffer zones are a very good strategy in overall noise compatible land use planning, it is often not a practical solution, due to the high amount of land that must be purchased. In many instances, the existing developments already border the highway.
- Noise insulation of public use or non-profit institutional structures only; private residences may be considered for such abatement only if a severe noise impact exists (see Sections 5.6 and 5.7).
- Construction of noise barriers within highway right-of-way, or acquisition of property rights for construction of noise barriers outside of the highway right-of-way.

Vegetation and pavement are often discussed in regards to noise abatement but are not measures that can be normally be used in lieu of other noise abatement measures:

- Vegetation is only potentially viable as a noise abatement measure if it is 100-200 feet wide, at least 16 feet tall (when considering ground level receivers), and sufficiently dense so that it cannot be seen through. If these conditions can be met, a noise reduction of up to 5 decibels is possible. Vegetation can definitely be of an aesthetic and psychological benefit, and if it is provided it must be made clear that, if it does not meet the above criteria for noise abatement, that it is being provided for visual, privacy, or aesthetic treatment only.
- A topic that has been researched for many years has focused on attempting to reduce the noise emissions that are due to the tire/pavement interaction. While it is accepted that different tires, pavements, and pavement surfacing textures do result in varying noise levels, it is difficult to forecast the overall pavement surface condition 20 years into the future. Due to this fact, and the requirement that noise mitigation must provide a "readily perceptible" reduction in noise levels over a long period of time, the use of different pavement types or surface textures cannot be considered as a noise abatement measure.

5.2 Noise Barriers

The most common noise mitigation measure is the noise barrier, a solid physical structure constructed between the highway and noise sensitive receivers. The barrier works by blocking the path of sound waves from the highway, forcing the sound to travel around or over the barrier. If a noise barrier is tall enough to break the line-of-sight between the highway and the receiver, constructed of sufficiently dense material (4 pounds per square foot minimum density), and does not have any openings or gaps, a noise reduction will be possible that will range from being readily perceptible to less than half as loud (5-15 decibels for most barriers) depending on the height and location of the barrier. **A barrier design must achieve at least a readily perceptible noise reduction (5 decibels) to be considered feasible for construction as a prudent investment of public funds.**

The most common types of noise barriers are earth berms, which is essentially a large natural or man-made earthen mound, and vertical walls, which can be constructed out of a variety of materials, most commonly concrete or masonry block. Berms, while more natural in appearance, do require a great deal of land and a very large footprint. Noise walls require much less space to be constructed, but may be subject to height limits due to structural and aesthetic reasons. Barriers have also been constructed by placing walls on top of berms to create a combination barrier.

More detailed information concerning design, structural, and aesthetic considerations of noise barrier construction at CDOT can be found in the *Noise Guide for Highways*, Volume IX of the *CDOT Design Guide,* August 1996.

5.3 Noise Barrier Acoustical Evaluation

Evaluations of possible noise barriers are to be done using the STAMINA 2.0 model (Colorado version) using the future conditions data. Various locations and

heights of barriers can be input into the model, which will calculate the noise levels with the barrier. The amount of reduction, also known as insertion loss, is defined as the future barrier noise levels subtracted from the future no-barrier condition.

Acoustically, the most effective noise barriers are generally located closest to the source (i.e. highway) or to the receivers. As a result, initial barrier placement should be considered and evaluated for either of these locations. In many cases, however, the CDOT right-of-way line is the best practical location for the barrier. Each possible barrier location shall be considered in the analysis if more than one possible location can be used.

Also to be considered are certain issues such as overall length of barrier, different heights, and compensation for situations that require breaks in the barrier (overlapping barriers). Performing this evaluation is an iterative process, done by altering certain inputs. The best judgment of the noise analyst should be used in all cases to determine which solution is recommended, but more than one option shall always be evaluated to ensure that nothing was missed during the analysis. As always, this process needs to be documented in the noise analysis report.

In a case where a legitimate noise barrier is already present, the first evaluation that needs to be made is what alterations can be done to the existing barrier to provide an additional substantial reduction of noise levels over what the barrier is already providing, if necessary. This option will then need to be evaluated under the feasibility and reasonableness guidelines. If the current barrier is still able to function properly as a noise barrier, as will likely be the case for a concrete or masonry barrier, it will not likely be feasible or reasonable to achieve an additional substantial noise reduction. If, however, the existing barrier poses functionality or maintenance problems, it can be replaced in-kind as a part of the Type I highway project. Cases such as these are common where older, wooden noise barriers have been installed. Decisions concerning these situations will be made on a case-by-case basis.

