Richmond Highway Bus Rapid Transit Project

NOISE AND VIBRATION ANALYSIS TECHNICAL REPORT

for

Fairfax County Department of Transportation

NOVEMBER 2021

EXECUTIVE SUMMARY

The Fairfax County Department of Transportation (FCDOT), in coordination with the Federal Transit Administration (FTA) as the lead federal agency, is proposing to implement bus rapid transit (BRT) service extending along VA 241/ North Kings Highway and Richmond Highway/US Route 1 from the Washington Metropolitan Area Transit Authority (WMATA) Metrorail station at Huntington in the north to US Army Garrison Fort Belvoir in the south (**Figure 1-1**). The project includes the construction of new BRT-dedicated median lanes; nine BRT stations; roadway widening; and streetscape improvements. The project would operate in both dedicated and mixed traffic lanes within the project limits.

This report details the studies undertaken and conclusions drawn from the noise and vibration analyses for the Richmond Highway BRT Project in Fairfax County, Virginia. While this project is intended primarily to provide improved transit services, the dominant noise source in the project corridor during both daytime and nighttime hours is highway traffic noise, making transit noise minimal by comparison. Therefore, per Section 4.1 of the FTA's *Transit Noise and Vibration Assessment* guidance manual, FHWA noise abatement criteria was used to assess potential noise impacts. Since the project involves the addition of rubber-tired transit vehicles, a vibration analysis was conducted using the FTA Vibration Screening Procedure.

The noise analysis portion of this study was conducted in accordance with the Federal Highway Administration (FHWA) and Virginia Department of Transportation (VDOT) noise assessment regulations and guidelines. The FHWA regulations for assessment and mitigation of highway traffic noise in the planning and design of federally-aided highway projects are contained in Title 23 of the United States Code of Federal Regulations §772 (23 CFR 772). These regulations state that a "Type I" traffic noise analysis is required if through travel lanes or interchange ramps are added. The operational vibration effects were evaluated using the guidelines set forth by the FTA's *Transit Noise and Vibration Assessment* guidance manual, FTA Report No. 0123, dated September 2018. All such analyses are in support of the CE.

This preliminary noise evaluation was performed for the NEPA stage of the project identifying potential noise walls; however, a more detailed analysis will be completed during final design. As such, potential noise barriers that were found to be feasible and reasonable during the preliminary noise analysis may not be found to be feasible and reasonable during the final design noise evaluation. Conversely, noise barriers that were not considered feasible and reasonable during the preliminary stage may meet the established criteria and be recommended for construction in final design.

The noise study details the noise impact and mitigation assessment for the existing conditions (2017) and the design year (2040) of the proposed action. The traffic data used in the noise analysis is based on VDOT's environmental traffic data (ENTRADA) analysis program. The worst noise hour was derived through an analysis of 15 AM and PM hours, which were then narrowed to the 6 AM and 7 AM hours by further analysis. Traffic volumes and speeds for those hours were modeled in FHWA's Traffic Noise Model (TNM), and the 7 AM hour was confirmed to produce the loudest noise levels for the overall Study Area.

Numerous noise-sensitive land uses exist on both northbound (NB) and southbound (SB) sides of the Richmond Highway BRT Study Area. See **Table ES-1** for a summary of predicted worst-hour noise level ranges.

Table ES-1: Predicted Worst-Hour Noise Levels for Modeled Receptors

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
01	Candlewood Suites and Hampton Inn hotels	50 - 62	51 - 63
02	Best Western hotel and Belvoir Plaza Apartments	37 - 57	42 - 58
03	Residences on Talbott Farm Drive	44 - 60	49 - 66
04	Residences on Lukens Lane	49 - 49	51 - 51
05	Residences at Terrace Towne Homes on Walutes Circle	42 - 70	44 - 55
06	Residences on Wyngate Manor Court, Washington Square Apartments	38 - 63	40 - 67
07	Residences at Ray's Mobile Colony	49 - 63	52 - 64
08	Residences on Halfe Street and Radford Avenue	47 - 57	49 - 58
09	Mount Zephyr community of residences on Sonia Court	37 - 58	39 - 63
10	Residences and daycare center on Mohawk Lane and Washington Avenue	50 - 67	53 - 63
11	Residences on Reddick Avenue	53 - 56	55 - 57
12	Residences on Central Avenue and Mary Evelyn Way	31 - 57	33 - 60
13	Residences in Parkside at Mount Vernon community, Vernon Heights Park	38 - 64	40 - 66
14	Spring Hills Mount Vernon assisted living facility	40 - 44	42 - 43
15	Residences on Shannons Green Way and Lamberts Lane	47 - 49	49 - 52
16	Residences on Mount Vernon Highway (SB)	50 - 56	53 - 56
17	Residences on Mount Vernon Highway (NB)	54 - 61	52 - 56
18	Residences on Napper Road and Brown Court, Little Hunting Creek Park	52 - 63	49 - 58
19	Residences at Spring Garden Apartments	50 - 68	50 - 69
20a	Residences on Kingland Road, Westford View Court, and Fordson Court	47 - 53	48 - 54
20b	Residences at Gum Springs Glen Apartments	52 - 61	54 - 61
21	Residences on Gum Springs Village Drive, Colonial Springs Blvd, Kings Village Road, Colonial Springs Court, Heritage Springs Court, and Fordson Road. Also St. John	33 - 69	34 - 68

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
	Baptist Church and Woodlawn Church		
22	Residences on Fordson Road	54 - 64	54 - 63
23	Residences on Boswell Avenue, Woodlawn Trail, and Vernon Square Drive	51 - 57	52 - 57
24	Residences on Camelia Drive and Poinsettia Drive	52 - 59	53 - 60
25	Residences and pool at Cherry Arms Apartments	48 - 68	49 - 70
26	Residence and exterior use at St. Louis Catholic Church	51 - 69	53 - 71
27	Residences on Memorial Heights Drive, Preston Avenue, E. Lee Avenue, and Groveton Street	49 - 59	51 - 61
28	Residences on Groveton Street and East Side Drive	49 - 66	51 - 60
29	Residences on East Side Drive and Memorial Street	45 - 53	47 - 55
30a	Residences on Memorial Street and Schooley Drive	48 - 54	49 - 56
30b	Residences on Beacon Hill Road and Beddoo Street	53 - 57	56 - 59
31	Residences on Dawn Drive, Fleming Street, and Hulvey Terrace	44 - 53	45 - 56
32	Residences at Huntington Walk and Huntington Run condominiums	45 - 69	47 - 70
33	Residences on Hillside Lane and Fairview Drive	50 - 58	52 - 61
34	Residences on Brent Street and Quander Road	50 - 70	54 - 61
35	Residences on Jamaica Drive, Belleview Avenue, and Fairhaven Avenue	53 - 67	54 - 68
36	Residences on Jamaica Drive, Bangor Drive, Fairhaven Avenue, and N. Kings Highway	54 - 67	55 - 68
37	Residences on Fairhaven Avenue, Bangor Drive, Massey Court, Byrd Lane, Fort Drive, and N. Kings Highway	53 - 68	55 - 69
38	Residences at The Courts at Huntington Station, Grand Pavillion Way, and Huntington Park Drive	44 - 62	46 - 63
39	Residences on Wagon Drive	47 - 62	49 - 63
40	Residences on Fort Lyon Court, James Drive, Jefferson Drive, Farmington Drive, Montecello Road, and N. Kings Highway	51 - 69	53 - 71
41	Residences on N. Kings Highway, Williamsburg Road, and Fairhaven Avenue	55 - 68	56 - 69
42	Residences on Fairhaven Avenue	55 - 68	56 - 69
43	Exterior use areas at Mt. Eagle Elementary School	63 - 64	64 - 65

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
44	Residences and Calvary Presbyterian Church on School Street	51 - 52	52 - 54
45a	Residences at Kings Gardens Apartments	50 - 59	52 - 61
45b	Residences on Franklin Street	54 - 61	55 - 62
46	Residences on Richmond Highway, Clayborne Avenue, and Collard Street	56 - 70	57 - 65
47	Residences on Richmond Highway, Collard Street, Arundel Avenue, and Spring Drive	54 - 70	56 - 66
48	Residences on Richmond Highway, Spring Drive, and Swain Drive	50 - 70	52 - 57
49	Residences on Fordson Road, Lockheed Blvd; exterior use at Quality Inn	41 - 60	42 - 62
50	Residences on Avery Park Court	57 - 58	59 - 60
51	Residences at Harmony Place Trailer Park on Pace Lane	50 - 68	53 - 63
52	Residences at Stony Brook Apartments on Buckman Road	53 - 53	55 - 56
53	Residences on Rolling Hills Avenue	54 - 67	55 - 62
54	Residences, pool at the Rolling Hills Apartments, and town home community on Roxbury Lane	41 - 63	42 - 65
55	Residences on Martha Street	47 - 67	48 - 70
56	Residences at Mount Vernon Apartments on Russell Road	45 - 52	49 - 54
57	Residences on Gregory Drive and Main Street	49 - 53	50 - 54
58	Buckman Road KinderCare facility	56	57
59	Residences at multi-story apartment building at Pole Road and Buckman Road	51	52
60	Residences at Pembrook Village condominiums on Pembrook Drive	54	54
61	Residences at Pinewood South condominiums on Buckman Road	46 - 62	47 - 63
62	Residences on Woodlawn Garden Apartments on Blankenship Street and Graves Street	42 - 64	43 - 66
63	Residences at Skyview Park town home community on Sky View Drive, Hallie Rose Street and Hallie Rose Place	39 - 52	43 - 54
64	Residences at Skyview Apartments, town homes on Towne Manor Court	41 - 62	45 - 67

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
65	Residences on Highland Lane and Engleside Street, including a first-row commercial undeveloped parcel	49 - 66	50 - 68
66	Pole Road Park	56	58
67	Roy Rogers restaurant outside dining area	66	66
68	Pillar Church of Dumfries exterior use	62 - 67	63 - 67
69	Residences on Backlick Road	53 - 57	53 - 57

Noise barrier analyses are warranted for all common noise environments (CNE) with noise impacts. All studied noise barriers are assumed to be physically feasible and were evaluated at various lengths and panel heights to determine if they met acoustic feasibility, design goal, and reasonableness criteria. Six potential noise barriers were shown to be feasible and reasonable for the proposed action.

Table ES-2 summarizes each barrier's feasibility, acoustical design details, benefited receptors, length, height, surface area, surface area per benefited receptor, and cost-reasonableness, where applicable.

Noise barriers that are shown to be feasible and reasonable in the preliminary design may not be feasible and reasonable in final design. All noise barriers would be further evaluated in final design to determine any engineering constraints or environmental factors associated with constructing the noise barrier.

Vibration anticipated from the project was analyzed using FTA's vibration Screening Procedure. The BRT would utilize rubber-tire bus vehicles. The surface of the bus lanes and stations constructed for this project would be asphalt; therefore, irregular surfaces would not be present. As a result, the vibration analysis concluded that no vibration impact is likely, and therefore no further analysis is required. The project is predicted to result in "no impact" associated with ground-borne vibration.

Roadway construction noise impacts are anticipated to be temporary in nature and would cease upon completion of the project construction phase. Construction noise would be limited by adhering to a VDOT specification requiring that construction not exceed established noise limits.

Table ES-2: Summary of Barrier Characteristics

Potential Barrier ID	CNE ID	Total Impacts	Barrier Length (Feet)	Barrier Height (Feet)	Surface Area (SF)	Impacted and Benefited	Feasible?	Meets Design Goals?	Average IL of Benefited Receptors (dBA)	Total Benefits	Cost @ $42 per SF	Barrier Square Feet per Benefited Receptor	Reason-able? (SF per Benefit <1,600)
03-P	03	1	126	15	1,890	1	Yes	Yes	6	2	$79,380	945	Yes
06-P	06	4	475	30	14,250	1	No						
13-P	13	15	350	15	5,250	11	Yes	Yes	9	44	$220,500	119	Yes
19-P	19	16	332	25	8,300	14	Yes	Yes	6	18	$348,600	461	Yes
21-P	21	10	920	15	13,800	10	Yes	Yes	9	69	$579,600	200	Yes
25-P	25	19	400	30	12,000	7	No						
26-P	26	2	802	30	24,060	2	Yes	Yes	10	5	$1,010,520	4,812	No
47-P	47	1	302	30	9,060	0	No						
62-P	62	8	755	20	15,100	8	Yes	Yes	8	42	$634,200	360	Yes
64-P	64	1	235	15	3,525	1	Yes	Yes	10	13	$148,050	271	Yes
68-P	68	1	429	15	6,435	1	Yes	Yes	10	3	$270,270	2,145	No

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1. INTRODUCTION

The Fairfax County Department of Transportation (FCDOT), in coordination with the Federal Transit Administration (FTA) as the lead federal agency, is proposing to implement bus rapid transit (BRT) service extending along VA 241/North Kings Highway and Richmond Highway/US Route 1 from the Washington Metropolitan Area Transit Authority (WMATA) Metrorail station at Huntington in the north to US Army Garrison Fort Belvoir in the south (**Figure 1-1**). The project includes the construction of new BRT-dedicated median lanes; nine BRT stations; roadway widening; and streetscape improvements. The project would operate in both dedicated and mixed traffic lanes within the project limits.

