Bus Base North

Bus Base North Noise and Vibration Technical Memorandum

June 2020

Sound Transit

Consultant Quality Control Form

Version	Title	Date	Originator/ Drafted by	Reviewed by	Approved by	Notes, as required
0	08.06 Bus Base North Noise and Vibration Technical Memorandum – Draft	10/4/2019	Steven Wolf	Larissa King Rawlins (Task Lead) Ed Reynolds (tech edit) Sandi Wise (QC Review)	Chris Wellander	Initial Issue
1	08.06 Bus Base North Noise and Vibration Technical Memorandum – Second Draft	12/4/2019	Steven Wolf	Larissa King Rawlins (Task Lead) Ed Reynolds (tech edit) Sandi Wise (QC Review)	Chris Wellander	Revised in response to comments received from Sound Transit
2	08.06 Bus Base North Noise and Vibration Technical Memorandum	6/18/2020	Steven Wolf	Larissa King Rawlins (Task Lead) Ed Reynolds (tech edit) Sandi Wise (QC Review)	Chris Wellander	Issued as final

Summary

The purpose of this study is to assess future noise and vibration effects from the construction and operation of the proposed Sound Transit Bus Base North (BBN) facility. The Federal Transit Administration (FTA) General Noise Assessment was used to predict noise levels from bus transit operations and evaluate the level of impact on noise-sensitive receivers. Noise-sensitive land uses were identified using Geographic Information System (GIS) mapping, assessor's parcel maps and aerial photos, and were verified through field work. The BBN is considered by FTA as a stationary source that includes a bus storage yard and operating and maintenance facility.

The BBN is located on vacant property, in the center of a light industrial/office park, at the intersection of 214th Street SE and 20th Avenue SE in Bothell. Land uses closest to the BBN site include:

- Shared bus and vehicle maintenance facility for the Northshore School District and the City of Bothell adjacent to the north
- Multi-story office buildings to the east and a large warehouse/manufacturing facility to the south
- Existing residences on 214th Street SE on the west side of SR 527, 730 feet to the west
- 220 Towns at Canyon Park residences, currently under construction and located at 2409 219th Place SE, 325 feet to the southeast
- North Creek Trail located 135 feet to the west

The FTA noise impact thresholds and the Washington State Maximum Environmental Noise levels at the existing residences on 214th Street SE and the 220 Towns at Canyon Park residences are not predicted to be exceeded. Construction noise is allowed by the Bothell Municipal Code during the daytime hours of 7 a.m. and 8 p.m. and Saturday from 9 a.m. to 6 p.m. and prohibited on Sunday and major holidays. Construction activities outside of allowed times would require a variance.

Based on the FTA Vibration Screening Assessment, residential receivers that are farther than 50 feet from the bus base would not be impacted by vibrations from the bus base. Since the closest existing residence is 730 feet to the west of the BBN on 214th Street SE and the closest residence, which is under construction, is 325 feet to the west, vibration-generating activities from operations or construction would not be noticeable and further vibration assessment is not needed.

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Acronyms and Abbreviations

BBN	Bus Base North
BMC	Bothell Municipal Code
BRT	bus rapid transit
dB	decibel
dBA	A-weighted decibel noise level
EDNA	Environmental Designations for Noise Abatement
FTA	Federal Transit Administration
L_{dn}	day/night sound level
L_{eq}	equivalent noise level
L_{max}	maximum noise level
MSF	maintenance and storage facility
PPV	peak particle velocity
ST	Sound Transit
VdB	decibel notation for vibration level
WAC	Washington Administrative Code

1 INTRODUCTION

1.1 Overview

As was identified in the *Sound Transit 3 (ST3) System Plan* (Sound Transit 2016), Sound Transit is planning for a new bus operations and maintenance facility (Bus Base North [BBN]) located near the Interstate I-405/State Route (SR) 522 corridors to service vehicles operating on the I-405 and SR 522/NE 145th bus rapid transit (BRT) lines and ST Express buses. The site identified for development of the BBN project is in the Canyon Park Subarea of Bothell along 20th Avenue SE, as shown in **Figure 1-1**.