As noise mitigation measures other than the construction of noise barriers are not usually practical, the following discussions concerning feasibility and reasonableness are presented in the context of considering noise barriers and noise barrier construction.

5.4 Feasibility

Feasibility deals with physical considerations and concerns with the construction of an acoustically effective noise barrier at a particular site and project.

5.4.1 Noise Reduction

The major feasibility criterion that is to be considered is to whether or not a substantial noise reduction can be obtained based on constraints that are inherent to the individual project. If a substantial reduction cannot be provided a noise barrier is not feasible and will not be recommended for inclusion in the project.

CDOT defines a substantial reduction goal as a barrier that is predicted to reduce noise levels to at least one adjacent front row receiver by at least 10 dBA. The initial barrier evaluation shall be performed to determine what will be required to achieve a 10 dBA reduction. If the barrier's height that is required for this reduction is found to be 25 feet or greater, then it can be considered not feasible and the barrier evaluation will take place at a lower height. Each barrier that is evaluated shall also be evaluated under the reasonableness criteria.

It is desired that barriers be optimized in terms of overall reduction (height) and cost-benefit, which is one of the factors for reasonableness. In this case, it is desired that a point be identified where a potential noise barrier provides the best balance between cost and benefit. This is not a trivial task, as the benefit versus cost relationship is not linear and a point of diminishing returns will be reached. An iterative process, however, can result in a barrier that will be optimal within the scope of the reduction goal (10 dBA or greater), and the minimum reduction required (5 dBA). **In any case, no barrier shall be deemed feasible if an absolute minimum reduction of 5 dBA cannot be achieved for at least one front-row receiver.**

A benefited receiver is one, impacted or not, which receives at least 3 dBA of noise reduction, corresponding to at least a perceptible benefit. This is reduction that is based on the addition of the noise barrier only, which is only considered after any shielding affects, such as for rows of buildings, are taken into account.

The overall noise environment should also be considered in whether or not a noise barrier will be feasible. If the area in question is one where aircraft or rail activity exists, a barrier that only mitigates highway noise might not be enough to reduce the overall background levels appreciably. In those cases, it would not normally be feasible to construct a highway traffic noise barrier. Other considerations that need to be taken into account are situations where a barrier will shield a main highway, but not a frontage road. In these cases, the overall noise environment shall be the basis for the determination if a substantial noise reduction is possible, not just the reduction to the mitigated source.

5.4.2 Safety and Maintenance Considerations

As is the case with any structure, there are obvious engineering, safety and maintenance issues that must be considered to determine its constructability, and thus, be a feasible proposition. If any of these issues are significant enough to cause a fatal flaw condition, then the barrier can be deemed not feasible. Examples of situations which can be considered fatal flaws include, but are not limited to, the following:

- Excessive reduction of sight distance.
- Creation of a continuous shadowing condition that may cause excessive icing of driving lanes through the winter months.

- Inability to provide for adequate snow/debris removal.

5.4.3 Constructability

If reliable and common engineering practices could be employed to construct a noise barrier, then that barrier is considered to be a feasible proposition. Other factors that are sometimes considered concurrently, such as costs, are to be evaluated separately under the reasonableness criteria described in section 5.5.

If it is obvious that the constructability of a noise barrier due to site limitations or engineering considerations is not possible without major modifications to the site or technological efforts, the barrier can be considered not to be feasible and no further analysis is required, however, this should only be used for situations that are very clear. If it may be possible that a barrier(s) can be constructed, the evaluation with the computer model will take place in order to determine if a substantial reduction can take place. Decisions such as these shall be thoroughly documented and justified in the noise study report.

A very common issue to consider in this case is the ability to construct a continuous barrier for the entire length of the impacted area. An effective noise barrier cannot be built if breaks for driveways, sidewalks, streets, utilities, drainage facilities or streams are needed, as these breaks drastically reduce the barrier's performance. One possible solution in a case such as this is to consider overlapping the barriers.

5.4.4 Berms

Most of the above feasibility discussions have focused on the construction of noise barrier walls. Berms, however, can be considered as an alternative to walls where possible, as they are generally more aesthetically pleasing and have a more natural appearance. Limitations with berms do need to be considered in the feasibility evaluation, as they do require a much larger footprint. Ideally, this will be enough of a footprint to provide no steeper than a 3:1 slope.

5.4.5 Considerations for Parallel Barriers

Due to multiple sound reflections, performance degradation of parallel barriers needs to be investigated if the width-to-height ratio is less than 10:1 (distance between the barriers is less than 10 times the height of the barriers) or if the barriers are closer together than 200 feet. In these cases, if it is found that the overall noise reduction has decreased, steps need to be taken to reduce this degradation. Possible solutions include raising the height of the barriers to overcome the degradation or investigating the use of absorptive treatments on either or both barriers to reduce the reflections. In these cases, retaining walls, if they are present, should be treated as barriers in the analysis.

