Noise Technical Assessment

October
2017

Jefferson Parkway: Culebra Street to North of Candelas Parkway

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TABLE OF CONTENTS

Chapter **Page**

TABLES

FIGURES

APPENDICES

Noise Terminology

Ambient noise — total noise level in a specified environment.

A-weighted — a frequency weighted network used to account for changes in sensitivity as a function of frequency.

Benefited receptor — the recipient of an abatement measure that receives a noise reduction at or above the minimum threshold of 5 dB(A), but not to exceed the highway agency's reasonableness design goal.

dB(A) — the A-weighted sound pressure level.

Decibel (dB) — a unit of sound level which denotes the ratio between two quantities that are proportional to power; the number of decibels is 10 times the base 10 logarithm of this ratio.

Feasibility — the combination of acoustical and engineering factors considered in the evaluation of a noise abatement measure.

Frequency — repetition rate of a cycle, the number of cycles per second.

Insertion loss – the difference in levels before and after installation of a barrier, where the source, terrain, ground, and atmospheric conditions have been analyzed as equivalent.

L_{eq} – the equivalent sound level which in a period of time contains the same acoustic energy as the time-varying sound level during the same time period.

Noise – any unwanted sound.

Noise Abatement Criteria (NAC) – objective absolute noise levels for varying land use categories that are used to determine if and where traffic noise impacts occur, as defined in 23 CFR 772.5.

Noise barrier – the structure, or structure together with other material, that potentially alters the noise at a site from a previous condition to a future condition.

Noise reduction — the difference in sound pressure level between any two points along the path of sound propagation.

Noise reduction design goal — the optimum desired dB(A) noise reduction determined from calculating the difference between future build noise levels with abatement, to future build noise levels without abatement. The Colorado Department of Transportation (CDOT) has set the noise reduction design goal to be at least 7 dB(A), at a minimum of one receptor.

Reasonableness — the combination of social, economic, and environmental factors considered in the evaluation of a noise abatement measure.

Receptor — a discrete or representative location of a noise sensitive area.

Substantial noise increase — an increase in noise levels of 10 dB(A) in the design year over the existing noise level.

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1 INTRODUCTION

The proposed project encompasses approximately five miles of Jefferson Parkway from Culebra Street to just north of Candelas Parkway, which passes through the Leyden Rock and Candelas communities in Arvada, Colorado within Jefferson County. The overall purpose of the noise analysis for Jefferson Parkway is to conclude if noise levels at any receiver near the proposed project will exceed applicable impact thresholds from implementation of the project.

1.1 Project Background

Jefferson County, the City and County of Broomfield, and the City of Arvada established the Jefferson Parkway Public Highway Authority (JPPHA) in May 2008. The mission of the JPPHA is to fulfill transportation needs in the area by completing the last remaining unbuilt section of the Denver metropolitan beltway. Jefferson Parkway is proposed as a toll facility from State Highway (SH) 128 near Interlocken Loop on the north to SH 93 near 64th Avenue on the south, located predominantly in unincorporated Jefferson County. The corridor was previously analyzed in the 2008 Northwest Corridor Transportation and Environmental Planning Study (TEPS). The corridor as it stands now is nearly identical to the tollway portion of the Recommended Alternative that was studied by the Colorado Department of Transportation (CDOT) and documented in the 2008 Northwest Corridor TEPS. The JPPHA and its partners have obtained an approximately 300-foot wide right-of-way for the Jefferson Parkway.

Jefferson Parkway is the last unbuilt portion of the Denver metropolitan beltway, and will be completed through a public-private partnership to finance, design, build, operate, and maintain the Parkway.

1.2 Project Limits

The portion of Jefferson Parkway evaluated in this noise technical assessment consists of Jefferson Parkway from just south beyond Culebra Street to north of Candelas Parkway (approximately five miles) to include two travel lanes in each direction with inside and outside shoulders of variable widths. These improvements are needed at this time because they support the long-term travel needs of the rapidly growing population of Arvada, surrounding communities, and the region.

1.3 How Noise is Defined

Noise is typically defined as unwanted or undesirable sound. The basic parameters of noise that affect humans are:

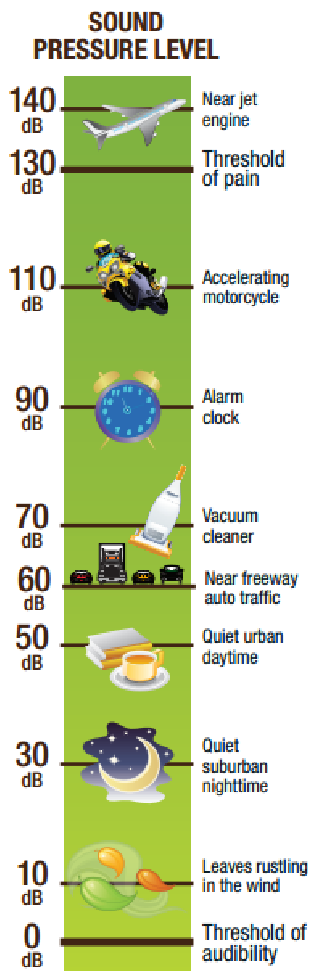
- Intensity or level,
- Frequency content, and
- Variation with time.