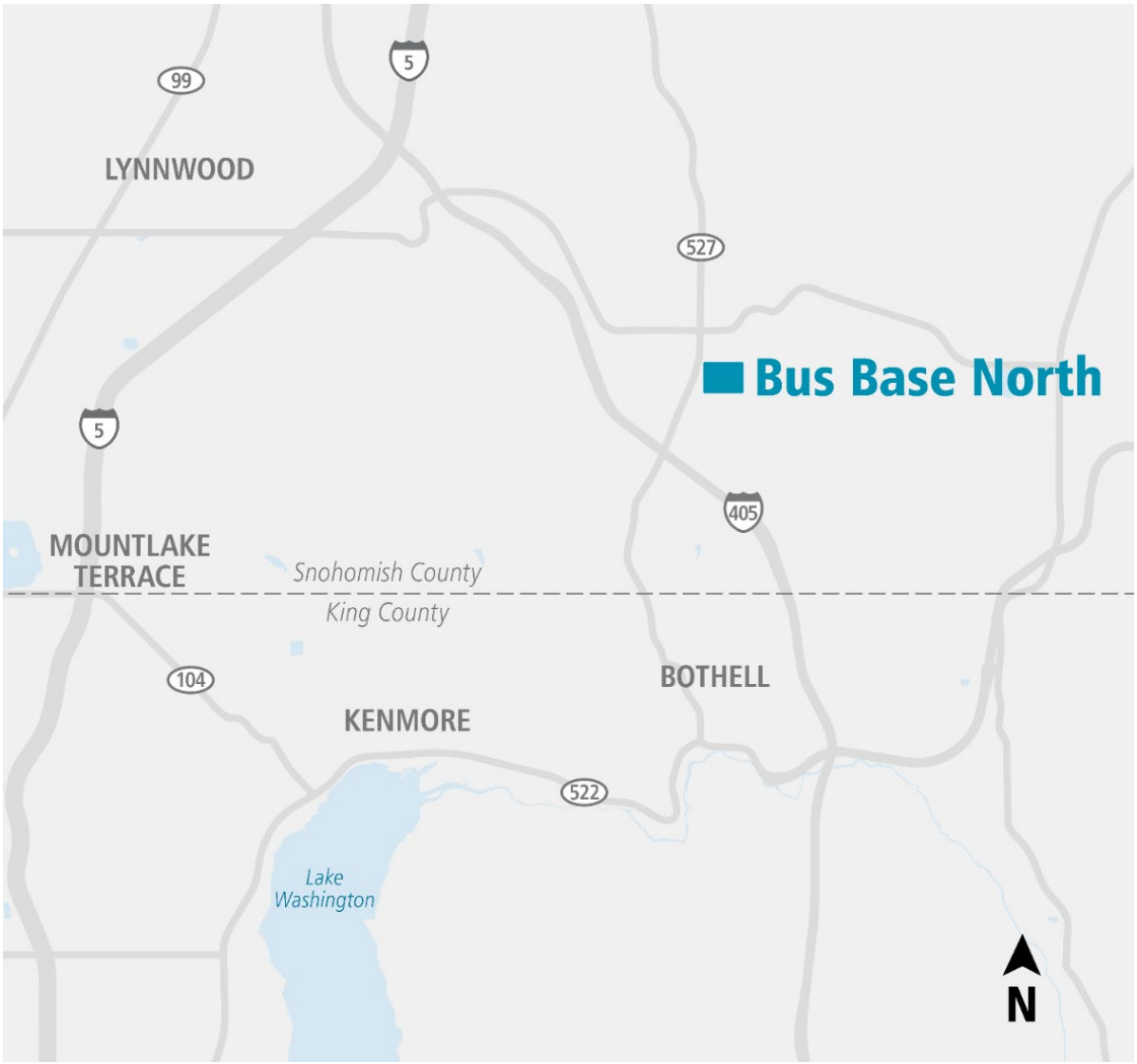


Figure 1-1 Bus Base North project vicinity

The BBN project would provide support for up to 80 articulated (60 feet in length) and 40 double-decker or standard transit coaches (40 feet in length). The fleet would primarily be diesel/electric hybrid buses, but approximately 10 of the buses would operate with battery-electric propulsion when the project opens. The facility would be configured to allow for the future potential conversion of the bus fleet to battery-electric buses if Sound Transit determines that to be an appropriate vehicle technology. The BBN project would include construction of the following:

- A maintenance and operations building
- Storage/parking for the 120 buses at ground level
- An aboveground, second-story parking deck to be provided for all employee and visitor parking, which would also provide cover for the bus parking area below
- A security guard house at the bus entrance gate to ensure that all vehicles entering the bus traffic areas have authorization to enter
- A bus wash building to accommodate a fully enclosed, two-bay, drive-through bus wash operation
- A fueling facility, including a support systems building and canopy-covered fueling lanes
- Stormwater facilities as needed to address regulatory and design requirements
- Utility and street connections

Sound Transit is expected to select a design/build contractor for the project in 2021. Following selection, the design/build contractor would develop the detailed construction documents for the project and permit applications would be submitted to the City of Bothell and other permitting agencies. Construction is anticipated to start in 2021 and to be completed in 2023 prior to the start of BRT services in 2024.

1.2 Purpose of technical memorandum

The purpose of this technical memorandum is to assess future noise and vibration effects on the surrounding land uses as a result of the construction and operation of the proposed BBN.

2 PROJECT DESCRIPTION

The BBN facility is a bus operations and maintenance facility on a 12.5-acre site, programmed and sized to maintain, service (including fuel and wash), and store up to 120 buses. These buses include the fleet that would operate on the proposed I-405 and SR 522/NE 145th BRT lines, as well as ST Express buses from existing lines of bus service. The site plan and layout of the facility are based on a conceptual level of design. These site plans are shown in **Figure 2-1** and **Figure 2-2**.

2.1 On-site facilities

The following provides a description of the proposed facilities on-site.

2.1.1 Maintenance and operations building

As shown in the conceptual site plans, the maintenance and operations building would be the primary structure on-site with a total building footprint of approximately 58,000 square feet. The maintenance and operations building would include two levels. The first floor is anticipated to include approximately 57,000 square feet of floor area, and the second floor is anticipated to include approximately 19,000 square feet of floor area, for a total floor area of approximately 76,000 square feet. The ground level is expected to house shop and maintenance bay functions and maintenance offices, while the operations offices, dispatch areas, driver areas, and administrative functions would be located on the second floor. The building would also include an enclosed paint booth (for vehicle touch ups, damage repairs, and full coach repainting) designed in accordance with regulatory requirements.