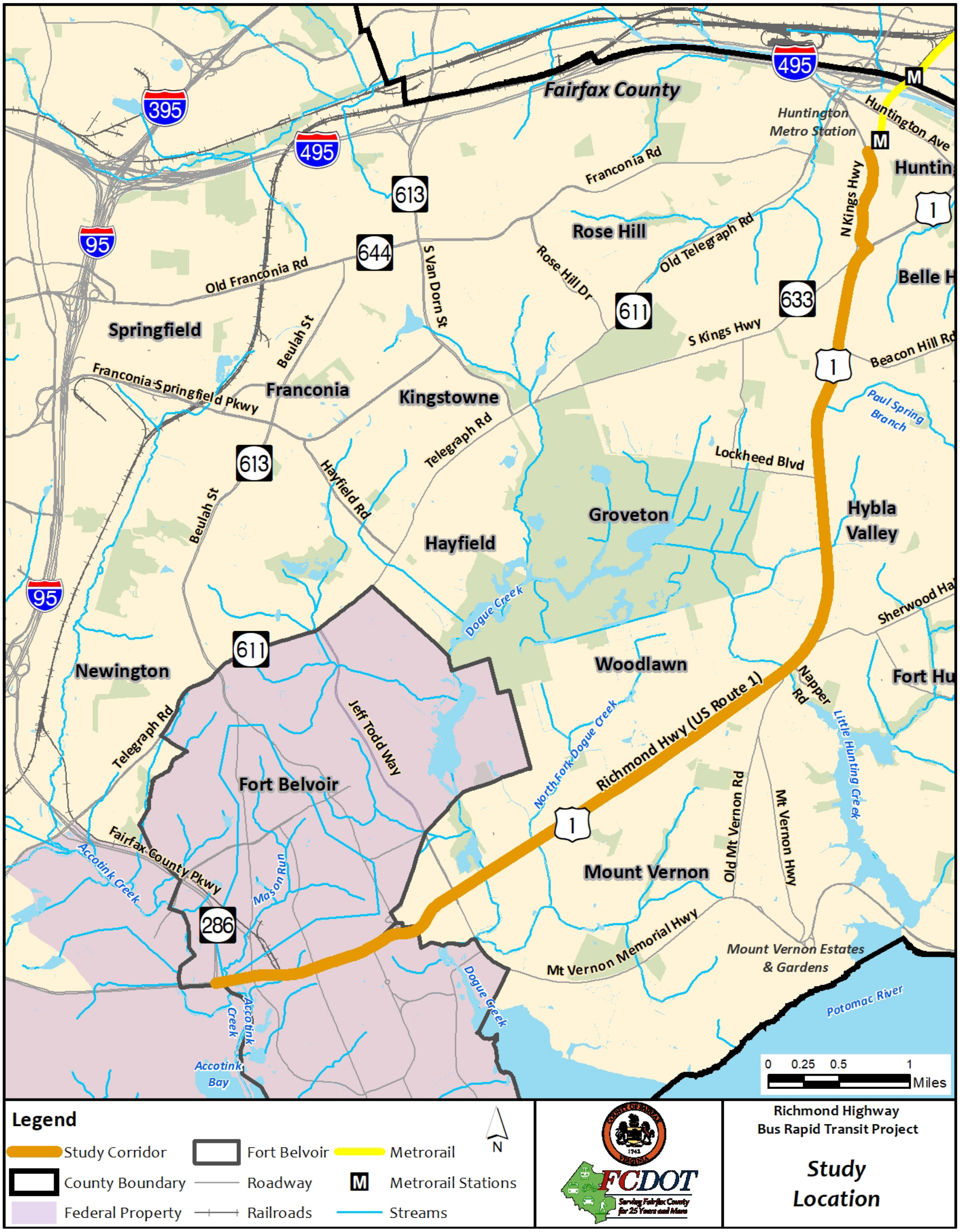
The purpose of this technical report is to detail the studies undertaken and conclusions drawn from noise and vibration impact analyses completed for the Richmond Highway BRT. Information in this report, described below, will support discussions presented in the Richmond Highway BRT Project CE.

- Section 1 provides an overview of the study, purpose and need, project Study Area, and noise-sensitive land uses.
- Section 2 details the noise analysis methodology, including regulations and guidelines, noise abatement criteria, and analysis procedures.
- Section 3 identifies the existing noise environment, and details the noise monitoring effort, model validation, common noise environments, and worst noise hour.
- Section 4 assesses the future noise environment, including predicted noise impacts, and potential mitigation.
- Section 5 discusses the potential for construction noise impacts and specifications for contractor activities.
- Section 6 provides an overview of the public involvement process, which includes noise compatible planning and voting procedures for potential noise barrier mitigation.
- Section 7 details the vibration analysis performed in accordance with FTA methodology.

1.1 Project Description

The proposed BRT system would operate in both dedicated and mixed-traffic lanes within the project limits. The BRT-dedicated lanes would range in width from 32 feet to 58 feet. Beginning at the Huntington Metro Station at the northern end of the corridor, the project would operate in mixed-traffic operations along North Kings Highway to Shields Avenue and Richmond Highway/US Route 1. From Shields Avenue south to Sherwood Hall Lane, Richmond Highway would be widened and reconstructed to accommodate the BRT-dedicated lanes within the road median. From Sherwood Hall Lane south to the intersection with Jeff Todd Way/Mount Vernon Memorial Highway, the BRT-dedicated lanes would be built within a future reserved median to be constructed as part of a separate Virginia Department of Transportation (VDOT) multi-modal project. South from Jeff Todd Way/Mount Vernon Memorial Highway to Belvoir Road at Fort Belvoir, new BRT-dedicated lanes would be constructed within the existing road median.

Figure 1-1: Study Location



1.2 Purpose and Need

The purpose of the Richmond Highway BRT Project is to provide higher quality transit service on US Route 1 / Richmond Highway from the Huntington Metrorail Station to US Army Garrison Fort Belvoir. The project will provide improved transit reliability, speed, choice, user experience, and community connectivity. The transportation needs for the project include:

- Improved transit service. Transit ridership on Richmond Highway is high compared to other corridors within Fairfax County, but existing transit service is slow due to traffic congestion and closely-spaced stops. These operating conditions make scheduled trip times unreliable, reducing its utility for all riders and making it a less attractive option for choice riders. Adding high-quality transit would provide additional transit choices and an improved level of service for the traveling public in the corridor.

- Increased transit capacity. Transit on Richmond Highway currently operates in mixed traffic. Due to the lack of dedicated right-of-way, bus service is unreliable, particularly during peak travel periods.

- Better connections to transit for pedestrians and bicycle riders. Richmond Highway is the principal transportation facility in the corridor and offers the only direct transit connections for regional trips, but existing bicycle and pedestrian facilities along the roadway are not continuous and are largely unbuffered from heavy highway traffic. Improved bicycle and pedestrian facilities would provide safer connections to transit facilities for local users.

1.3 Study Area – Noise-Sensitive Land Uses

Numerous noise-sensitive land uses exist within the project Study Area, consisting mainly of single-family, duplex, townhomes, and multi-family residential properties with exterior use. Recreational areas at churches and a school are also present, as well as the swimming pools at a motel and an apartment complex. Land use descriptions for each common noise environment (CNE) are shown in **Table 3-3**, located in **Section 3.3** of this report.

2. METHODOLOGY

While this project is intended primarily to provide improved transit services, the dominant noise source in the project corridor during both daytime and nighttime hours is highway traffic, making transit noise minimal by comparison. Therefore, per Section 4.1 of the FTA's *Transit Noise and Vibration Assessment* guidance manual, FHWA noise abatement criteria was used to assess potential noise impacts for this project. Additionally, since the project involves the addition of rubber-tire transit vehicles, a vibration analysis was conducted using the FTA vibration Screening Procedure.

2.1 FHWA and VDOT Noise Regulations and Guidelines

The noise analysis of the Richmond Highway BRT was conducted in accordance with FHWA and VDOT noise assessment regulations and guidelines. The *State Noise Abatement Policy* was developed to implement the requirements of 23 Code of Federal Regulations (CFR)§772, *Procedures for Abatement of*

Highway Traffic Noise and Construction Noise (July 13, 2011); FHWA's *Highway Traffic Noise Analysis and Abatement Policy and Guidance* (FHWA, 2011); and NEPA's noise-related requirements. The current VDOT *State Noise Abatement Policy* became effective on July 13, 2011 and was last updated on February 20, 2018.

2.1.1 Noise Abatement Criteria and Sound Level Metrics

To assess the degree of impact of highway traffic noise on human activity, the FHWA established Noise Abatement Criteria (NAC) for different categories of land use (see **Table 2-1**). The NAC are given in terms of the hourly, A-weighted, equivalent sound level in decibels (dB(A)). The A-weighted sound level is a single number measure of sound intensity with weighted frequency characteristics that corresponds to a human's subjective response to noise. Most environmental noise (and the A-weighted sound level) fluctuates from moment to moment, and it is common practice to characterize the fluctuating level by a single number called the equivalent sound level (L_{eq}). The L_{eq} is the value or level of a steady, non-fluctuating sound that represents the same sound energy as the actual time-varying sound evaluated over the same time period. For traffic noise assessment, L_{eq} is typically evaluated over a one-hour period and may be denoted as $L_{eq}(h)$.

2.1.2 Definition of Noise Impact

Traffic noise impacts occur if either of the following conditions is met:

- The predicted traffic noise levels (future design year) approach or exceed the NAC, as shown in **Table 2-1**. The VDOT *State Noise Abatement Policy* defines an "approach level" to be used when determining a traffic noise impact. The "approach level" has been defined by VDOT as one dB(A) less than the NAC. For example, for a category B receptor, which has a NAC of 67 dB(A), a noise level of 66 dB(A) would be considered an impact. If design year noise levels "approach or exceed" the NAC, then the activity is impacted, and a series of abatement measures must be considered.

- The predicted traffic noise levels are substantially higher than the existing noise levels. VDOT has defined a substantial noise increase to occur when the predicted (future design year) highway traffic noise levels are 10 dB(A) or more compared to the existing noise levels for all noise-sensitive exterior activity categories. For example, if a receptor's existing noise level is 50 dB(A), and the future noise level is predicted to be 60 dB(A), then it would be considered an impact. The noise levels of the substantial increase impact do not have to exceed the appropriate NAC. Receptors that satisfy this condition warrant consideration of highway traffic noise abatement.

If traffic noise impact is identified within the project corridor, then consideration of noise abatement measures is necessary. The final decision on whether to provide noise abatement along a project corridor will take into account the feasibility of the design and overall cost weighed against the environmental benefit.

Table 2-1: FHWA Noise Abatement Criteria

Activity Category	$L_{eq}(h)$[1]	Description of Activity Category
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose
B[2]	67 (Exterior)	Residential
C[2]	67 (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, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings
D	52 (Interior)	Auditoriums, daycare 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	72 (Exterior)	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F
F	–	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	–	Undeveloped lands that are not permitted (without building permits)

Source: 23 CFR §772

[1] Hourly Equivalent A-weighted Sound Level (dB(A))

[2] Includes undeveloped lands permitted for this activity category

FHWA and VDOT policies also require evaluations of undeveloped lands if they are considered “permitted,” that is, when there is a definite commitment to develop land with an approved specific design of land use activities as evidenced by the issuance of at least one building permit.

The VDOT approach criteria for a Category D area is 51 dB(A). However, this equates to a different exterior impact criterion depending on the building type and window condition. **Table 2-2** below lists the building noise reduction factors used to estimate interior highway traffic noise impacts for Land Use Activity Category D areas.