If all noise barriers that have been evaluated for a particular project are deemed not to be feasible (i.e. no barrier can be constructed that will result in a 5 dBA reduction to at least one receiver), the reasonableness criteria are not assessed and the noise

analysis is considered complete. This decision is to be discussed and documented in the noise study report.

5.5 Reasonableness

The reasonableness determination is a more subjective process than what is done to determine feasibility. It implies that common sense and good judgment have been used in the consideration of noise abatement. The process for evaluating the reasonableness of abatement is meant to be flexible enough to meet individual situations but able to be applied in as consistent and uniform a manner as possible on a statewide basis. The main consideration in this evaluation is whether or not the barrier is a practical solution for a certain situation.

The FHWA regulations are meant to give the states flexibility in complying with the requirements of 23CFR772, and many of the criteria that are to be considered are based on a range of possible solutions, many of which are to be determined by the individual states. While the determination of impacts is fairly standard and must be done by all states, the evaluation of any potential mitigation does not contain any mandates as to when mitigation is to be provided, other than after a determination of feasibility and reasonableness. In this determination, there is only one "absolute" criterion that is considered by CDOT in these guidelines: Even if a barrier meets all feasibility requirements and is deemed to be reasonable, it will not be built if the majority of the affected property owners do not want it to be built. A property is considered to be "affected" if it is predicted to receive at least a 3 dBA benefit from the barrier (i.e. is considered to be a "benefited" receiver).

The final determination of reasonableness of noise mitigation will be made only after a careful and thorough consideration of a wide range of criteria. The following are the criteria that will be considered by CDOT in its noise abatement evaluation. **None of the following reasonableness factors by itself shall be sole grounds for acceptance or rejection of mitigation.**

Each reasonableness factor discussed below will have one of four possible values:

- EXTREMELY REASONABLE – The proposed mitigation can be accomplished through minimal financial or social costs, or reflects a situation which warrants high consideration for mitigation.
- REASONABLE – The proposed mitigation can be accomplished through acceptable financial or social costs, or reflects a situation which warrants greater consideration for mitigation.
- MARGINALLY REASONABLE – The proposed mitigation can be accomplished through moderate financial or social costs, or reflects a situation that is moderately warranted for mitigation consideration.
- UNREASONABLE – The proposed mitigation cannot be accomplished without excessive financial or social costs, or reflects a situation in which mitigation consideration should be minimal at best.

5.5.1 Cost Benefit Index

In consideration of the cost of each potential noise barrier segment, the barrier benefit index shall be evaluated based on an estimate of cost per receiver per decibel of reduction. This will determine the "cost-reasonableness" of the abatement.

The cost benefit index, calculated as a ratio, is not intended to function as an accurate itemization of all of the different costs that are prevalent in the construction of a noise barrier, but rather to determine a consistent level of consideration that will be used for all CDOT noise abatement evaluations under these guidelines.

EXTREMELY REASONABLE: Less than $3000/receiver/decibel
REASONABLE: $3000-$3750/receiver/decibel
MARGINALLY REASONABLE: $3750-$4000/receiver/decibel
UNREASONABLE: More than $4000/receiver/decibel

This value will be determined by dividing the approximate cost of the barrier (length * height * unit cost) by the total decibel reduction that is predicted to occur. For evaluation purposes, the unit cost that will be used for this cost calculation will be a typical cost of $30 per exposed square foot, which will approximate all costs in construction of a standard concrete/masonry barrier that does not require special site considerations. If berms are possible and are potentially feasible, use the unit cost of $10 per square yard of earth for the berm portion of the calculation.

The total decibel reduction is the cumulative sum of all of the decibel reductions projected for each receiver that receives at least a 3 dBA benefit directly due to the noise barrier (all benefited or affected receivers).

For example, consider a barrier 10 feet high and 1000 feet long to protect a development of 16 homes. If 6 receivers are predicted to receive a 5 dBA benefit and 10 are predicted to receive a 7 dBA benefit, the cost benefit index value will be calculated as follows:

Cost = (10 ft. ht.) * (1000 ft. l.) * ($30/sq. ft) = $300000;
Benefit = (6 rec. * 5 dBA) + (10 rec. * 7 dBA) = 100 total dBA reduction;
Cost-Reasonableness Value = $300000/100 dBA = $3000/receiver/decibel.

This barrier would be considered REASONABLE.