The first parameter is determined by the level of sound, which is expressed in units of decibels (dB). By using this scale, the range of normally encountered sound can be expressed by values between 0 and 120 dB. On a relative basis, a 3-dB change in sound level generally represents a barely perceptible change in a common outdoor setting to someone with average hearing. A 5-dB positive change presents a “noticeable” change, and a 10-dB positive change is typically perceived as a doubling in the loudness while a 10-dB decrease in noise levels is perceived as a 50 percent reduction in loudness.

The frequency of noise is related to the tone or pitch of the sound and is expressed in terms of cycles per second called hertz (Hz). The human ear can detect a wide range of frequencies from about 20 Hz to 17,000 Hz. However, because the sensitivity of human hearing varies with frequency, the A-weighting system is commonly used. Sound levels measured using this weighting system are called "A-weighted" sound levels and are expressed in decibel notation as dBA. The A-weighted sound level is widely accepted as a proper unit for describing environmental noise.

Because environmental noise fluctuates from moment to moment, it is common practice to condense all this information into a single number called the equivalent sound level (Leq). The Leq is a measure of the average sound energy during a specified period of time (typically 1 hour or 24 hours). The Leq is defined as the constant level that, over a given period of time, transmits the same amount of acoustical energy to the receiver as the actual time-varying sound. Studies have shown that Leq is well correlated with human annoyance to sound, and therefore, this descriptor is widely used for environmental noise impact assessment. The Leq measured over a 1-hour period is the hourly Leq (1-hour) expressed as Leq(h), which is used to analyze highway noise impacts and abatement. **Figure 1** shows common sound pressure levels.

Figure 1. Typical Sound Levels



2 METHODOLOGY

The noise analysis was performed in accordance with the requirements of 23 CFR §772, Procedures for Abatement of Highway Traffic Noise and Construction Noise, using methodology established by CDOT's Noise Analysis and Abatement Guidelines (2015). Predicted noise levels were produced using the Federal Highway Administration (FHWA) Traffic Noise Model (TNM) 2.5. All measured and predicted noise levels are expressed in dBA. The hourly equivalent noise levels are defined as the equivalent average sound level that in a given hourly period contains the same acoustic energy as the time-varying sound for the same hourly period.

Noise from traffic emanates from four primary sources: the tire/road interface, engines, aerodynamics, and exhaust stacks. Each of these is considered in the TNM 2.5 model. The dBA numbers are used to determine the effect upon potential noise-sensitive sites.

CDOT has established noise levels at which impacts occur and noise abatement must be considered for various types of noise-sensitive sites. These noise levels are referred to as the Noise Abatement Criteria (NAC). As presented in **Table 1**, the NAC vary according to the land use activity category. Noise impacts occur and abatement measures must be considered when either of the following is true:

- Predicted traffic noise levels meet or exceed the NAC.
- A substantial noise increase of at least 10 dBA over existing conditions is predicted.

Table 1. CDOT Noise Abatement Criteria

Activity Category	Leq(h), dBA	Description of Land Use Activity Category
A	56 (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	66 (Exterior)	Residential.
C	66 (Exterior)	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreational areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	51 (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	71 (Exterior)	Hotels, motels, time-share resorts, vacation rental properties, 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 for development.

Source: CDOT, 2015

2.1 Noise Model

FHWA's TNM 2.5 was used for all traffic noise modeling. This software is required for all noise analysis per FHWA regulations (23 CFR §772). TNM calculates traffic noise levels based on input for the loudest hour traffic volumes, operating speeds, and surrounding environmental characteristics. This information then is used to determine which receptors would meet or exceed the established noise criteria or experience a substantial increase in noise levels over existing conditions.

Roadways and, in some instances, ramps that were modeled include Jefferson Parkway, Coal Creek Canyon Road/SH 72, Leyden Rock Road, subdivision roadways branching off Leyden Rock Road, Candelas Parkway, subdivision roadways branching off Candelas Parkway, and Indiana Street. The ramps at major intersections span approximately 1,000 to 1,600 feet outward (east to west) from the intersecting point with Jefferson Parkway (i.e. Candelas Parkway, Coal Creek Canyon Road/SH 72). Some terrain lines were captured in the noise models to account for rolling hills and elevation change.

2.1.1 Shielding

Shielding was assigned to receptors as applicable along the corridor by using building rows (representing residential structures) in TNM. To determine the percentage of noise blocked by the building row, the percentage of building lengths in the building row was used. The length of a building row includes the length of spaces between buildings through which noise could traverse.

2.1.2 Placement of Receptors

The receptor location was placed where there was an apparent area of frequent outdoor human use. Each receptor placed represented one dwelling unit or area of frequent human use. Only the ground level elevations for each receptor were used.