Table 2-2: Reduction Factors for Estimating Category D Interior Impacts

<table>
<tr><th>Exterior Evaluation</th><td>Leq(h) [dB(A)]</td><td>86</td><td colspan="2">76</td><td>71</td><td>61</td></tr>
<tr><th rowspan="4">Interior Evaluation</th><td>Building Type</td><td colspan="2">Masonry</td><td colspan="2">Light Frame</td><td>All</td></tr>
<tr><td>Window Condition</td><td>Double Glazed</td><td>Single Glazed</td><td>Storm Window</td><td>Ordinary Sash (closed)</td><td>Open</td></tr>
<tr><td>Noise Reduction Due to Structure Exterior (dB)</td><td>35</td><td colspan="2">25</td><td>20</td><td>10</td></tr>
<tr><td>Leq(h) [dB(A)]</td><td>(51)</td><td colspan="2">(51)</td><td>(51)</td><td>(51)</td></tr>
<tr><td colspan="7">• Adapted from Table 6 of report FHWA-HEP-10-025, <u>Highway Traffic Noise: Analysis and Abatement Guidance</u>. FHWA. 2011
• The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.</td></tr>
</table>

2.1.3 Analysis Procedure

When predicted design year noise levels approach or exceed the NAC during the worst noise hour of the day or cause a substantial increase in existing noise, consideration of traffic noise reduction measures is necessary. If it is found that such mitigation measures would cause adverse social, economic, or environmental effects that outweigh the benefits received, they may be dismissed from consideration. For this study, noise levels throughout the Study Area were determined for existing (2017) conditions and for the design year (2040).

All noise-sensitive land uses potentially affected by the project are near roads for which traffic data was developed as part of the environmental study. Therefore, all noise levels were computed from the appropriate worst-hour traffic data. The computation methods and computed noise levels are described below.

2.1.4 Traffic Noise Model

All traffic noise computations for this study were conducted using the latest version of the FHWA Traffic Noise Model (FHWA TNM 2.5). The FHWA TNM incorporates state-of-the-art sound emissions and sound propagation algorithms, based on well-established theory or on accepted international standards. The acoustical algorithms contained within the FHWA TNM have been validated with respect to carefully conducted noise measurement programs and show excellent agreement in most cases for sites with and without noise barriers.

2.1.5 Noise Model Inputs

Available project engineering plans, including 2018 survey data based on VDOT NAD 83 and NAVD 88, and topographic contours / building information provided by Fairfax County's Geographic Information System were used to create a three-dimensional model in TNM of the geometry of the existing and future design roadway configurations and the surrounding terrain and buildings. The noise modeling also accounted for such factors as propagation over different types of ground (acoustically soft and hard ground), elevated roadway sections, significant shielding effects from local terrain and structures, distance from the road, traffic speed, and hourly traffic volumes including percentage of medium and heavy trucks. To fully characterize existing and future noise levels at all noise-sensitive land uses in the Study Area, many noise prediction receivers (also called “receptors” and “sites”) were added to the measurement sites in the TNM model. TNM run files have been submitted with this report, with TNM printed data available upon request.

2.2 FTA Vibration Screening Procedure

This project involves the addition of rubber-tire transit vehicles; therefore, FTA methodology applies for the assessment of impacts. Vibration impact due to such vehicles is typically unlikely; as a result, the project improvements are first screened to determine whether they present certain conditions that could possibly generate impacts.

The Screening Procedure is based on a flow chart and standard table of impact distances that is used to determine if ground-borne vibration from the project could affect sensitive land uses. More detailed analysis is required if any sensitive land uses are within the screening distances. The Screening Procedure does not require specific knowledge about the vibration characteristics of the system or the geology of the area. If different propagation conditions are known to be present, then an adjustment is applied.

3. EXISTING NOISE ENVIRONMENT

3.1 Noise Monitoring

3.1.1 Noise Monitoring Methodology

A noise monitoring program was conducted along the Richmond Highway BRT corridor, consistent with FHWA and VDOT recommended procedures to document existing ambient noise levels in noise-sensitive locations in the study corridor, and to provide a means for validation of the noise prediction model. Thirty-three short-term noise measurements of 30-minute duration were conducted in the Study Area. Long-term monitoring of 24-hour duration was not necessary with this project given the availability of comprehensive data for AM and PM loudest-hour traffic for Existing and Build conditions.

3.1.2 Noise Monitoring Schedule

Short-term noise measurements of 30-minute duration were conducted on August 28, 29, and 30, 2018. Short-term measurements characterize existing noise levels in the Study Area but were not necessarily conducted during the worst noise hour of the day. They may include contributions from sources other than traffic, such as aircraft, cicadas, or sirens. The data was collected in one-minute Leq intervals so that extraneous data could later be separated or excluded. The total measurement period Leq could then be determined both with and without the data that included these events. By comparing the two totals, the significance of non-traffic events to the overall noise level can be determined for the measurement period. Traffic video was also recorded during each measurement session in order to provide traffic data for the model validation effort.

3.1.3 Noise Monitoring Instrumentation

Noise monitoring was conducted using RK&K-owned Rion NL-42 (ANSI Type 2) integrating sound level meters. All RK&K's noise measurement instruments are calibrated regularly at a certification laboratory, with calibrations traceable to the National Institute of Standards and Technology. During the monitoring program, the sound level meters were calibrated in the field using a handheld acoustic calibrator at the beginning and end of each measurement period. During the measurement program, the weather was generally sunny, with temperatures in the low to mid-90s (Fahrenheit), with light, variable winds.

3.1.4 Noise Monitoring Locations

Measurement locations are shown in **Appendix I**, Figure 1, with short-term site numbers denoted by the prefix "M." Measurement locations and noise levels are shown in **Table 3-1**.

3.1.5 Noise Monitoring Documentation

Appendix E provides details of the data acquired during the noise measurement program, including noise monitor output, traffic counts, site sketches, photographs, and noise monitor specifications.

3.1.6 Noise Monitoring Results

Short-term noise monitoring is not a process to determine design year noise impacts or barrier locations. Short-term noise monitoring provides a level of consistency between what is present in real-world situations and how that is represented in the computer noise model. Short-term monitoring does not need to occur within every CNE to validate the computer noise model.

The measured noise levels appear in **Table 3-1** as equivalent sound levels (Leq). As described above, the Leq is a sound-energy average of the fluctuating sound level (in A-weighted decibels, dBA) measured over a specified period of time. **Table 3-1** also provides the site address, as well as the date, start time, and duration of each measurement. Measured noise levels are presented both in terms of the "Total Leq," which includes noise level contributions from every one-minute period, and the "Traffic-only Leq," which excludes those one-minute periods that contained noise events unrelated to traffic.

Table 3-1: Short-Term Noise Measurement Results

Site	Address	Date	Time Start	Duration (minutes)	Total Leq dB(A)	Traffic Only Leq, dB(A)
M-01	9123 Backlick Road	8/28/2018	11:15	30	58	56
M-02	9001 Woodlawn Road	8/28/2018	11:15	30	60	59
M-03	8743 Richmond Hwy, Belvoir Plaza Apartments	8/28/2018	12:49	30	56	56
M-04	8722 Talbott Farm Dr	8/28/2018	12:49	30	57	56
M-05	8719 Talbott Farm Dr	8/28/2018	12:49	30	64	63
M-06	8662 Walutes Cir	8/28/2018	12:49	30	54	53
M-07	8535 Engleside St	8/28/2018	14:23	30	59	59
M-08	8535 Wyngate Manor Ct	8/28/2018	14:23	30	59	59

Site	Address	Date	Time Start	Duration (minutes)	Total Leq dB(A)	Traffic Only Leq, dB(A)
M-09	8583 Richmond Hwy, Washington Square Apartments	8/28/2018	14:23	30	63	63
M-10	8424 Sky View Dr, Skyview Apartments	8/28/2018	14:23	30	63	63
M-11	8488 Richmond Hwy, Woodlawn Garden Apartments	8/29/2018	9:47	30	63	63
M-12	8467 Diablo Ct	8/29/2018	9:47	30	59	59
M-13	4260 Buckman Rd, Pinewood South Condominiums	8/29/2018	9:47	30	62	62
M-14	4241 Sonia Ct	8/29/2018	9:47	30	57	57
M-15	8354 Hunter Murphy Cir	8/29/2018	11:17	30	57	57
M-16	3707 Rolling Hills Ave, Rolling Hills Apartments (pool)	8/29/2018	11:17	30	57	56
M-17	7837 Richmond Highway, Gum Springs Glen Apartments	8/29/2018	12:32	30	80	62
M-18	Gum Springs Village Drive, open space	8/29/2018	12:32	30	72	64
M-19	Near 9460 Poinsettia Drive	8/29/2018	14:38	30	59	59
M-20	7212 Fordson Road, open space near Quality Inn pool	8/29/2018	14:38	30	59	59
M-21	7133 Richmond Hwy, near Cherry Arms Apartments pool	8/29/2018	14:38	30	67	67
M-22	2903 Popkins Lane, yard near St. Louis Catholic Church	8/29/2018	14:38	30	61	61
M-23	7024 Richmond Highway	8/29/2018	14:38	30	72	72
M-24	3100 Collard Street	8/30/2018	9:46	30	71	70
M-25	2922 Groveton Street	8/30/2018	9:46	30	62	61
M-26	2817 Schooley Drive	8/30/2018	9:46	30	59	59
M-27	2709 Fleming Street	8/30/2018	11:00	30	57	57
M-28	6429 Richmond Highway, Huntington Walk condominiums	8/30/2018	11:00	30	69	63
M-29	2812 Franklin Street, Seventh Day Adventist Church	8/30/2018	11:00	30	65	60
M-30	6105 North Kings Highway	8/30/2018	12:20	30	63	62
M-31	6028 North Kings Highway	8/30/2018	12:20	30	63	62
M-32	5949 North Kings Highway	8/30/2018	12:20	30	65	65
M-33	5950 Grand Pavilion Way, The Courts at Huntington Station	8/30/2018	12:20	30	62	61

For monitoring sites where data was excluded due to momentary non-traffic events, the difference between "Total" and "Traffic Only" levels is small. However, at site M-17, a few minutes of leaf-blowing activity and emergency vehicle sirens elevated the Total Leq to 80 dB(A), leaving a Traffic Only level of 62 dB(A). Similarly, with site M-18, the Total Leq was 72 dB(A) due to a few minutes of sirens, resulting in a Traffic Only level of 64 dB(A).

3.1.7 Noise Model Validation

A validation of the noise modeling assumptions was conducted using the traffic counted on nearby roadways simultaneous with the noise measurement at each site as input to the noise prediction model. These observed traffic counts are provided in the **Appendix E** field logs. Computed noise levels based on the counted traffic were compared to the measured noise levels to confirm the assumptions about aspects of the TNM model, such as the acoustical shielding provided by intervening terrain and existing noise barriers. The modeling assumptions were refined, as necessary, to obtain appropriate agreement between the computed and measured values. The validated modeling assumptions at the measurement sites and for the existing geometry were then extended to the design year alternative and applied at prediction locations where no measurements were made.

Predicted noise levels are within the three dB(A) requirement at all but three sites: M-22, M26, and M-27. In each case, non-traffic noise was present throughout the measurements, making it difficult to exclude. In the case of M-22, cicada and air conditioning noise became persistent throughout. Cicada noise was particularly evident during the measurements at site M-27, which was also compounded by the relatively great distance to the mainline roadway. At M-26, car wash operations across the street on Schooley Drive, which include the use of a large drying fan, provided persistent extraneous noise that elevated measured noise levels. These areas would be evaluated further if the impact and mitigation analyses were possibly affected by the lack of model validation. Excluding the aforementioned sites, the overall average difference between measured and computed levels is +0.4 dB(A). The comparison of measured versus computed sound levels at each the measurement sites is shown in **Table 3-2**.