As mentioned earlier, receiver points that were used in the modeling usually represent several actual receivers. It is very important to properly quantify these receivers to obtain an accurate count of the benefits achieved to be used for the

calculation. For the calculation, each benefited individual residence, business, etc. is to be counted as one receiver. For multi-family residences, each unit adjacent to the highway should count as one receiver. If the multi-family structure is predicted to receive an overall benefit of 8 dBA, for example, but there are 4 separate units, then an overall benefit of 32 dBA (4*8) must be used in the calculation.

In many cases, the number of receivers and their locations are not easily defined. The noise analyst in this case must use good judgment in determining these values, with the overall social benefit being the primary consideration in this evaluation. Special use facilities, such as parks and churches, should be handled with the same consideration and judgment on a case-by-case basis.

5.5.2 Build Noise Level

The future projected noise levels with the completion of the project should, on average, be at least 66 dBA for consideration of noise mitigation for the front row receivers.

EXTREMELY REASONABLE: Design-year noise levels 70 dBA or more
REASONABLE: Noise levels of 66-70 dBA
MARGINALLY REASONABLE: Noise levels 63-66 dBA
UNREASONABLE: Levels less than 63 dBA

This criterion gives greater consideration to areas which are or will be subjected to a higher absolute level of noise.

5.5.3 Impacted Persons' Desires

The opinions and desires of the impacted community should be of primary importance in the evaluation of reasonableness of a noise barrier. At least 50% of the affected property owners should want the noise barrier.

EXTREMELY REASONABLE: More than 75% in support
REASONABLE: 50-75% supportive
MARGINALLY REASONABLE: 25-50% supportive
UNREASONABLE: Less than 25% supportive

These values are normally based on residential areas, as normally mitigation for commercial and special-use areas by themselves are not reasonable. The percentages are to be based on the properties that benefit from the noise barrier (i.e. receive at least a 3 dBA benefit). In all cases, each individual property owner or their official designee or representative shall be the party to be consulted in this manner.

5.5.4 Development Type

The mixture of development types plays a major role in determining the reasonableness of mitigation. To be considered, the amount of residential

development should be at least 75% of the overall development in the area around the project.

EXTREMELY REASONABLE: Greater than 75% residential
REASONABLE: 50-75% residential
MARGINALLY REASONABLE: 25-50% residential
UNREASONABLE: Less than 25% residential

In general, the term "residential" as described above also includes other category "B" type development, such as parks, churches, hospitals, hotels, etc.

5.5.5 Development Existence

To be fully considered for a reasonable project, the majority of the development in the area of a highway improvement should have been in existence for at least 15 years before the consideration of the project.

EXTREMELY REASONABLE: Greater than 75% of properties at least 15 years old
REASONABLE: 50-75% at least 15 years old
MARGINALLY REASONABLE: 25-50% at least 15 years old
UNREASONABLE: Less than 25% at least 15 years old

The spirit of this criterion is to give greater consideration to long-term residents.

5.5.6 Build Noise Level vs. Existing Noise Level

The future build noise levels over the existing levels will be more of an issue if there is to be a readily perceptible increase with the completion of the project.

EXTREMELY REASONABLE: Greater than a 10 dBA increase
REASONABLE: 5-10 dBA increase
MARGINALLY REASONABLE: 0-5 dBA increase
UNREASONABLE: A project that will result in a decrease in projected noise levels.

This criterion allows greater consideration for projects that receive a perceptible increase in noise levels. In any case, this criterion is to still give consideration and not dismiss a potential barrier just because the project is not contributing any additional noise, especially if the overall noise levels are projected to be very high (70 dBA or greater).

Upon review of these criteria, the decision that is made should be well documented in the noise study report. To aid in this documentation, completion of CDOT form 1209 is required and is to be included within the noise study report (see Appendix C for a copy of the form). This form is to be filled out for each barrier segment or each distinct area of the project that were evaluated in the analysis.

5.6 Special Considerations for Severe Impacts

If a private-use residential property is determined to be severely impacted by noise (75 dBA exterior levels or a 30 dBA or more increase in noise levels), then extra-ordinary abatement measures may be considered if no other possible abatement is determined to be feasible and reasonable. One such method that can be used in these cases is noise insulation of the structure, which can include such measures as sealing windows and doors, filling voids in the structure, installation of an air-conditioning system, or other use of noise-absorbing material.

The consideration of extraordinary abatement measures in the case of severe highway traffic noise impacts can be made on a case-by-case basis and is not a mandatory requirement at this time.