2.1.3 Traffic and Speed

In accordance with CDOT's guidelines and FHWA regulations (23 CFR 772.9 (d)), the loudest hour noise levels should be used to determine noise impacts. The loudest noise hour is typically the hour with the highest volume of traffic traveling at the fastest, congestion-free speeds. For the Jefferson Parkway noise analysis, one speed limit (65 miles per hour [mph]) was assumed for all of Jefferson Parkway and Coal Creek Canyon Road/SH 72, one speed limit was modeled for Indiana Street (50 mph), one speed limit was modeled for Candelas Parkway (45 mph), one speed limit was modeled for Leyden Rock Drive (35 mph), and one speed limit was modeled for all residential roads (25 mph). The Indiana Street speed limit is expected to be reduced once the Parkway is constructed; use of the higher speed limit in the model represents a worst-case scenario for noise analysis.

Some traffic volumes included in the traffic study were generated from the Focus travel demand model, an activity-based model for the Denver region. Future traffic forecasts for the proposed project used the 2040 design year (Michael Baker International, 2016). While both AM peak and PM peak hour traffic volumes were generated using the Focus models, AM peak hour traffic volumes were used because they represented a worst-case scenario for noise analysis. The opening day (year 2020) traffic volumes were prepared (HDR, 2017), using standard extrapolation techniques and a ratio of traffic volumes from the 2040 traffic analysis.

Traffic volumes on local streets were included in the model where available, even though the low speeds of the roadways and the low traffic volumes do not contribute significantly to the overall noise level experienced by the surrounding noise-sensitive receptors. For the existing conditions, volumes were derived from the traffic study or from counts taken during noise measurements where traffic data was unavailable.

For the future conditions, due to unavailable truck percentage data in the traffic report, a 5% growth rate was assumed for roadways in both the Leyden Rock Subdivision and the Candelas Subdivision. Further, one medium truck was included in truck traffic to account for moving and/or delivery vehicles throughout the neighborhoods. For all other modeled roadways, including Jefferson Parkway, Candelas Parkway, and Indiana street, the percentage of traffic that was observed in the traffic study for the proposed project was applied to remaining roads where traffic data was unavailable. This same approach was applied for commercial truck traffic percentages for roads in the proposed project where traffic data was unavailable. Also, future local traffic was capped in areas where there were limited numbers of houses.

2.1.4 Location Data

Accurate vertical and horizontal data for roadways, receptors, and building rows were needed for noise modeling. MicroStation, geographic information systems (GIS), and field reviews were used to provide vertical/horizontal data for all features. These resources provided approximate elevations of the major roadways, neighborhood roads, and receptors. There were no existing noise walls within the project limits.

The model included topography from the data available; however, the study may not have accounted for all the berms present because recent construction may have altered the topography. Berms were placed in the model at the southern end of 93rd Ave., near Candelas Parkway; at the west ends of the Leyden Rock development, on both sides of Jefferson Parkway; and south and west of 85thLane/86th Ave., on the south side of the Parkway.

2.1.5 Number of Lanes in TNM Model

In cases where there are multiple lanes of travel, up to two lanes having the same traffic characteristics may be combined in the model as one lane of travel per direction. The current design of Jefferson Parkway has two lanes in each direction. One road segment was modeled to represent two lanes in TNM. TNM lanes were also used to model shoulders along Jefferson Parkway to accurately model the full width of the surface pavement. Ramps, some local roads and neighborhood roads were modeled as one lane in TNM. The lane was modeled down the center of both lanes for a two-lane section or in the center of the lane for a one-lane section. For a two-lane cross street with one lane in each direction, the street was modeled down the center of both lanes in TNM. For cross streets with multiple lanes in each direction, each direction was modeled separately in TNM. Shoulders and turning lanes were modeled as necessary to accurately represent the full width of pavement on frontage roads and cross streets.

2.1.6 Apartments/Hotels/Condos

Noise-sensitive structures with multiple floors having areas of frequent human outdoor use (such as balconies or patios) were not present within the study area.

2.1.7 Rounding

Noise values were rounded to the nearest whole number when reporting existing and future noise volumes, per Section 3.6 of the CDOT *Noise Analysis and Abatement Guidelines*.

2.2 Identification of Noise-Sensitive Sites

The project limits were reviewed to identify existing and future development, and land uses. Among these reviewed areas, noise sensitive locations known as receptors were identified within the study area. The study area for this assessment consists of 500 feet from the edge of the proposed project pavement. Existing receptors, including residences, businesses and permitted future sites of residences and businesses, were captured within the existing model run, and the model runs for 2020 and 2040. Receptors were assigned their appropriate NAC in the models based on the current guidance.