Table 3-2: Computed vs. Measured Sound Levels at Measurement Sites

Site No.	Address	Land Use	Measured Leq Traffic-Only dB(A)	Computed Leq dB(A)	Difference
M-01	9123 Backlick Road	Residential	56.4	54.2	-2.2
M-02	9001 Woodlawn Road	Church	59.4	62.2	2.8
M-03	8743 Richmond Hwy, Belvoir Plaza Apartments	Residential	55.8	58.2	2.4
M-04	8722 Talbott Farm Dr	Residential	56.3	55	-1.3
M-05	8719 Talbott Farm Dr	Residential	63.2	64.7	1.5
M-06	8662 Walutes Cir	Residential	53.4	56	2.6
M-07	8535 Engleside St	Residential	59.4	61.3	1.9
M-08	8535 Wyngate Manor Ct	Residential	59.3	61.9	2.6
M-09	8583 Richmond Hwy, Washington Square Apartments	Residential	63.1	65.4	2.3

Site No.	Address	Land Use	Measured Leq Traffic-Only dB(A)	Computed Leq dB(A)	Difference
M-10	8424 Sky View Dr, Skyview Apartments	Residential	63.3	64.6	1.3
M-11	8488 Richmond Hwy, Woodlawn Garden Apartments	Residential	62.7	61.6	-1.1
M-12	8467 Diablo Ct	Residential	59.2	56.3	-2.9
M-13	4260 Buckman Rd, Pinewood South Condominiums	Residential	62.3	62.8	0.5
M-14	4241 Sonia Ct	Residential	57.1	57.4	0.3
M-15	8354 Hunter Murphy Cir	Residential	57.4	55.1	-2.3
M-16	3707 Rolling Hills Ave, Rolling Hills Apartments (pool)	Residential	56.2	56.9	0.7
M-17	7837 Richmond Highway, Gum Springs Glen Apartments	Residential	61.8	61.2	-0.6
M-18	Gum Springs Village Drive, open space	Residential	63.9	65.5	1.6
M-19	Near 9460 Poinsettia Drive	Residential	58.7	58	-0.7
M-20	7212 Fordson Road, open space near Quality Inn pool	Hotel	58.9	60.7	1.8
M-21	7133 Richmond Hwy, near Cherry Arms Apartments pool	Residential	67.1	66.9	-0.2
M-22	2903 Popkins Lane, yard near St. Louis Catholic Church	Residential	61	51.3	-9.7
M-23	7024 Richmond Highway	Residential	71.7	70.3	-1.4
M-24	3100 Collard Street	Residential	70.2	68.1	-2.1
M-25	2922 Groveton Street	Residential	61.3	62.3	1
M-26	2817 Schooley Drive	Residential	59.3	54	-5.3
M-27	2709 Fleming Street	Residential	57.4	45.3	-12.1
M-28	6429 Richmond Highway, Huntington Walk condominiums	Residential	63.1	62.8	-0.3
M-29	2812 Franklin Street, Seventh Day Adventist Church	Church	60.2	60	-0.2
M-30	6105 North Kings Highway	Residential	62.4	64.9	2.5
M-31	6028 North Kings Highway	Residential	62.3	64.4	2.1
M-32	5949 North Kings Highway	Residential	65	65.8	0.8
M-33	5950 Grand Pavilion Way, The Courts at Huntington Station	Residential	60.7	61.7	1
Overall Average / Standard Deviation*					+0.4 / 1.7

** not including sites M-22, M-26, and M27*

3.2 Undeveloped Lands and Permitted Developments

Highway traffic noise analyses are performed for developed lands as well as undeveloped lands if they are considered “permitted.” Undeveloped lands are deemed to be permitted when there is a definite commitment to develop land with an approved specific design of land use activities as evidenced by the issuance of at least one building permit.

In accordance with FHWA and VDOT traffic noise policies, an undeveloped lot is considered to be planned, designed, and programmed if a building permit has been issued by the local authorities prior to the Date of Public Knowledge for the relevant project. VDOT considers the “Date of Public Knowledge” as the date that the final NEPA approval is made. VDOT has no obligation to provide noise mitigation for any undeveloped land that is permitted or constructed after this date.

Review of issued permits was conducted in an analysis in 2019, using the Fairfax Inspections Database Online and in coordination with the Fairfax County Department of Land Development Services. This review identified no other building permits for potentially noise-sensitive properties. Additional analyses will be undertaken as the design effort progresses. Any updates, including new permitted land uses, will be addressed in a reevaluation at that time.

3.3 Common Noise Environment Determination

Receptors are grouped into CNEs per guidance from FHWA and VDOT. Each of these areas has similar sources of noise and similar land uses within them. **Table 3-3** presents a list of the CNEs in the Study Area with FHWA Activity categories, including short descriptions of the associated land use and the general location for each. CNE boundaries are also illustrated in **Appendix I**, Figure 1.

Table 3-3: Common Noise Environment (CNE) Descriptions

CNE ID	FHWA Activity Category	Description of Land Use and Location
01	E	Candlewood Suites and Hampton Inn hotels exterior use areas on Richmond Highway (NB)
02	B, E	Best Western hotel and Belvoir Plaza Apartments on Richmond Highway (NB)
03	B	Residences on Talbott Farm Drive
04	B	Residences on Lukens Lane
05	B	Residences at Terrace Towne Homes on Walutes Circle
06	B	Residences on Wyngate Manor Court, Washington Square Apartments
07	B	Residences at Ray’s Mobile Colony on Richmond Highway (NB)
08	B	Residences on Halfe Street and Radford Avenue
09	B,C	Mount Zephyr community of residences on Sonia Court; includes solid brick privacy wall and gazebo area that are expected to be impacted by the proposed improvements
10	B,C	Residences and daycare center on Mohawk Lane and Washington Avenue
11	B	Residences on Reddick Avenue

CNE ID	FHWA Activity Category	Description of Land Use and Location
12	B	Residences on Central Avenue and Mary Evelyn Way; includes solid brick privacy wall that is not expected to be impacted by the proposed improvements
13	B,C	Residences in Parkside at Mount Vernon community, Vernon Heights Park area
14	B	Spring Hills Mount Vernon assisted living facility with two exterior use areas
15	B	Residences on Shannons Green Way and Lamberts Lane
16	B	Residences on Mount Vernon Highway (SB)
17	B	Residences on Mount Vernon Highway (NB)
18	B,C	Residences on Napper Road and Brown Court, Little Hunting Creek Park area
19	B	Residences at Spring Garden Apartments on Richmond Highway (NB)
20a	B	Residences on Kingland Road, Westford View Court, and Fordson Court
20b	B	Residences at Gum Springs Glen Apartments on Richmond Highway (NB)
21	B,C	Residences in town home community on Gum Springs Village Drive, Colonial Springs Blvd, Kings Village Road, Colonial Springs Court, Heritage Springs Court, and Fordson Road; includes St. John Baptist Church and Woodlawn Church
22	B	Residences on Fordson Road
23	B	Residences on Boswell Avenue, Woodlawn Trail, and Vernon Square Drive
24	B	Residences on Camelia Drive and Poinsettia Drive
25	B,C	Residences with patios, balconies, and pool at Cherry Arms Apartments on Richmond Highway and Grandview Drive
26	B,C,D	Residence and exterior use at St. Louis Catholic Church
27	B	Residences on Memorial Heights Drive, Preston Avenue, E. Lee Avenue, and Groveton Street
28	B	Residences on Groveton Street and East Side Drive
29	B	Residences on East Side Drive and Memorial Street
30a	B	Residences on Memorial Street and Schooley Drive
30b	B	Residences on Beacon Hill Road and Beddoo Street
31	B	Residences on Dawn Drive, Fleming Street, and Hulvey Terrace
32	B	Residences at Huntington Walk and Huntington Run condominiums in the 6400 block of Richmond Highway
33	B	Residences on Hillside Lane and Fairview Drive
34	B	Residences on Brent Street and Quander Road
35	B	Residences on Jamaica Drive, Belleview Avenue, and Fairhaven Avenue
36	B	Residences on Jamaica Drive, Bangor Drive, Fairhaven Avenue, and N. Kings Highway
37	B	Residences on Fairhaven Avenue, Bangor Drive, Massey Court, Byrd Lane, Fort Drive, and N. Kings Highway

CNE ID	FHWA Activity Category	Description of Land Use and Location
38	B	Residences at The Courts at Huntington Station adjacent to Richmond Highway (NB), also Grand Pavillion Way, and Huntington Park Drive
39	B	Residences on Wagon Drive
40	B	Residences on Fort Lyon Court, James Drive, Jefferson Drive, Farmington Drive, Montecello Road, and N. Kings Highway
41	B	Residences on N. Kings Highway, Williamsburg Road, and Fairhaven Avenue
42	B	Residences on Fairhaven Avenue
43	C,D	Mt. Eagle Elementary School exterior use areas located on Richmond Highway (SB)
44	B,C,D	Residences and Calvary Presbyterian Church on School Street
45a	B	Residences with patios and balconies at Kings Gardens Apartments on S Kings Highway
45b	B,C,D	Residences on Franklin Street, Seventh Day Adventist Church
46	B	Residences on Richmond Highway, Clayborne Avenue, and Collard Street
47	B	Residences on Richmond Highway, Collard Street, Arundel Avenue, and Spring Drive
48	B	Residences on Richmond Highway, Spring Drive, and Swain Drive
49	B,E	Residences on Fordson Road, Lockheed Blvd; exterior use (pool) at Quality Inn
50	B	Residences on Avery Park Court
51	B	Residences at Harmony Place Trailer Park on Pace Lane
52	B	Residences at Stony Brook Apartments on Buckman Road
53	B	Residences on Rolling Hills Avenue
54	B	Residences, pool at the Rolling Hills Apartments, and town home community on Roxbury Lane
55	B	Residences on Martha Street
56	B	Residences at Mount Vernon Apartments on Russell Road with patios and balconies
57	B	Residences on Gregory Drive and Main Street
58	C	Buckman Road KinderCare facility on Buckman Road
59	B	Residences at multi-story apartment building at Pole Road and Buckman Road
60	B	Residences at Pembrook Village condominiums on Pembrook Drive, with balconies
61	B	Residences at Pinewood South condominiums on Buckman Road, with patios and balconies. Also, town homes on Diablo Court
62	B	Residences on Woodlawn Garden Apartments on Blankenship Street and Graves Street, with patios and balconies
63	B	Residences at Skyview Park town home community on Sky View Drive, Hallie Rose Street and Hallie Rose Place

CNE ID	FHWA Activity Category	Description of Land Use and Location
64	B	Residences with patios and balconies at Skyview Apartments on Sky View Drive. Also, town home community on Towne Manor Court
65	B,E	Residences on Highland Lane and Engleside Street, including a first-row commercial undeveloped parcel
66	C	Pole Road Park southern boundary, off Richmond Highway (SB)
67	E	Roy Rogers restaurant outside dining area at the intersection of Jeff Todd Way and Richmond Highway
68	C,D	Pillar Church of Dumfries on Woodlawn Road and Richmond Highway, exterior use area
69	B	Residences on Backlick Road

3.4 Receptor Identification and NAC Categorization

The Study Area includes mostly residential land use and developments, as well as some exterior commercial land use. All noise-sensitive receptors fall under Categories B, C, D, or E. No Category A land uses were identified. Category B land uses consist of a variety of single-family, duplex, multi-story, and townhomes. Category C land uses consist of residential, church, and school recreational areas, as well as park land. Several Category D (interior) land uses were identified. Category E land uses consist of hotel external use, which includes patios and swimming pools, as well as a fast-food exterior dining area.

To fully characterize existing and future noise levels at all noise-sensitive land uses in the Study Area, approximately 1,800 additional noise prediction receptors (also called "receivers" and "sites") were incorporated to the TNM model in addition to the 33 ambient measurement sites. Each of these receptors represents exterior noise-sensitive land use. Site ID names for the newly modeled receptors are prefixed with the letter "R" followed by a site number, i.e., "R-1234."

3.5 Worst Noise Hour

Analysis for the Richmond Highway BRT Project involved monitoring existing (2017) and future design year (2040) noise conditions in the Study Area with the FHWA-approved computerized TNM. The modeling accounted for existing terrain and buildings, and for existing and proposed roadways with projected worst noise-hour traffic. The traffic data used in the noise analysis is based on VDOT's environmental traffic data analysis program (ENTRADA). This analysis utilizes screening calculations from VDOT's Loudest Hour Spreadsheet to calculate the traffic noise levels for significant roadway segments at reference distances to determine candidate worst noise hours for the proposed action. Candidate hours are between 6 AM and 10 PM.

ENTRADA was imported to the latest version of VDOT's Loudest Hour spreadsheet for 11 significant traffic zones within the Study Area. The calculations showed that the 6 AM and 7 AM hours dominated all other potential candidates in both directional and combined direction noise predictions in the Build condition. Further analysis, utilizing TNM with Build traffic for those candidate hours and nearly 500 representative receptors, found that the candidate hours were almost indistinguishable on the Richmond Highway portion of the project, but significantly different on the North Kings Highway segment. The 7 AM hour was determined to be the best representative of the worst noise hour of the day for the entire Study Area. As such, 7 AM traffic data is used for all TNM roadways, for all conditions. For the Build condition, the BRT weekday AM peak headway of six minutes (ten buses per hour) is added to the new BRT-dedicated median lanes.