5.7 Special Considerations for Non-Profits

Public use or nonprofit institutional structures, such as churches and schools, may be considered for noise insulation in accordance with 23CFR772.13.c(6). This evaluation is strictly voluntary and can be made on a case-by-case basis. Care must be taken in this evaluation as to the condition of the structure, its current amenities, and overall use characteristics to be sure that any proposals consider fully the implications of providing the abatement. One such case is for a facility which is not subjected to high interior noise levels unless the windows are open, but must remain open for the purposes of ventilation, and thus, provide proper use and enjoyment of the facility. Any decisions in this regard must be thoroughly and completely documented in the text of the noise report.

6. Construction Considerations

The approach to this discussion should be general in scope and consider the temporary nature of construction activities. Included should be the types of activities that are expected to be performed and the equipment that will be used. If desired, noise levels that are associated with these activities can be researched through product or process literature and presented in the report. Computerized prediction models have been developed for the calculation of noise from construction but are very sophisticated and require a great deal of input. As a result, use of these models to analyze construction noise is not required.

6.1 Noise

No detailed analysis or mitigation measures are required, but the noise analysis should at least identify low-cost, common sense mitigation measures that can be included on the project. Examples are limitations of work to daytime (or specified) hours, ensuring that equipment utilized properly maintained mufflers, modification of backup alarm systems, location of haul roads, and public outreach. This may be more of an issue when dealing with large, complex projects in major urban areas. In these cases, a more detailed discussion of the impacts and mitigation measures is necessary.

6.2 Vibration

A vibration analysis is generally not necessary for construction activities unless there are vibration-sensitive businesses in the area. Before construction begins, each vibration-sensitive area must be identified and a temporary vibration mitigation plan be developed.

6.3 Local Ordinances

Some entities have passed local noise ordinances which may restrict the amount of noise that can be emitted from a construction operation during certain hours or in certain areas (i.e. residential neighborhoods). In all cases, these noise ordinances must be obeyed unless a variance has been requested from and approved by the local agency of authority. This is something that may be needed if the work is envisioned to be very extensive or lengthy in nature.

7. Community Considerations

7.1 Public Involvement

Decisions concerning noise abatement should include involvement from the public, in particular the citizens who reside or perform business adjacent to the proposed noise barrier. For every project that a noise barrier is recommended, the affected residents' input shall be solicited. The affected residents include everyone who is shown, through the noise analysis, to receive a noise reduction from the proposed barrier. This will almost always include all first row property owners, and may include those in the second and third rows as well. These are the opinions that must be given the most consideration, but all members of the community at large should be able to provide their input as well.

Education should also be provided to members of the general public within the scope of public meetings and publications that describe noise, noise-related impacts, traffic noise mitigation, and enforcement issues. Various publications are available on the FHWA web site (http://www.fhwa.dot.gov/environment/noise.htm) that explain many of these concepts.

7.2 Coordination with Local Agencies

Upon completion of the noise study technical report, information shall be provided to local government agencies within whose jurisdiction the highway project is located as to the implications of the project on that particular local community in the future. The overall goal of this effort will be to prevent future traffic noise impacts on currently undeveloped lands and to attempt to promote noise compatible land use planning.

Proper noise compatible land use planning is very likely the best approach in dealing with the issue of highway traffic noise. The premise is very simple: Refrain from placing noise sensitive developments adjacent to highways. In reality, this is very difficult to do. As the jurisdiction over most of the land in these cases

belongs to local governments, it is up to them to determine what activities to pursue in consideration of the best interests of their citizens. While the State of Colorado encourages local governments to plan their developments in such a manner to minimize the impacts of highway traffic noise, such as the creation of buffer zones or placing less sensitive developments such as office buildings near the highway, there are no mandates currently in effect that prohibit noise sensitive development adjacent to highways.

Information shall be provided to the local officials as to the best estimation of future noise levels at various distances away from the centerline of the project for both un-developed and developed lands. In particular, the distance estimate of the projected 66 dBA contour (category "B" approach criterion) should be emphasized. The noise study report should be forwarded to the local authorities, as well as any other explanation or information that will aid the local officials in planning for future traffic noise impacts, such as the FHWA publications "The Audible Landscape: A Manual for Highway Noise and Land Use" and "Guidelines for Considering Noise in Land Use Planning and Control". Upon request, CDOT will provide additional available material and technical support and guidance which may be of assistance.

8. NEPA Documentation Requirements

For each and every Type I project, regardless of which level of documentation (CE, EA, EIS) is being used for that particular project, a detailed noise study report will be required to be submitted for CDOT review and comment. This finalized report will be submitted and included with all project information and documentation.

8.1 Categorical Exclusions

For Categorical Exclusion projects, there is usually no published environmental document. Rather, CDOT Form 128 is used to document the environmental clearances, to include noise. Completion of the detailed noise technical report, which has addressed the comments and concerns of the CDOT environmental review process, will suffice as far as project clearance documentation is concerned. The date that the noise analysis has been accepted will be noted on the 128.