In general, most of the receptors in the Jefferson Parkway corridor are residential development (Category B) that would be adjacent to the future roadway right of way. These developments include the Leyden Rock Subdivision, located north of W. 82nd Avenue and south of Coal Creek Canyon Road/SH 72, and the Candelas Subdivision, located north of Candelas Parkway. There are also scattered commercial and industrial businesses (Category E and F) and residences within the noise study area, outside of these two subdivisions. Category F facilities are located north of Coal Creek Canyon Road, north of Candelas Parkway and adjacent to Indiana Street.

2.3 Ambient Noise Measurements and TNM Model Validation

To characterize the existing noise environment and to validate the computer noise model, field measurements were taken within the project area following procedures documented in FHWA's *Highway Traffic Noise: Analysis and Abatement Policy and Guidance* (FHWA, 2011) and CDOT's *Noise Analysis and Abatement Guidelines* (CDOT, 2015). Noise measurements were collected on July 20, July 27, and July 30, 2017 from approximately 9:30 AM to 3:30 PM, over the course of both a full weekday and weekend day. Some measurements were taken during high traffic hours, and some were taken during quiet hours.

Traffic noise measurements were collected via a Larson Davis 812 Sound Level Meter. The meter was calibrated by the manufacturer or another certified laboratory within one year prior to data collection, and the meter was calibrated in the field prior to and immediately after measurement collection. **Table 2** lists the results of the noise measurements.

The noise measurements used in this noise study area were taken at seven locations within 500 feet of the proposed location of Jefferson Parkway. These sites were in the vicinity of noise-sensitive sites, where safe access to monitoring sites existed, where representative sampling of free-flow traffic (traffic counts) could be obtained, and where roadway geometry remained relatively constant. Traffic counts were performed at the time of monitoring. Vehicle counts were separated into three categories: cars, medium trucks, and heavy trucks. Vehicle speeds were modeled based on posted speed limit, as actual travel speed readings were unable to be collected in the field.

Data collection efforts focused on noise sensitive receptors within NAC B land uses. No interior readings were taken while in the field. Additionally, the seven monitoring locations were distributed throughout the corridor. Noise monitoring locations are shown on **Figure 2** and **Figure 3**. As shown in **Table 2**, measured noise levels approximately 10 feet to 180 feet from existing roadways ranged from 39 dBA to 55 dBA.

In accordance with industry standards and accepted best practices, detailed noise models were created using the FHWA Traffic Noise Model (TNM) v.2.5. The noise models were validated to within acceptable tolerances of field-monitored traffic noise data. The results of the validation effort are listed in Table 2. The results show that the validation model predicted noise levels at all but one location within ±3 decibels of the actual field measurement. The one measurement site that did not validate (measurement site V7), was in an area of rolling open terrain with a raised railroad bed ahead of the noise meter, and a wooden fence and steep uphill residences behind the noise meter. These physical features could have contributed to the measurement site not validating within the model. Further, traffic counts were obtained from Coal Creek Canyon Road/SH 72 at this location, but traffic counts were not obtained from Indiana Street in the distance, a likely contributor to noise, as the roadway has greater traffic. Successful validation of sites in different neighborhoods with different roadway geometry, traffic conditions, terrain lines, and shielding (buildings and other impediments to the propagation of noise) provided high confidence in the TNM model results and subsequent decisions made in the remaining portions of the noise study.

Table 2. Study area noise measurements and TNM model validation results

Measurement Site Number	Location Name	Description	Location from Edge of Nearest Roadway (feet)	Noise Reading (dBA)	TNM Validation Result (dBA)	Difference
V2	Candelas Subdivision off Joyce Way	Small park area	104	42	42	0
V7	Leyden Rock Subdivision path below Torrey Street at W. 87th Avenue	Bare path behind subdivision fence line	180	55	49	-6
V8	Leyden Rock Subdivision near W. 87th Avenue	W. 87th Avenue cul-de-sac behind houses	160	43	43	0
V9	Near Leyden Rock Subdivision at W. 85th Place and Leyden Rock Drive	Hillside of roadway intersection	45	52	52	0
V10	Leyden Rock Subdivision at intersection of W. 86th Avenue and W. 86th Lane	Sidewalk at the roadway intersection	10	48	45	-3
V11	Leyden Rock Subdivision at intersection of W. 84th Lane and Windy Court	Sidewalk at the roadway intersection	10	46	44	-2
V13	Leyden Rock Subdivision at W. 84th Place cul-de-sac	Sidewalk at cul-de-sac	10	39	41	+2