Appendix C provides tables of worst noise hour existing and future traffic data used in the noise model for all roadways in the Study Area.

3.6 Modeled Existing Environment

The Existing noise environment was assessed for 2017 and the Build noise environment was assessed for design year 2040.

There are no existing noise walls in the Study Area.

A total of 146 receptors, representing 143 residential homes and 3 recreational sites, are predicted to experience noise levels that approach or exceed the NAC under the Existing (2017) condition. The majority of these are front-row properties with direct exposure to the roadway. While shown for the Existing condition, the determination of noise impacts only applies to the Build condition as per Section 2.1.1 of this report. See **Table 3-4** for predicted Worst-Hour Existing noise level ranges, which also includes noise levels for the design year. Build conditions are discussed further in the next section.

Table 3-4: Predicted Worst-Hour Noise Levels for Modeled Receptors

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
01	Candlewood Suites and Hampton Inn hotels	50 - 62	51 - 63
02	Best Western hotel and Belvoir Plaza Apartments	37 - 57	42 - 58
03	Residences on Talbott Farm Drive	44 - 60	49 - 66
04	Residences on Lukens Lane	49 - 49	51 - 51
05	Residences at Terrace Towne Homes on Walutes Circle	42 - 70	44 - 55
06	Residences on Wyngate Manor Court, Washington Square Apartments	38 - 63	40 - 67
07	Residences at Ray's Mobile Colony	49 - 63	52 - 64
08	Residences on Halfe Street and Radford Avenue	47 - 57	49 - 58
09	Mount Zephyr community of residences on Sonia Court	37 - 58	39 - 63
10	Residences and daycare center on Mohawk Lane and Washington Avenue	50 - 67	53 - 63
11	Residences on Reddick Avenue	53 - 56	55 - 57
12	Residences on Central Avenue and Mary Evelyn Way	31 - 57	33 - 60

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
13	Residences in Parkside at Mount Vernon community, Vernon Heights Park	38 - 64	40 - 66
14	Spring Hills Mount Vernon assisted living facility	40 - 44	42 - 43
15	Residences on Shannons Green Way and Lamberts Lane	47 - 49	49 - 52
16	Residences on Mount Vernon Highway (SB)	50 - 56	53 - 56
17	Residences on Mount Vernon Highway (NB)	54 - 61	52 - 56
18	Residences on Napper Road and Brown Court, Little Hunting Creek Park	52 - 63	49 - 58
19	Residences at Spring Garden Apartments	50 - 68	50 - 69
20a	Residences on Kingland Road, Westford View Court, and Fordson Court	47 - 53	48 - 54
20b	Residences at Gum Springs Glen Apartments	52 - 61	54 - 61
21	Residences on Gum Springs Village Drive, Colonial Springs Blvd, Kings Village Road, Colonial Springs Court, Heritage Springs Court, and Fordson Road. Also St. John Baptist Church and Woodlawn Church	33 - 69	34 - 68
22	Residences on Fordson Road	54 - 64	54 - 63
23	Residences on Boswell Avenue, Woodlawn Trail, and Vernon Square Drive	51 - 57	52 - 57
24	Residences on Camelia Drive and Poinsettia Drive	52 - 59	53 - 60
25	Residences and pool at Cherry Arms Apartments	48 - 68	49 - 70
26	Residence and exterior use at St. Louis Catholic Church	51 - 69	53 - 71
27	Residences on Memorial Heights Drive, Preston Avenue, E. Lee Avenue, and Groveton Street	49 - 59	51 - 61
28	Residences on Groveton Street and East Side Drive	49 - 66	51 - 60
29	Residences on East Side Drive and Memorial Street	45 - 53	47 - 55
30a	Residences on Memorial Street and Schooley Drive	48 - 54	49 - 56
30b	Residences on Beacon Hill Road and Beddoo Street	53 - 57	56 - 59
31	Residences on Dawn Drive, Fleming Street, and Hulvey Terrace	44 - 53	45 - 56
32	Residences at Huntington Walk and Huntington Run condominiums	45 - 69	47 - 70
33	Residences on Hillside Lane and Fairview Drive	50 - 58	52 - 61
34	Residences on Brent Street and Quander Road	50 - 70	54 - 61
35	Residences on Jamaica Drive, Belleview Avenue, and Fairhaven Avenue	53 - 67	54 - 68

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
36	Residences on Jamaica Drive, Bangor Drive, Fairhaven Avenue, and N. Kings Highway	54 - 67	55 - 68
37	Residences on Fairhaven Avenue, Bangor Drive, Massey Court, Byrd Lane, Fort Drive, and N. Kings Highway	53 - 68	55 - 69
38	Residences at The Courts at Huntington Station, Grand Pavillion Way, and Huntington Park Drive	44 - 62	46 - 63
39	Residences on Wagon Drive	47 - 62	49 - 63
40	Residences on Fort Lyon Court, James Drive, Jefferson Drive, Farmington Drive, Montecello Road, and N. Kings Highway	51 - 69	53 - 71
41	Residences on N. Kings Highway, Williamsburg Road, and Fairhaven Avenue	55 - 68	56 - 69
42	Residences on Fairhaven Avenue	55 - 68	56 - 69
43	Exterior use areas at Mt. Eagle Elementary School	63 - 64	64 - 65
44	Residences and Calvary Presbyterian Church on School Street	51 - 52	52 - 54
45a	Residences at Kings Gardens Apartments	50 - 59	52 - 61
45b	Residences on Franklin Street	54 - 61	55 - 62
46	Residences on Richmond Highway, Clayborne Avenue, and Collard Street	56 - 70	57 - 65
47	Residences on Richmond Highway, Collard Street, Arundel Avenue, and Spring Drive	54 - 70	56 - 66
48	Residences on Richmond Highway, Spring Drive, and Swain Drive	50 - 70	52 - 57
49	Residences on Fordson Road, Lockheed Blvd; exterior use at Quality Inn	41 - 60	42 - 62
50	Residences on Avery Park Court	57 - 58	59 - 60
51	Residences at Harmony Place Trailer Park on Pace Lane	50 - 68	53 - 63
52	Residences at Stony Brook Apartments on Buckman Road	53 - 53	55 - 56
53	Residences on Rolling Hills Avenue	54 - 67	55 - 62
54	Residences, pool at the Rolling Hills Apartments, and town home community on Roxbury Lane	41 - 63	42 - 65
55	Residences on Martha Street	47 - 67	48 - 70
56	Residences at Mount Vernon Apartments on Russell Road	45 - 52	49 - 54
57	Residences on Gregory Drive and Main Street	49 - 53	50 - 54

CNE ID	Area Description	Range of Predicted Worst-Hour Leq Exterior Noise Levels dB(A)	
		Existing 2017	Build 2040
58	Buckman Road KinderCare facility	56 - 56	57 - 57
59	Residences at multi-story apartment building at Pole Road and Buckman Road	51 - 51	52 - 52
60	Residences at Pembrook Village condominiums on Pembrook Drive	54 - 54	54 - 54
61	Residences at Pinewood South condominiums on Buckman Road	46 - 62	47 - 63
62	Residences on Woodlawn Garden Apartments on Blankenship Street and Graves Street	42 - 64	43 - 66
63	Residences at Skyview Park town home community on Sky View Drive, Hallie Rose Street and Hallie Rose Place	39 - 52	43 - 54
64	Residences at Skyview Apartments, town homes on Towne Manor Court	41 - 62	45 - 67
65	Residences on Highland Lane and Engleside Street, including a first-row commercial undeveloped parcel	49 - 66	50 - 68
66	Pole Road Park	56	58
67	Roy Rogers restaurant outside dining area	66	66
68	Pillar Church of Dumfries exterior use	62 - 67	63 - 67
69	Residences on Backlick Road	53 - 57	53 - 57

4. FUTURE NOISE ENVIRONMENT

4.1 Modeled Future Environment

A total of 168 receptors, representing 165 residential homes and three recreational sites, are predicted to experience noise levels that approach or exceed the NAC under the Design Year (2040) Build condition. Noise impacts are predicted in many, but not at all, CNEs within the 500-foot study limit, depending on the proximity to the mainline roadway. Build noise levels are generally one to three dB(A) greater than Existing levels.

For some CNEs, the upper ranges for the Build condition are listed as lower when compared to the corresponding Existing condition. This is due to either of two reasons:

- For CNEs 05, 10, 28, 34, 46, 47, 48, 51, and 53, some front-row receptors become potential acquisitions in the Build condition due to the proposed widening, and therefore, are not included in the tabulated Build results.
- At CNEs 17 and 18, proposed roadway elevations increased by approximately ten feet above existing to accommodate a new bridge over Little Hunting Creek, which breaks the line-of-sight

between some receptors and southbound travel lanes and results in lower predicted noise levels at some receptors.

Three exterior-use areas at institutional sites were modeled with a receptor grid as described in Appendix E of VDOT's *Highway Traffic Noise Impact Analysis Guidance Manual,* at CNE 26 (St. Louis Catholic Church), CNE 43 (Mt. Eagle Elementary School), and CNE 68 (Pillar Church). The grid at the school consists of just two receptors to represent picnic benches due to the limited space between the school building and sidewalk. The area between the sidewalk and North Kings Highway is landscaped, and not modeled as an active outdoor use area. These sites are also evaluated for Category D analysis.

Two additional institutional sites exist at CNE 44 (Calvary Presbyterian Church) and CNE 45b (Seventh Day Adventist Church) but have no exterior use. All five institutional sites were assessed for Category D land use, and interior noise levels were predicted for each. Since all identified facilities have air conditioning and masonry construction, an outside-to-inside noise reduction value of 25 decibels is applied to exterior noise levels predicted by TNM. Since 51 dB(A) is the impact threshold for Category D use, an exterior noise level of 76 dB(A) would be required to impact the interior of the building. No Category D impacts are predicted for the entire project area. **Appendix D** includes interior and exterior noise level data.

A summary of noise impacts by CNE and land use are shown in **Table 4-1**.

Table 4-1: Noise Impacts by CNE and Land Use

CNE ID	Residential Category B		Recreational Category C		Institutional Category D		Commercial Category E	
	Existing 2017	Build 2040	Existing 2017	Build 2040	Existing 2017	Build 2040	Existing 2017	Build 2040
01	0	0	0	0	0	0	0	0
02	0	0	0	0	0	0	0	0
03	0	**1**	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0
05	**1**	0	0	0	0	0	0	0
06	0	**4**	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0
10	**1**	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	**15**	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	**16**	**16**	0	0	0	0	0	0
20a	0	0	0	0	0	0	0	0
20b	0	0	0	0	0	0	0	0
21	**10**	**10**	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0
25	**13**	**18**	**1**	**1**	0	0	0	0
26	0	0	**1**	**1**	0	0	0	0
27	0	0	0	0	0	0	0	0
28	**2**	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0
30a	0	0	0	0	0	0	0	0
30b	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0
32	**9**	**9**	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
34	**3**	0	0	0	0	0	0	0

CNE ID	Residential Category B		Recreational Category C		Institutional Category D		Commercial Category E	
	Existing 2017	Build 2040	Existing 2017	Build 2040	Existing 2017	Build 2040	Existing 2017	Build 2040
35	**1**	**2**	0	0	0	0	0	0
36	**8**	**8**	0	0	0	0	0	0
37	**16**	**16**	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0
40	**13**	**17**	0	0	0	0	0	0
41	**34**	**34**	0	0	0	0	0	0
42	**4**	**4**	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0
45a	0	0	0	0	0	0	0	0
45b	0	0	0	0	0	0	0	0
46	**2**	0	0	0	0	0	0	0
47	**2**	**1**	0	0	0	0	0	0
48	**3**	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0
51	**1**	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0
53	**3**	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0
55	**1**	**1**	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0
62	0	**8**	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0
64	0	**1**	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0
68	0	0	**1**	**1**	0	0	0	0
69	0	0	0	0	0	0	0	0
Totals	**143**	**165**	**3**	**3**	**0**	**0**	**0**	**0**

4.2 Noise Abatement Determination

4.2.1 Alternative Abatement Measures

VDOT guidelines recommend a variety of mitigation measures that should be considered in response to transportation-related noise impacts. While noise barriers and/or earth berms are generally the most effective form of noise mitigation, additional mitigation measures exist which have the potential to provide considerable noise reductions, under certain circumstances. Mitigation measures considered for this project include:

- Traffic management;
- Alignment modifications;
- Acoustical insulation of public use and non-profit facilities;
- Buffer lands;
- Construction of noise barriers; and
- Construction of earth berms.