8.2 Environmental Assessments and Environmental Impact Statements

Environmental Assessments and Environmental Impact Statements, within the body of the document, will provide a summary of the noise technical report. In particular, this summary will include the impacts that are expected and an evaluation of any potential mitigation measures. Although at the early stages of the environmental analysis and documentation effort final design information is not available, every effort must be made to make an initial determination of impacts and evaluation of mitigation measures, even if final decisions will not be made until the design process for the project.

Before the adoption of the final Environmental Impact Statement or Finding of No Significant Impact, noise abatement measures which are reasonable and feasible and are likely to be incorporated into the project and noise impacts for which no apparent solution is available must be identified. This information must be included in the final environmental document. The purpose of this requirement is that the intentions concerning noise abatement must be made as early as possible in the process. If it is determined that mitigation cannot be provided, the decision must be thoroughly documented with strong supporting evidence provided.

The noise study report shall be available for review within the technical appendix section of the environmental document. The noise study report must be finalized and approved before the environmental documents are approved and signed.

9. Extenuating Circumstances

It is virtually impossible to address every single special consideration that may arise in a specific highway project and its corresponding noise analysis. When circumstances arise such that unusual or unique considerations must be made that are not explicitly covered under these guidelines, decisions will be made in accordance with the spirit of the FHWA regulations and the CDOT guidelines. It is desired that this decision be made via collaboration between CDOT regional environmental personnel, the environmental consultant responsible for the noise analysis, the CDOT noise specialist, and, for Federal-aid projects, FHWA Division office staff. Unusual and unique circumstances will be considered on an individual project basis and the decision-making process must be fully documented in the noise technical report.

Appendix A—Key Definitions

23CFR772—Title 23, Code of Federal Regulations, Part 772 (The FHWA Noise Standard).

ADT—Average Daily Traffic.

Abatement—Measures used to substantially reduce traffic noise levels.

Approach—Noise levels which are within 1 dBA of the Noise Abatement Criteria for a corresponding land use category.

Automobiles—All vehicles with 2 axles and 4 tires. Includes passenger cars, vans, and light panel and pick-up trucks.

Background Noise—The total of all noise in a system or situation, independent of the presence of the desired signal (ambient noise).

Benefited Receiver—Any receiver which is predicted to receive at least a 3 dBA reduction in noise as a result of a noise abatement measure. Also referred to as "affected".

Berm—An earthen mound constructed for use as a noise barrier.

CDOT—Colorado Department of Transportation.

CDOT Form 1209—Noise abatement worksheet to be filled out for each noise analysis for CDOT projects.

Cost Benefit Index—A value used to determine the cost-reasonableness of noise abatement based on an average barrier cost per unit area.

Date of Public Knowledge—The date of approval of the appropriate environmental document for a highway project (CE, FONSI, ROD).

Decibel—The basic unit for measuring the difference of sound pressure levels of a sound event from a reference pressure. To approximate the range of frequencies of sound most audible to the human ear, an "A-weighting" factor is applied. Sound levels are usually reported in A-weighted decibels, abbreviated dBA.

DHV—Design Hour Volume; the traffic count determined to reflect the "worst-hour" noise conditions.

Design Year—The future year used to estimate the probable traffic volume for which a highway is designed (usually 20 years from start of construction). This year is used as the basis for calculating the predicted future (20-year) noise levels.

Existing Noise Levels—The level of noise measured or modeled at a receiver for the pre-construction condition of the highway project area.

FHWA—Federal Highway Administration.

Heavy Trucks—Any vehicle with three or more axles.

Impacted Receivers—Any receiver which, under future conditions, is either subjected to noise levels that approach or exceed the noise abatement criteria or a substantial increase in noise levels.

Insertion Loss—The predicted reduction in noise levels resulting from implementation of noise abatement measures.

Leq(h)—Hourly Equivalent Noise Level; the equivalent steady-state sound level that contains the same amount of acoustic energy as the time-varying sound level over a one hour period; the noise descriptor that is used for all traffic noise analyses for CDOT projects.

Loudness—The perceived assessment of the intensity of sound/noise.

Medium Trucks—Any vehicle with 2 axles and 6 tires.

NEPA—National Environmental Policy Act.

Noise—Unwanted sound; any sound that is generally considered annoying or offensive.

Noise Abatement Criteria (NAC)—Absolute noise levels that are used to determine when a noise impact occurs (if approached or exceeded).

Noise Barrier—A solid structure constructed between a noise source and noise impacted receivers to serve to abate the highway traffic noise.

Parallel Barriers—Two barriers which face each other on opposite sides of a highway.