Figure 2. Noise Monitoring Locations

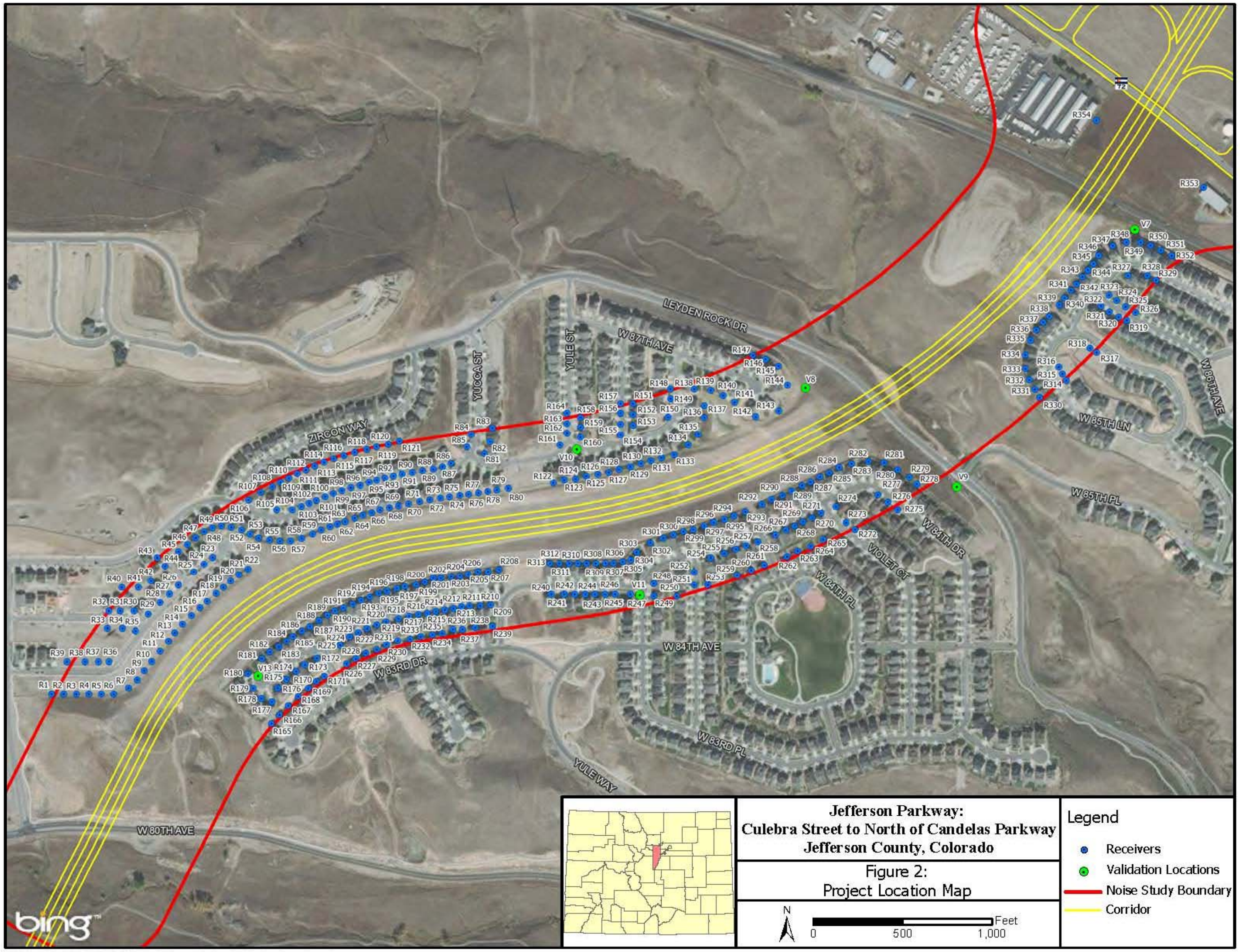


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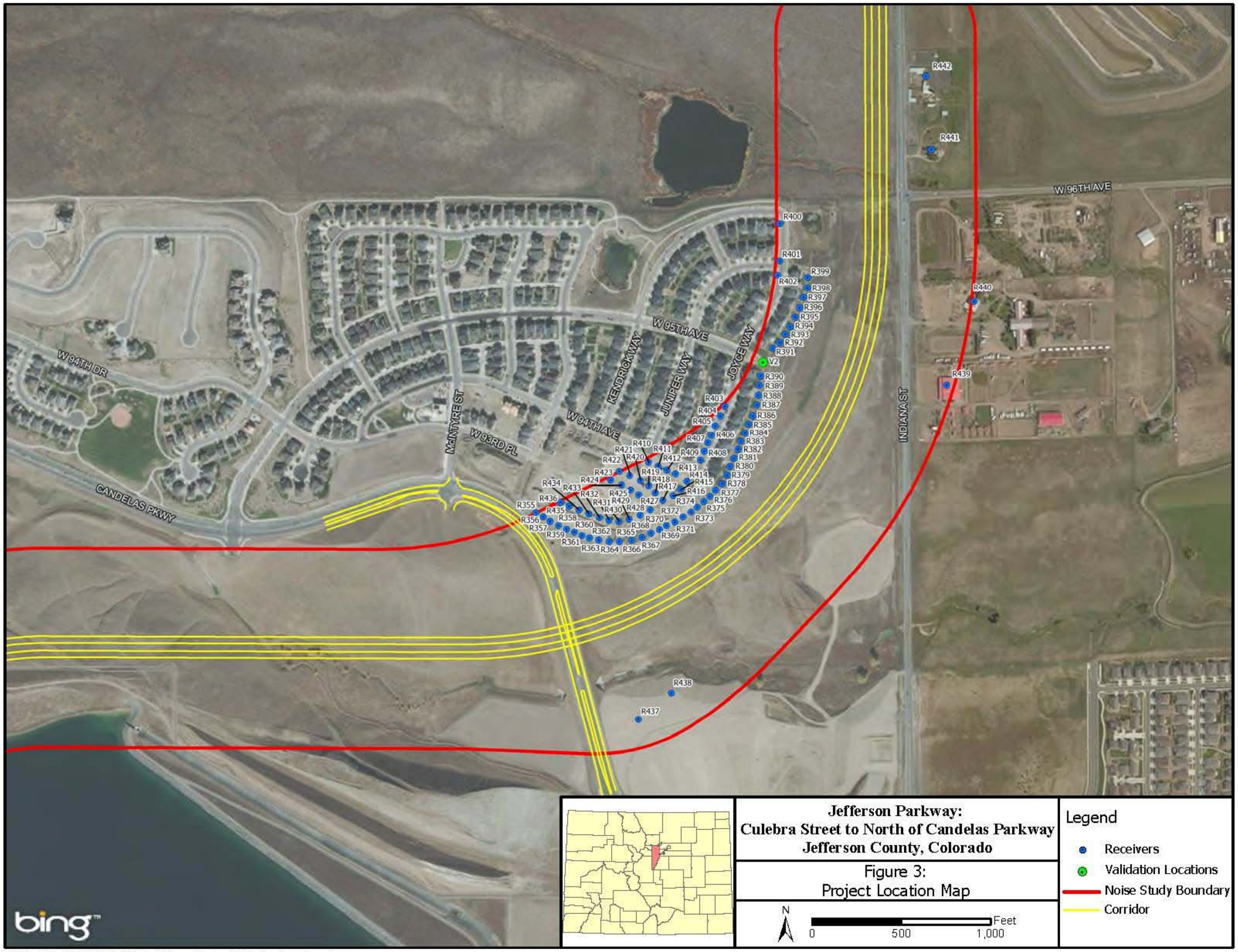
Figure 3. Noise Monitoring Locations (cont'd)



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3 EFFECTS ANALYSIS

The effects analysis compares the effects of the proposed project to the existing conditions and to the NAC to determine whether impacts would occur at noise-sensitive receptors.

Modeled locations are shown in Appendix B, Data and TNM Modeling Results, of this report. Based on CDOT's Noise Analysis and Abatement Guidelines, 66 dBA was used as the approach noise level in the analysis of the existing conditions in the study area for Activity Categories B and C (see **Table 1**). Existing noise levels for each modeled location can be found in Appendix B of this technical report.

The assessment of noise effects from traffic operations is based on a comparison of projected future noise exposure with existing conditions and with the NAC for noise-sensitive land use categories. The following subsections describe the methodologies followed for the noise effects analysis.

At each end of the model where receivers were located further beyond the noise study area, an additional approximately 800 feet of roadway (well over four times the distance of the receiver in relation to its distance from the roadway in this instance) was left in the model to account for roadway noise.

3.1 Existing Conditions

Existing conditions are modeled to assess the noise levels that noise sensitive receptors currently experience. This analysis creates a baseline to compare the proposed project to determine if there will be substantial increases in noise over existing levels. The existing conditions model uses current roadway configuration with existing traffic data.