Additionally, the Noise Policy Code of Virginia (HB 2577, as amended by HB 2025) states that whenever the Commonwealth Transportation Board or the Department plan for or undertake any highway construction or improvement project, and such project includes or may include the requirement for the mitigation of traffic noise impacts, first consideration should be given to the use of noise-reducing design and low-noise pavement materials and techniques in lieu of construction of noise walls or sound barriers. Vegetative screening, such as the planting of appropriate conifers, in such a design would be utilized to act as a visual screen if visual screening is required. Consideration will be given to these measures during the final design stage, where feasible. The response from project management is included in **Appendix G**.

Traffic Control Measures (TCM): Traffic control measures, such as speed limit restrictions, truck traffic restrictions, and other traffic control measures that may be considered for the reduction of noise emission levels are not practical for this project. These traffic control measures would be counterproductive to the project's objective of alleviating traffic and reducing congestion. Reducing speeds would not be an effective noise mitigation measure since a substantial decrease in speed is necessary to provide adequate noise reduction.

Alteration of Horizontal and Vertical Alignments: The alteration of the horizontal and vertical alignment has been considered to reduce or eliminate the impacts created by the proposed project. Shifting the horizontal alignment is not practical for this project. Even if possible, such shifts often create undesirable impacts such as right-of-way acquisition, temporary/permanent easements, and retaining walls. Shifting the roadway alignment away from the impacted residences often increases impacts to receptors located on the opposite side of the proposed roadway. For this project, the proposed widening mostly shifts traffic closer to land uses on the SB side of the roadway, which is the side of the roadway least populated with residential properties.

Insulation: This noise abatement measure option applies only to public and institutional use buildings. Since no public or institutional use structures are anticipated to have interior noise levels exceeding FHWA's interior NAC, this noise abatement option would not be applied.

Acquisition of Buffering Land: The purchase of property for noise barrier construction or the creation of a "buffer zone" to reduce noise impacts is only considered for predominantly unimproved properties because the amount of property required for this option to be effective would create significant additional impacts (e.g., in terms of residential displacements), which were determined to outweigh the benefits of land acquisition.

Construction of Noise Barriers / Berms: Construction of noise barriers can be an effective way to reduce noise levels at areas of outdoor activity. Noise barriers can be wall structures, earth berms, or a combination of the two. The effectiveness of a noise barrier depends on the distance and elevation difference between roadway and receptor and the available placement location for a barrier. Gaps between overlapping noise barriers also decrease the effectiveness of the barrier, as opposed to a single connected barrier. The barrier's ability to attenuate noise decreases as the gap width increases.

Noise walls and earth berms are often integrated into the highway design in response to the identified noise impacts. The effectiveness of a freestanding (post and panel) noise barrier and an earth berm of equivalent height are relatively consistent; however, an earth berm is perceived as a more aesthetically pleasing option.

The use of earth berms is not always an option due to the excessive space they require adjacent to the roadway corridor. At a standard slope of 2:1, every one-foot in height would require four feet of horizontal width. This requirement becomes more complex in urban settings where residential properties often abut the proposed roadway corridor. In these situations, implementation of earth berms can require significant property acquisitions to accommodate noise mitigation. The cost associated with the acquisition of property to construct a berm can significantly increase the total costs to implement this form of noise mitigation.

Availability of fill material to construct a berm also needs to be considered. On proposed projects where proposed grading yields enough excess waste material, earth berms are often cost-effective mitigation options. For balance or borrow projects, the implementation of earth berms is often an expensive solution due to the need to identify, acquire, and transport the material to the project site. Earth berms are not considered a viable mitigation option in the Study Area and are unlikely to be evaluated in the final design stage.

As a general practice, noise barriers are most effective when placed at a relatively high point between the roadway and the impacted noise-sensitive land use. To achieve the greatest benefit from a potential noise barrier, the barrier should break the line-of-sight (to the greatest degree possible) between the roadway and the receptor. In roadway fill conditions where the highway is above the natural grade, noise barriers are typically most effective when placed on the edge of the roadway shoulder or on top of the fill slope. In roadway cut conditions, where the roadway is located below the natural grade, barriers are typically most effective when placed at the top of the cut slope. Engineering and safety issues have the potential to alter these typical barrier locations.

For this project, noise barriers are the only feasible mitigation option for impacted receptors.

4.2.2 Feasibility Criteria

All receptors that meet the warranted criterion must progress to the “feasible” phase. This phase of the noise abatement criteria requires that both of the following acoustical and engineering conditions be considered:

(1) At least a five dB(A) highway traffic noise reduction at impacted receptors. Per 23 CFR 772, FHWA requires the highway agency to determine the number of impacted receptors required to achieve at least five dB(A) of reduction. VDOT requires that 50 percent or more of the impacted receptors experience five dB(A) or more of insertion loss to be feasible, and

(2) The determination that it is possible to design and construct the noise abatement measure. The factors related to the design and construction include: safety, barrier height, topography, drainage, utilities, and maintenance of the abatement measure; maintenance access to adjacent properties; and general access to adjacent properties (i.e., arterial widening projects).

4.2.3 Reasonableness Criteria

All receptors that meet the feasibility criterion must progress to the “reasonableness” phase. This phase of the noise abatement criteria requires that all of the following conditions be considered:

- The viewpoints of the benefited receptors,
- Cost effectiveness value, and
- Noise reduction design goal.

Typically, the limiting factor related to barrier reasonableness is the cost effectiveness value, where the total surface area of the barrier is divided by the number of benefited receptors receiving at least a five dB(A) reduction in noise level. VDOT’s approved cost is based on a maximum square footage of abatement per benefited receptor, a value of 1,600 square feet per benefited receptor.

For non-residential properties, such as parks and public use facilities, a special calculation is performed in order to quantify the type and duration of activity and compare to the cost effectiveness criterion. The determination is based on cost, severity of impact (both in terms of noise levels and the size of the impacted area and the activity it contains), and amount of noise reduction.

Noise Reduction Design Goals: The design goal is a reasonableness factor indicating a specific reduction in noise levels that VDOT uses to identify that a noise abatement measure effectively reduces noise. The design goal establishes a criterion, selected by VDOT, which the noise abatement must achieve. VDOT’s noise reduction design goal is defined as a seven dB(A) of insertion loss for at least one impacted receptor, meaning that at least one impacted receptor is predicted to achieve a seven dB(A) or greater noise reduction with the proposed barrier in place. The design goal is not the same as acoustic feasibility, which defines the minimum level of effectiveness for a noise abatement measure. Acoustic feasibility indicates that the noise abatement measure can, at a minimum, achieve a discernible reduction in noise levels.

Noise reduction is measured by comparing the future design year build condition pre- and post-barrier noise levels. This difference between unabated and abated noise levels is known as “insertion loss” (IL).

It is important to optimize the noise barrier design to achieve the most effective noise barrier in terms of both IL and cost. Although at least a five dB(A) reduction is required to meet the feasibility criteria, the following tiered noise barrier abatement goals are used to govern barrier design and optimization.

- Reduction of future highway traffic noise by seven dB(A) at one or more of the impacted receptor sites (required criterion).
- Reduction of future highway traffic noise levels to the low-60-decibel range when practical (desirable).
- Reduction of future highway traffic noise levels to existing noise levels when practical (desirable).

Cost-Effectiveness: Typically, the limiting factor related to barrier reasonableness is the cost effectiveness value, where the total surface area of the barrier is divided by the number of benefited receptors receiving at least a five-dBA reduction in noise level. VDOT's approved cost is based on a maximum square footage of abatement per benefited receptor, a value of 1,600 square feet per benefited receptor.

Where multi-family housing includes balconies at elevations that exceed a 30-foot-high barrier, or the topography causes receptors to be above the elevation of a 30-foot barrier, these receptors are not assessed for barrier benefits and are not included in the computation of the barrier's reasonableness.

For non-residential properties, such as parks and public use facilities, a calculation is performed in order to quantify the type and duration of activity and compare to the cost effectiveness criterion. The determination is based on cost, severity of impact (both in terms of noise levels and the size of the impacted area and the activity it contains), and amount of noise reduction. A grid system, consisting of receptors spaced at 100 feet, was incorporated for recreational areas at two churches and one school.

The Viewpoints of the Benefited Receptors: VDOT shall solicit the viewpoints of all benefited receptors through certified mailings and obtain enough responses to document a decision as to whether or not there is a desire for the proposed noise abatement measure. Fifty percent or more of the respondents shall be required to favor the noise abatement measure in determining reasonableness. Community views in and of themselves are not sufficient for a barrier to be found reasonable if one or both of the other two reasonableness criteria are not satisfied.

4.2.4 Existing Noise Barriers

No noise barriers are present in the Study Area for the Existing condition.

4.2.5 Noise Barrier Evaluation

Noise barrier analyses are warranted only for CNEs with predicted noise impacts under the Future Design Year (2040) Build condition. Noise barriers were evaluated at impacted CNEs 03, 06, 13, 19, 21, 25, 26, 47, 62, 64 and 68. No other CNEs were evaluated for noise mitigation.

While impacts are predicted within CNEs 32, 35, 36, 37, 40, 41, 42 and 55, noise barriers are not considered feasible due to existing vehicular and/or pedestrian access requirements. Therefore, mitigation for these CNEs are not addressed in this section. Information on the noise levels associated with these CNEs can be found in **Appendix D**.

All potential noise barriers deemed physically feasible were evaluated at various lengths and uniform panel heights of 15 feet to 30 feet, in five-foot increments to determine whether they meet acoustic feasibility, design goal, and reasonableness criteria. Potential barriers are shown in **Appendix I,** Figure 1.

Six potential noise barriers were shown to be both feasible and reasonable at CNEs 03, 13, 19, 21, 62 and 64. Noise barriers that are shown to be feasible and reasonable in the preliminary design may not be feasible and reasonable in final design. All noise barriers would be further evaluated in final design to determine any engineering constraints associated with constructing the noise barrier.

Barrier 03-P is a potential barrier for CNE 03. Located along the northbound side of Richmond Highway just north of Cooper Road, and to the south of Talbott Farm Drive, the barrier would be 126 feet in length and 15 feet in height, with a surface area of 1,890 square feet. The barrier would benefit the single impacted receptor and one additional non-impacted receptor on Talbott Farm Drive. Barrier 03-P is feasible because it would benefit at least 50 percent of the impacted receptors. Barrier 03-P also meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, as well as the cost-reasonableness criteria with a surface area per benefited receptor value of 945 – below VDOT’s maximum value of 1,600. The potential barrier is both feasible and reasonable.

Barrier 06-P is a potential three-barrier system for CNE 06. Located along Richmond Highway NB, from south of Wyngate Manor Court to south of Forest Place, the barrier would total 475 feet in length and 30 feet in height, with a surface area of 14,250 square feet. The potential barrier system would benefit just one of four impacted receptors and nine additional non-impacted receptors below the points of intersection on Wyngate Manor Court and Washington Square Apartments, which has balconies on all floors. Because Barrier 06-P would not benefit at least 50 percent of impacted receptors, the potential noise barrier system is determined to be not feasible.

Barrier 13-P is a potential barrier for CNE 13. Located along the northbound side of Richmond Highway, north of Central Avenue, the barrier would be 350 feet in length and 15 feet in height, with a surface area of 5,250 square feet. The barrier would benefit 11 out of 15 impacted receptors and 33 additional non-impacted receptors on Hunter Murphy Circle and Shannons Green Way. Barrier 13-P is feasible because it would benefit at least 50 percent of the impacted receptors. Barrier 13-P also meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, as well as the cost-reasonableness criteria with a surface area per benefited receptor value of 119 – well below VDOT’s maximum value of 1,600. The potential barrier is both feasible and reasonable.

Barrier 19-P is a potential two-barrier system for CNE 19. Located along the northbound side of Richmond Highway, north of Napper Road, the barrier would total 332 feet in length and 25 feet in height, with a surface area of 8,300 square feet. The barrier would benefit 14 out of 16 impacted receptors and four additional non-impacted receptors that are below the points of intersection at Spring Garden Apartments. Barrier 19-P is feasible because it would benefit at least 50 percent of the impacted receptors. Barrier 19-P also meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, as well as the cost-reasonableness criteria with a surface area per benefited receptor value of 461 – well below VDOT’s maximum value of 1,600. The potential barrier system is both feasible and reasonable.