Planned, Designed, and Programmed—Development on currently undeveloped land that has secured a formal building permit.

Predicted Noise Levels—Post-construction noise levels as determined via use of a traffic noise prediction model for the design year.

Privacy Fence—Fences constructed on private property or edges of development that are primarily used to separate individual lots from a roadway, and not constructed for noise abatement purposes.

Receiver—Any location of an outdoor area where frequent human activity occurs that may be impacted by highway traffic noise and may benefit from reduced noise levels.

Severe Noise Impact—A situation where predicted noise levels are 75 dBA or higher or an increase of 30 dBA over existing levels is predicted as a result of a highway project.

Shielding—Noise reduction attributable to any structures or terrain features which are located between a noise source and receiver.

Sound—Mechanical energy produced by pressure fluctuations in a medium (air, water, etc.) that travels in waves and can be detected by the human ear.

Substantial Increase—When the predicted noise levels increase by 10 dBA or more over the existing noise levels as a result of a highway project.

Substantial Noise Reduction—A noise level reduction of at least five decibels through noise abatement efforts.

Substantial Noise Reduction Goal—It shall be the goal of CDOT to achieve a feasible and reasonable reduction of at least ten decibels through noise abatement efforts.

STAMINA—Current FHWA approved traffic noise prediction model for use on CDOT projects. Uses Colorado vehicle emission levels as approved in 1995.

Study Zone—A 500 foot "halo" around the extents of a project which must be considered in the noise analysis. Measured from the edge of the traveled way, not the highway centerline.

Traffic Noise Impacts—Impacts which occur when the predicted traffic noise levels approach or exceed the noise abatement criteria or when the predicted traffic noise levels substantially exceed the existing noise levels.

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

Type II Projects—A proposed Federal or Federal-aid highway project for noise abatement on an existing highway. No formal Type II program currently exists in Colorado.

Undeveloped Lands—Lands on which exist no current human activity areas or are not currently planned, designed, and programmed for future development.

Worst Traffic Noise Condition—Traffic conditions that yield the highest absolute noise levels by consisting of the highest volume of traffic traveling at the highest possible speed. This is the hourly condition that is to be input into the model and normally reflects LOS "C" conditions. In general, this is the roadway design hour traffic volume at the posted speed limit.

Appendix B—Noise Technical Report Requirements

The purpose of the noise technical report is to provide complete documentation of a highway traffic noise analysis.

The noise analysis shall include the following steps for each alternative under detailed study, to include the "no-action" alternative:

- Identification of existing activities (receivers), developed lands, and undeveloped lands for which development is planned, designed, and programmed,
- Determination of existing noise levels,
- Prediction of future noise levels,
- Identification of traffic noise impacts, and, if necessary,
- Documentation of the evaluation of noise abatement measures.

Within the body of the report, the above steps taken shall be documented in a manner which allows clear comprehension to the reader of what analysis was done and its underlying reasoning.

The noise report shall include the following (this does not necessarily have to be in the following order and can be included as appendices where appropriate):

- **Introduction and Study Area.** Describe in detail the project that is being proposed and the study zone that is being considered.
- **Noise Basics and Applicable Guidelines.** Describe general sound and noise terminology and the guidelines and regulations that are being adhered to in the development of the noise analysis.
- **Measurement Procedures.** Describe where and when noise measurements were taken and report the results. List in a table each measurement location and the corresponding results. Not every receiver needs to be measured individually, but enough locations are required in representative points throughout the project. Collect traffic data during the measurements to be used in the validation step.
- **Measurement/Model Comparison (Validation).** Compare the measurement results with the results obtained using the computer model. Report this data in tabular form as well. In general, agreement within 3 dBA will be acceptable. If the difference for any locations is more than 3 dBA, an explanation must be provided as to the reasons for the difference. This may require that the field measurements be repeated.
- **Model Input Data.** Describe the data that is to be included in the modeling of the existing and future conditions. Include and quantify all receivers which are within the study zone of the project. Include and describe which roadways, terrain features, buildings, and ground conditions are present. Describe in detail which traffic data is to be used for the modeling, to include the speeds. Generally, this will be the design hour volume for the roadway, which reflects Level of Service "C" volumes, at the posted or future design speed limit. If the design year

traffic projections do not meet the LOS "C" conditions, use those values (do not model to the capacity of the highway unless the traffic is projected to meet that capacity). Be sure to obtain as accurate a split as possible on medium truck and heavy truck volumes.