3.2 Proposed Project 2020

Noise conditions in 2020 are modeled to assess the noise levels that noise sensitive receptors will experience when Jefferson Parkway opens. This analysis compares the effects of the proposed project to determine increases in noise over existing levels due to the project. The model uses the current design for Jefferson Parkway and the future roadway configuration with future 2020 traffic data.

3.3 Proposed Project 2040

The proposed project is modeled to assess the noise levels that noise sensitive receptors will experience in future years with project improvements. The proposed project model uses the current design for Jefferson Parkway and uses future roadway configurations with future 2040 traffic data.

3.4 Noise Analysis Results

3.4.1 Existing Conditions Analysis

A total of 442 receptors were analyzed in all noise models included in this study, most of which were located within established or currently being developed subdivisions. As summarized in **Table 3**, there is one receptor (R441 - Category B) that has traffic noise impacts within the study area. This receptor is located adjacent to Indiana Street (see **Figure 2**).

3.4.2 2020 Analysis

As summarized in **Table 3**, there are no receptors that have traffic noise that will exceed the NAC threshold within the study area in 2020. All the impacts are due to substantial noise increases (noise levels greater than 10 dBA or more from the existing noise level). The decibel change ranges from -4 dBA to +30 dBA over existing noise levels, and the average increase is 10 dBA over existing noise levels.