Barrier 21-P is a potential two-barrier system for CNE 21. Located along Richmond Highway NB, on each side of Kings Village Road, the noise barrier system would benefit all ten impacted receptors and 59 additional non-impacted receptors on Colonial Springs Court, Kings Village Road, Heritage Springs Court, and Gum Springs Village Drive. The barrier system would total 920 feet in length and 15 feet in height, with a surface area of 13,800 square feet. Barrier 21-P is feasible because it would benefit at least 50 percent of the impacted receptors. Barrier 21-P also meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, as well as the cost-reasonableness criteria with a surface area per benefited receptor value of 200 – well below VDOT's maximum value of 1,600. The potential barrier system is both feasible and reasonable.

Barrier 25-P is a potential barrier for CNE 25. Located along Richmond Highway NB, south of the entrance to Cherry Arms Apartments, the barrier would be 400 feet in length and 30 feet in height, with a surface area of 12,000 square feet. Access requirements prohibit extension of the barrier to the north. Barrier 25-P would benefit just seven out of 19 impacted receptors, including the pool, and 16 additional non-impacted receptors at the multi-story apartments. Because Barrier 25-P would not benefit at least 50 percent of impacted receptors, the potential barrier is determined to be not feasible.

Barrier 26-P is a potential barrier for CNE 26. Located along Richmond Highway NB, from north of Cherry Arms Apartments to Popkins Lane, the barrier would be 802 feet in length and 30 feet in height, with a surface area of 24,060 square feet. Barrier 26-P would benefit both impacted receptors, and three additional non-impacted receptors on the St. Louis Catholic Church recreational area. The potential barrier is feasible because it would benefit at least 50 percent impacted receptors. While Barrier 26-P meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, it fails the cost-reasonableness criteria with a surface area per benefited receptor value of 4,812 – well above VDOT's maximum value of 1,600. The potential noise barrier is determined to be feasible but not reasonable.

Barrier 47-P is a potential barrier for CNE 47. Located along Richmond Highway SB between Collard Street and Spring Drive, this barrier alignment is made possible by the potential displacement of two residences due to the project widening. The barrier would be 302 feet in length and 30 feet in height, with a surface area of 9,060 square feet. Barrier 47-P would not benefit the single impacted receptor, nor any other non-impacted receptors. Because Barrier 47-P would not benefit at least 50 percent of impacted receptors, the potential barrier is determined to be not feasible.

Barrier 62-P is a potential two--barrier system for CNE 62. Located along the southbound side of Richmond Highway, north of Frye Road, the barrier would total 755 feet in length and 20 feet in height, with a surface area of 15,100 square feet. The barrier would benefit all eight impacted receptors and 34 additional non-impacted receptors that are below the points of intersection at Woodlawn Garden Apartments. Barrier 62-P is feasible because it would benefit at least 50 percent of the impacted receptors. Barrier 62-P also meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, as well as the cost-reasonableness criteria with a surface area per benefited receptor value of 360 – well below VDOT's maximum value of 1,600. The potential barrier system is both feasible and reasonable.

Barrier 64-P is a potential barrier for CNE 64. Located along the southbound side of Richmond Highway just south of Sky View Drive, the barrier would be 235 feet in length and 15 feet in height, with a surface area of 3,525 square feet. The barrier would benefit the single impacted receptor and 12 additional non-impacted receptors on Towne Manor Court. Barrier 64-P is feasible because it would benefit at least 50 percent of the impacted receptors. Barrier 64-P also meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, as well as the cost-reasonableness criteria with a surface area per benefited receptor value of 271 – well below VDOT's maximum value of 1,600. The potential barrier is both feasible and reasonable.

Barrier 68-P is a potential barrier for CNE 68. Located along Richmond Highway SB, north of Woodlawn Road, the barrier would be 429 feet in length and 15 feet in height, with a surface area of 6,435 square feet. Barrier 68-P would benefit the single impacted grid receptor, and two additional non-impacted grid receptors on the Pillar Church recreational area. The potential barrier is feasible because it would benefit at least 50 percent impacted receptors. While Barrier 68-P meets the reasonableness design goal criteria of a seven-dB(A) noise reduction at one impacted receptor, it fails the cost-reasonableness criteria with a surface area per benefited receptor value of 2,145 – above VDOT's maximum value of 1,600. The potential noise barrier is determined to be feasible but not reasonable.

See **Table 4-2** for a compilation of potential barrier characteristics.

Table 4-2: Summary of Barrier Characteristics

Potential Barrier ID	CNE ID	Total Impacts	Barrier Length (Feet)	Barrier Height (Feet)	Surface Area (SF)	Impacted and Benefited	Feasible?	Meets Design Goals?	Average IL of Benefited Receptors (dBA)	Total Benefits	Cost @ $42 per SF	Barrier Square Feet per Benefited Receptor	Reason-able? (SF per Benefit <1,600)
03-P	03	1	126	15	1,890	1	Yes	Yes	6	2	$79,380	945	Yes
06-P	06	4	475	30	14,250	1	No						
13-P	13	15	350	15	5,250	11	Yes	Yes	9	44	$220,500	119	Yes
19-P	19	16	332	25	8,300	14	Yes	Yes	6	18	$348,600	461	Yes
21-P	21	10	920	15	13,800	10	Yes	Yes	9	69	$579,600	200	Yes
25-P	25	19	400	30	12,000	7	No						
26-P	26	2	802	30	24,060	2	Yes	Yes	10	5	$1,010,520	4,812	No
47-P	47	1	302	30	9,060	0	No						
62-P	62	8	755	20	15,100	8	Yes	Yes	8	42	$634,200	360	Yes
64-P	64	1	235	15	3,525	1	Yes	Yes	10	13	$148,050	271	Yes
68-P	68	1	429	15	6,435	1	Yes	Yes	10	3	$270,270	2,145	No

5. CONSTRUCTION NOISE AND VIBRATION

The degree of construction noise impact generated during the construction phase of the proposed action would vary, as it is directly related to the types and number of equipment used and the proximity to the noise-sensitive land uses within the Study Area. Land uses that are sensitive to traffic noise could also be sensitive to construction noise. Any construction noise impacts that would occur as a result of roadway construction measures are anticipated to be temporary in nature and would cease upon completion of the project construction phase. Construction noise would be limited by adhering to a VDOT specification requiring that construction not exceed established noise limits. This specification can be found in VDOT's 2016 *Road and Bridge Specifications*, Section 107.16(b.3), "Noise." The contractor would be required to conform to this specification to reduce the impact of construction noise on the surrounding community. The specifications have been reproduced below:

- The Contractor's operations shall be performed so that exterior noise levels measured during a noise-sensitive activity shall not exceed 80 decibels. Such noise level measurements shall be taken at a point on the perimeter of the construction limit that is closest to the adjoining property on which a noise-sensitive activity is occurring. A noise-sensitive activity is any activity for which lowered noise levels are essential if the activity is to serve its intended purpose and not present an unreasonable public nuisance. Such activities include, but are not limited to, those associated with residences, hospitals, nursing homes, churches, schools, libraries, parks, and recreational areas.
- The County may monitor construction-related noise. If construction noise levels exceed 80 decibels during noise-sensitive activities, the Contractor shall take corrective action before proceeding with operations. The Contractor shall be responsible for costs associated with the abatement of construction noise and the delay of operations attributable to noncompliance with these requirements.
- The County may prohibit or restrict to certain portions of the project any work that produces objectionable noise between 10 PM and 6 AM. If other hours are established by local ordinance, the local ordinance shall govern.
- Equipment shall in no way be altered so that resulting noise levels are greater than those produced by the original equipment.
- When feasible, the Contractor shall establish haul routes that direct his vehicles away from developed areas and ensure that noise from hauling operations is kept to a minimum.

These requirements shall not be applicable if the noise produced by sources other than the Contractor's operation at the point of reception is greater than the noise from the Contractor's operation at the same point.

The operation of construction equipment also causes ground vibrations that spread through the surrounding ground. These vibrations tend to diminish over distance, and the level of annoyance for humans depends upon the extent, distance, and duration of the vibration-generating activities. Construction-related vibration rarely causes structural damage to buildings. Construction activities that typically generate the most severe vibration include blasting and impact pile driving. However, neither blasting nor pile driving is currently planned for BRT construction. Therefore, no prolonged annoyance nor damage from construction vibration is expected, and no quantitative assessment is necessary at this time.

6. PUBLIC INVOLVEMENT PROCESS

6.1 Noise Compatible Planning

6.1.1 Noise-Compatible Land-Use Planning

Per FHWA and VDOT policies, the County will possess and apply noise prediction results for noise-compatible land-use planning and noise impact zones for undeveloped lands within the project corridor. Sections 12.1 and 12.2 of VDOT's 2011 *Highway Traffic Noise Impact Analysis Guidance Manual* outline the data and methods available to the County. The intent is for the County to possess sufficient information for planning the uses of undeveloped land adjacent to highways to minimize the potential impacts of highway traffic noise.

Entering the Quiet Zone is a brochure that provides general information and examples to elected officials, planners, developers, and the general public about the problem of traffic noise, including effective responses to it. A link to this brochure on FHWA's website is provided here:

http://www.fhwa.dot.gov/environment/noise/noise_compatible_planning/federal_approach/land_use/qz00.cfm

A wide variety of administrative strategies may be used to minimize or eliminate potential highway noise impacts, thereby preventing the need or desire for costly noise abatement structures such as noise barriers in future years. There are five broad categories of such strategies:

- Zoning;
- Other legal restrictions (subdivision control, building codes, health codes);
- Municipal ownership or control of the land;
- Financial incentives for compatible development; and
- Educational and advisory services.

The Audible Landscape: A Manual for Highway and Land Use is a very well-written and comprehensive guide addressing these noise-compatible land use planning strategies, with significant detailed information. This document is available through FHWA's website, at

http://www.fhwa.dot.gov/environment/noise/noise_compatible_planning/federal_approach/audible_landscape/al00.cfm

6.1.2 Noise Impact Zones in Undeveloped Land along the Study Corridor

Under the revised 2011 FHWA and VDOT noise policies, noise impact zones adjacent to project roadways in undeveloped lands must be identified. To determine these zones, noise levels are computed at various distances from the edge of the project roadways in each of the undeveloped areas of the project Study Area. Then the distances from the edge of the roadway to the NAC sound levels are determined through interpolation. Distances vary in the project corridor due to changes in traffic volumes or terrain features. Any noise-sensitive sites within these zones should be considered noise impacted if no barrier is present to reduce sound levels.

There are two areas of potential development in the south-central portion of the Study Area – one on the Richmond Highway NB side of the roadway, south of CNE 02, and another on the Richmond Highway SB side, within CNE 65. For both properties, the minimum safe distance from the edge of roadway to 71 dB(A) is predicted to be 20 feet; for 66 dB(A), the distance is 80 feet.

North Hill is a large, planned development for affordable housing on what is currently an approximately 35-acre parcel of unimproved land in the central portion of the Study Area, near the 7200 block of Richmond Highway NB. While long slated for development, no building permits were identified for this property during the initial analysis in 2019. The minimum safe distance from the edge of roadway to 71 dB(A) is predicted to be 30 feet; for 66 dB(A), the distance is 110 feet.

6.1.3 VDOT's Noise Abatement Program

Information on VDOT's noise abatement program is available on VDOT's Website, at: http://www.virginiadot.org/projects/pr-noise-walls-about.asp. The site provides information on VDOT's noise program and policies, noise walls, and a downloadable noise wall brochure.

6.2 Voting Procedures

For noise barriers determined to be feasible and reasonable, the affected public that will be benefited by the proposed mitigation will be given an opportunity to decide whether they are in favor of construction of the noise barrier. A final determination as to the construction of barriers will be made after the design public hearing process. Before final decisions and approvals can be made to construct a noise barrier, a final design noise analysis will be performed. For barriers that are determined to be feasible and reasonable, input from the owners and residents of those receptor units that will be benefited by the proposed mitigation may vote by completing and returning the citizen survey that they receive in the mail. The initial citizen survey is sent out as certified mail, so the disposition of the letters can be tracked. Of the votes tallied, 50 percent or more must be in favor of a proposed noise barrier for that barrier to be considered further. Upon completion of the citizen survey, the VDOT Noise Abatement staff will make recommendations to the Chief Engineer for approval. Approved barriers will be incorporated into the road project plans. A technical memorandum of the results of the public survey will be prepared.