- **Modeling.** For all receivers, model the noise levels for the existing, all future alternatives being considered, and the future no-action alternative. List all data in tabular form for easy comparison. All receivers shall be identified with an address, business name, or location in addition to whatever modeling convention is used (i.e. R1-1200 Oak Street) and to which land-use category they were classified. If any modeled receivers represent more than one actual receiver, that information also needs to be included (R1, 1200 Oak Street, Category B, 5 residences) as well.
- **Mitigation Analysis and Evaluation.** If noise impacts are identified, mitigation must be evaluated under the feasibility and reasonableness guidelines. Evaluate abatement first to attempt to achieve a 10 dBA reduction for at least one receiver (CDOT goal), then, if necessary, evaluate different abatement strategies in an iterative process down to 5 dBA (minimum reduction). At least two barrier placements and heights should be analyzed unless it is very obvious that only one location/height will be possible. The goal of this effort is to attempt to "optimize" the barrier given the feasibility and reasonableness factors.
- **Mitigation Recommendation.** Explain in detail the final recommendations concerning noise mitigation. This information will also be used in the environmental document, if applicable.
- **Construction Noise.** A brief discussion of the implications of construction noise and typical mitigation measures that can be used is also required.
- **Maps.** To aid in visualization of the project, maps should be included as appendices to the noise study report that locate the project, modeled receivers, measurement locations, and barrier locations.
- **CDOT Form 1209.** A copy of the CDOT Noise Abatement Worksheet should be filled out and attached as an appendix as well. Fill out one form for each barrier segment or project area analyzed.
- **Noise Modeling Data.** A copy of the input and output data can either be included in the appendix, or preferably, submitted with the report on floppy disks or CD.

Appendix C—Noise Abatement Worksheet

COLORADO DEPARTMENT OF TRANSPORTATION
NOISE ABATEMENT DETERMINATION

Instructions: To complete this form refer to CDOT Noise Analysis Guidelines

Project #	Project code (SA#)	STIP #	Project Location:

A. FEASIBILITY:

1. Can a continuous noise barrier or berm be constructed?. . . . . ❒ YES ❒ NO
2. Can a substantial noise reduction be achieved by constructing a noise barrier or berm?…
   10 dBA: ❒ YES ❒ NO 7-10 dBA: ❒ YES ❒ NO 5-7 dBA: ❒ YES ❒ NO
3. Are there any "fatal flaw" safety or maintenance issues involving the proposed noise barrier or berm?. . . . . ❒ YES ❒ NO

B. REASONABLENESS:

	EXTREMELY REASONABLE	REASONABLE	MARGINALLY REASONABLE	UNREASONABLE
1. Cost Benefit Index (per receiver per dBA). .	❒ Less than $3000	❒ $3000-$3750	❒ $3750-$4000	❒ More than $4000
2. Average Build Noise Level	❒ 70 dBA or More	❒ 66 - 70 dBA	❒ 63 - 66 dBA	❒ Less than 63 dBA
3. Impacted persons' desires	❒ More than 75%	❒ 50% - 75%	❒ 25% - 50%	❒ Less than 25%
4. Development Type (Category B*)	❒ More than 75%	❒ 50% - 75%	❒ 25% - 50%	❒ Less than 25%
5. Development Existence (15 years or more) .	❒ More than 75%	❒ 50% - 75%	❒ 25% - 50%	❒ Less than 25%
6. Build Noise Level vs. Existing Noise Level .	❒ Greater than 10 dBA	❒ 5 - 10 dBA	❒ 0 - 5 dBA	❒ Noise Level Decrease

***Category B – Residential, School, Hospital, Park, Picnic/Active Sports Area, Motel, Church, Library**

C. INSULATION CONSIDERATION:

1. Are normal noise abatement measures physically infeasible or economically unreasonable?. . . . . ❒ YES ❒ NO

   If the answer to 1 is YES, then:

2. a. Does this project have noise impacts to public or non-profit buildings?. . . . . ❒ YES ❒ NO
   b. If yes, is it reasonable and feasible to provide insulation for these buildings?. . . . . ❒ YES ❒ NO
3. a. Is private residential property affected by a 30 dB(A) or more noise level increase?. . . . . ❒ YES ❒ NO
   b. Are private residences impacted by 75 dB(A) or more?. . . . . ❒ YES ❒ NO

D. ADDITIONAL CONSIDERATIONS:

E. DECISION:

1. Are noise mitigation measures feasible?. . . . . ❒ YES ❒ NO
2. Are noise mitigation measures reasonable?. . . . . ❒ YES ❒ NO
3. Is insulation of buildings both feasible and reasonable?. . . . . ❒ YES ❒ NO
4. Shall noise mitigation measures be provided?. . . . . ❒ YES ❒ NO

F. DECISION DESCRIPTION AND JUSTIFICATION

Completed by:	**Date:**