There are 184 receptors expected to experience substantial noise impacts. These receptors are located in the Leyden Rock Subdivision, located north of W. 82nd Avenue and south of Coal Creek Canyon Road/SH 72, and the Candelas Subdivision, located north of Candelas Parkway, or in other locations scattered north and south through the study area near Jefferson Parkway. The individual results for each receptor are in Appendix B, TNM Results. No receptors are anticipated to be acquired by the project.

3.4.3 2040 Analysis

Noise levels in 2040 increase by approximately 3-4 dBA over noise levels in 2020. As summarized in **Table 3**, there are 245 receptors that have potential noise impacts within the study area in 2040. These receptors are located in the Leyden Rock Subdivision, located north of W. 82nd Avenue and south of Coal Creek Canyon Road/SH 72, and the Candelas Subdivision, located north of Candelas Parkway, or in other locations scattered north and south through the study area near Jefferson Parkway. The individual results for each receptor are in Appendix B, TNM Results. No receptors are anticipated to be acquired by the project.

Most of the impacts (244 of the 245 receptors) in 2040 are substantial noise increases (noise levels greater than 10 dBA or more from the existing noise level), and not the NAC threshold alone. It should be noted that among the 244 receptors that are expected to experience a substantial noise increase, 43 of those receptors have both a substantial noise increase and exceed their associated NAC. The decibel change ranges from -2 dBA to +33 dBA over existing noise levels, and the average increase is 14 dBA over existing noise levels.

Table 3. Noise Results Summary

Results	Existing	Proposed Project 2020	Proposed Project 2040
Noise Impacts			
Number of Receptors	442	442	442
Number of Receptors that exceed NAC (≥NAC)	1	0	44
Number of Receptors with Substantial Noise Increase (≥10 dBA)	N/A	184	244
Leq(h) (dBA) Minimum	27	37	40
Leq(h) (dBA) Maximum	70	66	68
NAC Category with Noise Impacts			
NAC A	0	0	0
NAC B	1	184	243
NAC C	0	0	0
NAC D	0	0	0
NAC E	0	0	2
NAC F	0	0	0

3.5 Noise Abatement

Noise abatement is only considered for areas that have impacted noise-sensitive receptors. Receptors are considered impacted if the noise level exceeds the NAC thresholds outlined in **Table 1** or if the receptor experiences a substantial increase in noise (at least a 10 dBA increase over existing noise levels). While there are multiple options that can be used to mitigate noise impacts, the most common noise abatement measure is the addition of noise walls.

The impact threshold is a guidance to consider noise abatement measures, not a requirement to build them. The JPPHA board has not made any decisions yet regarding noise abatement. The JPPHA citizen advisory committee will have many chances to review this information, discuss the impact of the information presented, and consider potential alternatives.

3.5.1 Potential Abatement Strategies

Abatement measures available include traffic system management techniques, alignment modifications, property acquisition, vegetation, and noise walls.

3.5.2 Traffic system management

Traffic system management techniques that limit motor vehicle speeds and reduce traffic volumes can be used to abate traffic noise. Generally, it would take a speed reduction of at least 20 mph to achieve a readily perceptible (5 dBA) reduction of noise. However, Jefferson Parkway will remain a major thoroughfare supporting intrastate commerce, and speed limits will not be reduced.

3.5.3 Alignment modifications

Alignment modification involves orienting and/or sighting the roadway at sufficient distances from the noise-sensitive areas to minimize traffic noise. Alignment modifications were not considered in the design of the Jefferson Parkway corridor; thus, no alignment modifications are present within the future model.

Elevation changes, raising or lowering the grade of the highway by more than five feet, also have the potential to alter the noise effects. However, the developer for Leyden Rock will be asked to put the grade within five feet of the final elevation.

3.5.4 Property acquisition

Property acquisition programs to provide noise buffer zones are not feasible due to the limited availability and prohibitive cost of vacant land in proximity to noise-sensitive sites.

3.5.5 Vegetation

A stand of trees planted closely together with a very dense undergrowth of vegetation can reduce noise if it tall enough and dense enough that it cannot be seen over or through. Noise can be reduced by up to five decibels with at least 30 meters of dense vegetation that maintains its density through all the seasons of the year. However, usually it is not feasible to plant enough trees and other vegetation and maintain them along a highway to achieve such an effect, especially in the arid west. Planting trees and vegetation to block the sight distance to highways has been shown to have a psychological benefit, without lessening the noise levels.

3.5.6 Berms

Earthen berms reduce noise levels by blocking the sound path between a roadway and a noise-sensitive site. However, to prevent erosion, the slopes of berms must be constructed at no greater than a 3:1 scale. This usually means that additional space is required to achieve this slope.

3.5.7 Noise walls

Noise walls reduce noise levels by blocking the sound path between a roadway and a noise-sensitive site. They are built only if they are found to be feasible and reasonable. For a noise wall to be recommended for inclusion or advancement in the project area, it must be both feasible and reasonable to construct. The reasonable and feasible criteria have not yet been approved by JPPHA.