7. VIBRATION ANALYSIS

This section presents the background, methodology, and results of the vibration analysis for the Richmond Highway BRT Project. This vibration assessment was conducted in accordance with NEPA and the guidelines set forth by FTA. The operational effects were evaluated using the guidelines set forth by the FTA's *Transit Noise and Vibration Assessment* guidance manual, FTA Report No. 0123, dated September 2018. This report analyzes the potential vibration contribution of added passenger bus traffic on new dedicated bus lanes, and new BRT stations associated with the project.

7.1 Affected Environment

7.1.1 Human Perception of Vibration

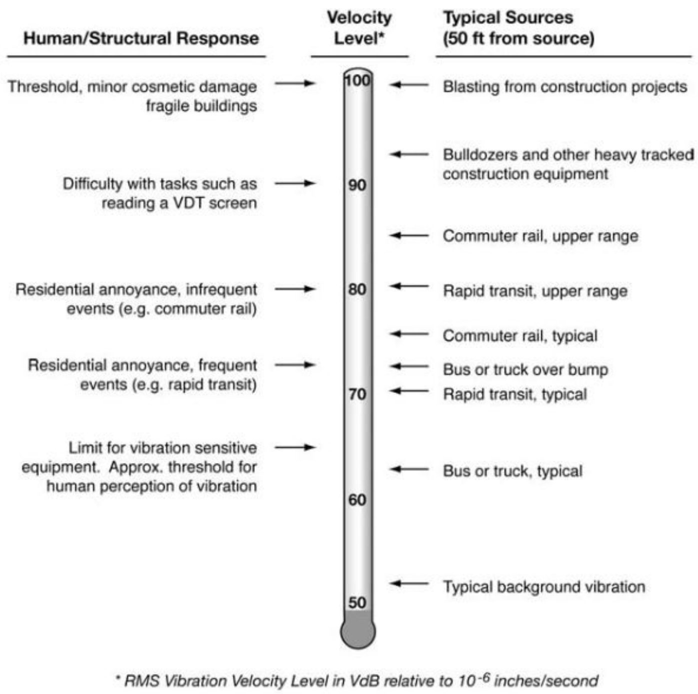
Ground-borne vibration can be a serious concern for nearby neighbors of a transit system route or maintenance facility, causing buildings to shake and rumbling sounds to be heard. However, in contrast to airborne noise, ground-borne vibration is not a common environmental problem. It is unusual for vibration from sources such as buses and trucks to be perceptible, even in locations close to major roads. Some common sources of ground-borne vibration are trains, buses on rough roads, and construction activities such as blasting, pile-driving, and operating heavy earth-moving equipment.

Vibration is an oscillatory motion, which can be described in terms of displacement, velocity, or acceleration. Displacement, in the case of a vibrating floor, is the distance that a point on the floor moves away from its static position. The velocity represents the instantaneous speed of the floor movement and acceleration is the rate of change of the speed. The response of humans, buildings, and equipment to vibration is normally described using velocity or acceleration.

Vibration amplitudes are usually expressed as either peak particle velocity (PPV) or the root mean square (RMS) velocity. The PPV is defined as the maximum instantaneous peak of the vibration signal. The RMS of a signal is the average of the squared amplitude of the signal. Although PPV is appropriate for evaluating the potential for building damage, it is not suitable for evaluating human response. Since it takes some time for the human body to respond to vibration signals, RMS amplitude is more appropriate to evaluate human response to vibration than PPV. For sources such as trucks or motor vehicles, peak vibration levels are typically six to 14 dB higher than RMS levels. FTA uses the abbreviation "VdB" for vibration decibels to reduce potential confusion with sound decibel.

The RMS vibration velocity level in decibels (VdB) is used to describe human annoyance criteria and impacts and uses a reference quantity of one micro-inch per second. Decibel notation acts to compress the range of numbers required in measuring vibration. **Figure 7-1** illustrates common vibration sources and the human and structural responses to ground-borne vibration. As shown, the threshold of perception for human response is approximately 65 VdB; however, human response to vibration is not usually significant unless the vibration exceeds 70 VdB. Vibration tolerance limits for sensitive instruments, such as MRI or electron microscopes, could be much lower than the human vibration perception threshold.

Figure 7-1: Typical Levels of Ground-Borne Vibration



Source*: Transit Noise and Vibration Impact Assessment,* Federal Transit Administration, Washington, DC, September 2018.

7.1.2 Regulatory Framework and Evaluation Criteria

The FTA's guidance manual, *Transit Noise and Vibration Impact Assessment*, presents the basic concepts, methods, and procedures for evaluating the extent and severity of vibration impacts from transit projects. Transit vibration impacts are assessed based on land use categories and sensitivity to vibration from transit sources under the FTA guidelines. The FTA land use categories and required noise metrics are shown in **Table 7-1**.

Table 7-1: FTA Vibration Land Use Categories

Land-Use Category		Description
-	Special Buildings	This category includes special-use facilities that are very sensitive to vibration and noise that are not included in the categories below and require special consideration. However, if the building will rarely be occupied when the source of the vibration (e.g., the train) is operating, there is no need to evaluate for impact. Examples of these facilities include concert halls, TV and recording studios, and theaters.
1	High Sensitivity	This category includes buildings where vibration levels, including those below the threshold of human annoyance, would interfere with operations within the building. Examples include buildings where vibration-sensitive research and manufacturing is conducted, hospitals with vibration-sensitive equipment, and universities conducting physical research operations. The building's degree of sensitivity to vibration is dependent on the specific equipment that will be affected by the vibration. Equipment moderately sensitive to vibration, such as high-resolution lithographic equipment, optical microscopes, and electron microscopes with vibration isolation systems are included in this category.** For equipment that is more sensitive, a Detailed Vibration Analysis must be conducted.
2	Residential	This category includes all residential land use and buildings where people normally sleep, such as hotels and hospitals. Transit-generated ground-borne vibration and noise from subways or surface running trains are considered to have a similar effect on receivers.
3	Institutional	This category includes institutions and offices that have vibration-sensitive equipment and have the potential for activity interference such as schools, churches, doctors' offices. Commercial or industrial locations including office buildings are not included in this category unless there is vibration-sensitive activity or equipment within the building. As with noise, the use of the building determines the vibration sensitivity.

The criteria for acceptable ground-borne vibration are expressed in terms of RMS velocity levels in decibels and the criteria for acceptable ground-borne noise are expressed in terms of A-weighted sound levels. The limits are specified for the three land-use categories defined in **Table 7-2**.

Table 7-2: FTA Ground-Borne Vibration Impact Criteria for Human Annoyance

Land-Use Category		Ground-Borne Vibration Impact Levels (VdB re: 1 Micro-in/sec)		
		Frequent Events[1]	Occasional Events[2]	infrequent Events[3]
1	High Sensitivity	65 Vdb[4]	65 Vdb[4]	65 Vdb[4]
2	Residential	72 Vdb	75 Vdb	80 Vdb
3	Institutional	75 Vdb	78 Vdb	83 Vdb

Notes:

1. "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.

2. "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.

3. "Infrequent Events" is defined as more than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.

4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment, such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.

7.1.3 Vibration Assessment Methodology

The FTA's guidance manual, *Transit Noise and Vibration Impact Assessment,* established methodologies for assessing the potential for a transit project to generate ground-borne vibration that exceeds the expectable vibration limits described previously. The steps include a screening evaluation, a general assessment, and a detailed analysis.

The Screening Procedure is based on a flow chart and standard table of impact distances that is used to determine if ground-borne vibration from the project may affect sensitive land uses. More detailed analysis is required if any sensitive land uses are within the screening distances. The Screening Procedure does not require any specific knowledge about the vibration characteristics of the system or the geology of the area. If different propagation conditions are known to be present, a simple adjustment is provided.

The General Assessment is an extension of the screening procedure. It uses generalized data to develop a curve of vibration level as a function of distance from the track. The vibration levels at specific buildings are estimated by reading values from the curve and applying adjustments to account for factors such as track support system, vehicle speed, type of building, and track and wheel condition. The general level deals only with the overall vibration velocity level and the A-weighted sound level. It does not consider the frequency spectrum of the vibration or noise.

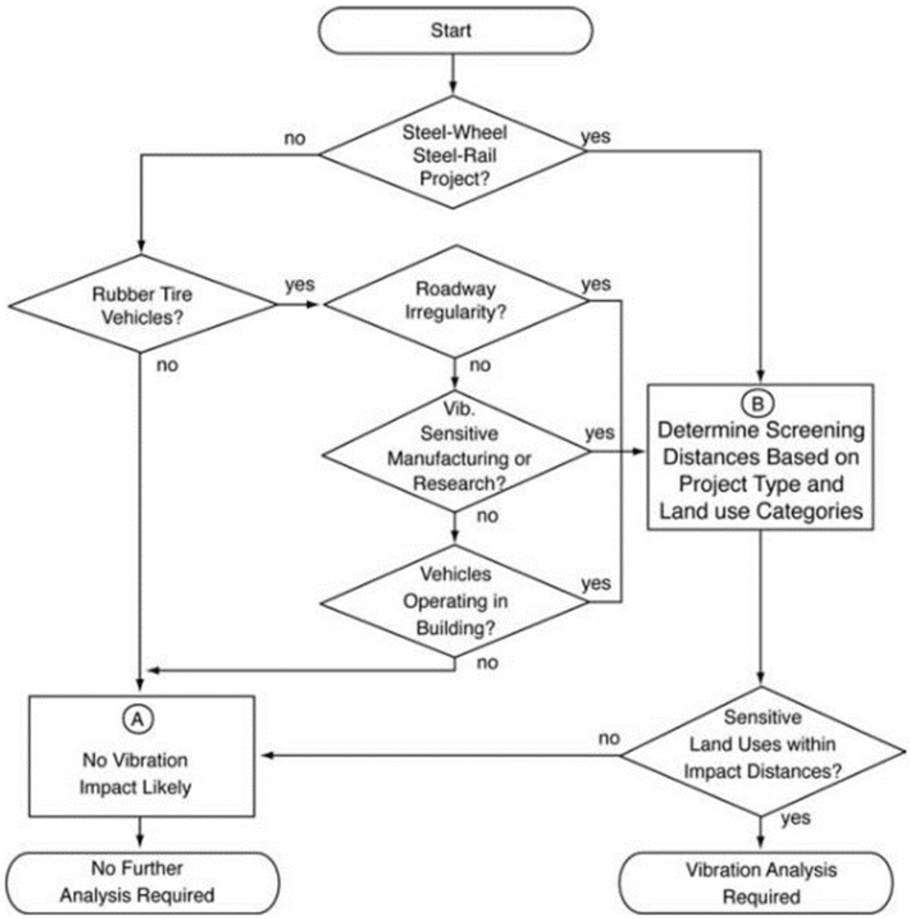
The Detailed Analysis involves applying all the available tools for accurately projecting the vibration impact at specific sites. The procedure includes a test of the vehicle (or similar vehicle) to define the forces generated by the vibration source and tests at the site in question to define how the local geology affects vibration propagation. It is considerably more complex to develop detailed projections of ground-borne vibration than it is to develop detailed projections of airborne noise.

Table 7-3 provides the screening distances for the vibration assessments, and **Figure 7-2** provides a flowchart of the ground-borne vibration screening process.

Table 7-3: FTA Screening Distances for Vibration Assessment

Type of Project	Critical Distances for Land Use Categories		
	Cat. 1	Cat. 2	Cat. 3
Conventional Commuter Rail	600	200	120
Rail Rapid Transit	600	200	120
Light Rail Transit	450	150	100
Intermediate Capacity Transit	200	100	50
Bus Projects (if not previously screened out)	100	50	--

Figure 7-2: Ground-Borne Vibration Screening Process



Source*: Transit Noise and Vibration Impact Assessment,* Federal Transit Administration, Washington, DC, September 2018.

7.1.4 Vibration Assessment

Using the FTA's screening flowchart (**Figure 7-2**), the Richmond Highway BRT Project would consist of the addition of rubber-tire bus vehicles. The surface of the additional bus lanes and stations for this project would be asphalt; therefore, irregular surfaces would not be present. Also, there are no land uses with vibration-sensitive manufacturing or research, nor are there vehicles operating in buildings within the project corridor. Due to these conditions, the flowchart indicates that no vibration impact would be likely, and therefore no further analysis is required. The project is predicted to result in "no impact" associated with ground-borne vibration.