To be considered feasible according to CDOT guidelines, a noise wall must:

- Achieve at least a 5-dBA reduction for at least one impacted receptor by constructing a noise barrier
- Not reduce safety, such as reducing sight distance, or create a fatal flaw drainage, terrain or maintenance issue
- Be possible to construct with reliable and common engineering practices
- Be no more than 20 feet in height

To be considered reasonable according to CDOT guidelines, noise mitigation must:

- Create an insertion loss (the difference in noise levels after mitigation and before mitigation) of 7-dBA or greater for at least one receptor
- Meet financial standards for cost effectiveness. A hypothetical example of a cost effectiveness calculation is a 1,000-foot long, 10-foot high barrier that provides protection for a development of 16 homes. A 5-dBA benefit was experienced by six receptors, and a 7-dBA reduction was experienced by 10 receptors. The results in such a scenario would achieve a cost-benefit index of $4,500 per decibel reduction per benefited receptor, which would be considered economically reasonable.
- Be wanted or chosen by the benefited community. Benefited receptors, defined as any property containing a noise-sensitive receptor that receives at least a 5-dBA reduction, participate in a Benefited Receptor Preference Survey. The required survey is usually deferred until the final design phase of the project. The benefited receptor's desires will not be included in the reasonableness analysis in this noise technical assessment. The survey is required prior to construction of the proposed project. Ultimately to meet all reasonability criteria, the benefited receptor survey must be performed, and more than 50 percent of the responding owners and residents must support the construction of the noise wall.

If any of the reasonability requirements are not met, further analysis of the wall is not necessary. For example, if a wall does not benefit any receptors by at least 7 dBA, then the cost-benefit index would not be calculated due to the wall failing to meet reasonability criteria.

If a noise wall fails to meet all the feasibility and reasonability criteria, the wall cannot be recommended. If a single criterion for feasibility or reasonability is not met, further analysis for that particular noise mitigation is not necessary. If a wall does meet all the feasibility and reasonability requirements, it would be recommended pending completion of a benefited receptor survey with more than 50 percent approval by owners and residents.

3.6 Construction Noise

Construction noise will present the potential for short-term impacts to those receptors located along the corridor and along designated construction access routes. Vibrations can occur from general construction equipment use near noise-sensitive receptors, particularly pile driving for substructure elements from compaction equipment. The primary source of construction noise is expected to be diesel-powered equipment, such as trucks and earth-moving equipment, and construction activities such as demolition hammers on trackhoes, rubble load outs, and tailgate and bucket bang. Pile driving is expected to be the loudest construction operations. Piles would be required at most major bridge installations.

This project will abide by the appropriate city codes as they pertain to construction noise. If noise levels during construction are expected to exceed the limits from the city codes, the contractor must obtain the necessary ordinance variance.

3.6.1 Construction Mitigation

Construction noise impacts to all noise-sensitive receptors will be presented to the public as part of the public involvement program that will occur if the project moves forward with construction. Public suggestions regarding construction noise will be considered and implemented where appropriate. Prior to construction, all germane ordinance variations and permissions must be acquired. By contract agreement, each construction contractor could be required to submit a work plan outlining work schedules and intended mitigation measures prior to initiating construction. Typical construction noise mitigation measures can be found in the FHWA's *Highway Construction Noise Handbook* (2006). Heavy vibration construction activities that occur within approximately 50 feet of existing structures would require care to prevent structural damage. Details of these provisions would be determined during final design and before construction begins.

The following best management practices (BMPs) may be required of the contractor, where determined to be feasible and reasonable:

- Construct permanent sound barriers prior to roadway construction, where possible from a construction staging standpoint
- Use noise blankets on equipment and quiet-use generators
- Minimize construction duration in residential areas as much as possible
- Minimize night-time activities in residential areas as much as possible
- Reroute truck traffic away from residential streets where possible
- Combine noisy operations to occur in the same time period
- Use alternative construction methods in sensitive areas, such as sonic or vibratory pile driving
- Conduct pile driving and other high-noise activities during day-time construction, where possible
- Avoid areas of work near noise-sensitive receptor locations, or minimize work in these areas where people or the environment are noise sensitive
- Eliminate slamming of truck beds, truck tailgates, and equipment buckets
- Idle equipment motors when the equipment is not in immediate use
- Minimize back-up distances for trucks and other equipment
- Schedule trucks appropriately to minimize long queuing lines
- Install noise shielding when in close proximity to residences

Contractors also should consider maintaining contact with the public through a 24-hour telephone contact line for questions and concerns and by providing schedules of planned construction activities.

For more information on construction noise issues, see FHWA's *Highway Construction Noise Handbook* (2006).

3.7 Statement of Likelihood

The final decision on the implementation of noise abatement measures constructed along Jefferson Parkway will be made by JPPHA during final design should the project proceed, and then after a survey of and consensus from benefited receptors. If during final design, conditions substantially change that impact the implementation of possible noise abatement measures, the JPPHA will solicit the viewpoints of those affected as part of the reevaluation of reasonableness.

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