Figure 2-1 Bus Base North – Ground-level site plan

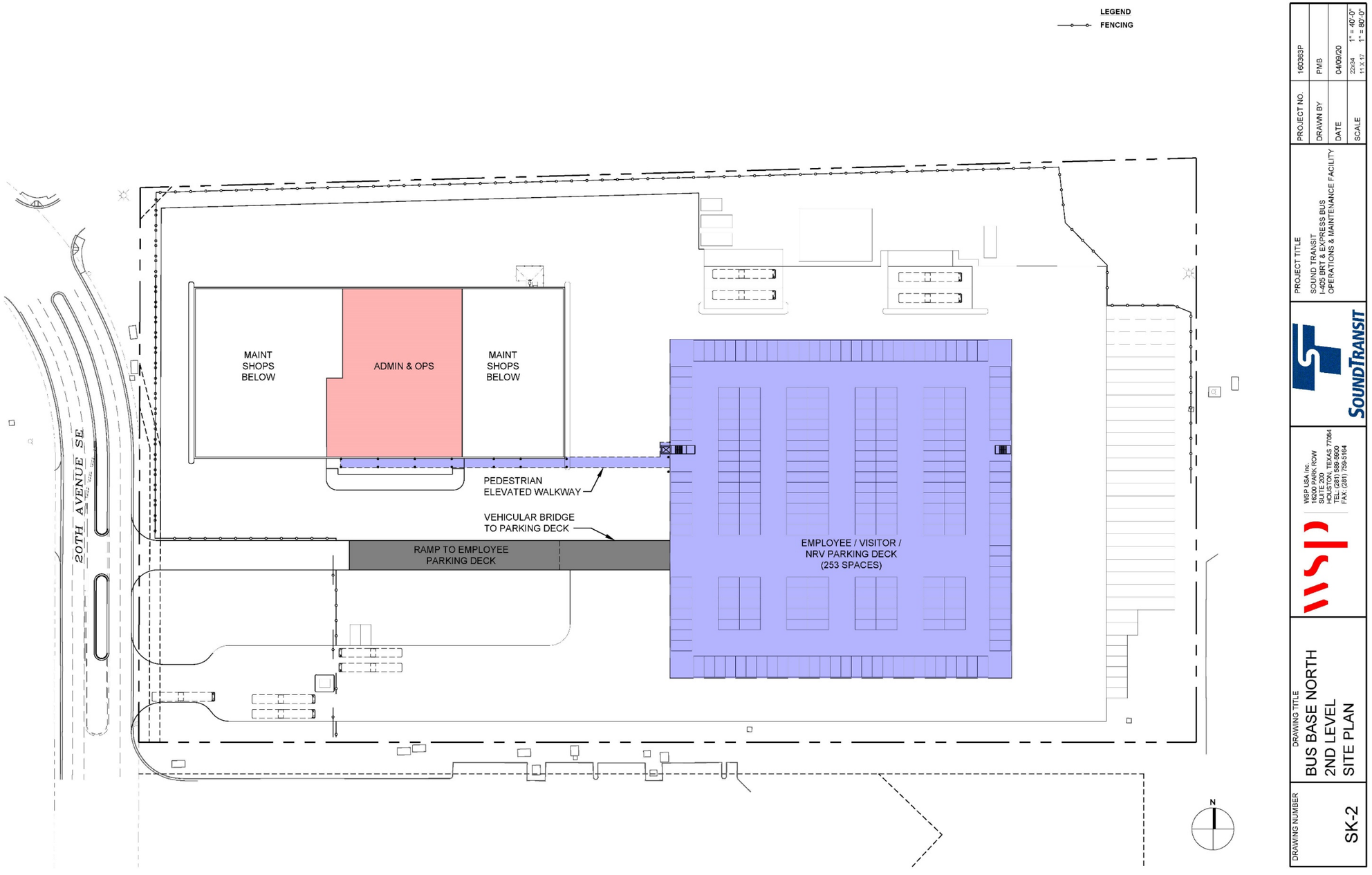


Figure 2-2 Bus Base North – Second-level site plan

2.1.2 Bus storage and elevated parking deck

Storage/parking for the 120 buses would occur on the ground level in the eastern portion of the site, set back from 20th Avenue SE. Access to the bus parking area would be from a bus-only entrance/exit driveway from 20th Avenue SE along the southern property boundary. The bus parking area includes space for the electrical charging infrastructure that would be needed for the potential future conversion to a battery-electric bus fleet.

Above the ground-level bus parking area, a second-story parking deck with approximately 250 parking stalls and approximately 105,000 square feet in area, would be provided for employee and visitor parking and non-revenue vehicles (vehicles used by staff for service and other non-customer transportation uses). This parking deck would cover the bus parking area and would provide weather protection for the parked buses, an overhead structure to attach lighting for the bus parking area, and a structure to attach potential future overhead electric charging equipment. Automobile access to the parking deck would be from a second driveway from 20th Avenue SE, just north of the bus entrance/exit driveway, to a dedicated drive and ramp. The parking deck would likely include an elevated pedestrian walkway directly into the second floor of the maintenance and operations building and would also include an elevator and egress stairs, as required by code, to provide pedestrian access to the ground-level bus parking area below.

2.1.3 Security guard house

An approximately 100-square-foot security building would be located at the bus entrance/exit driveway to monitor access and help control the ingress and egress of buses at the site. Entrance and exit gates would be located on each side (to the north and south) of the security building. Two security guard parking spaces would be provided just northeast of the security building.

2.1.4 Fuel and wash buildings

A bus wash building, approximately 4,500 square feet in size, would accommodate a fully enclosed, two-bay, drive-through bus wash operation.

A fueling facility would be provided, including an approximately 1,000-square-foot support systems building and an approximately 3,000-square-foot canopy over two fueling lanes. The support systems building would include lube tanks for fluids used at the fuel island, an air compressor to run the pumps and equipment at the fuel island, vacuum equipment used to clean the buses during servicing, computerized equipment for the fuel/fluid management systems, a custodial room, and staff restrooms. An area for aboveground fuel tanks would be sited to the north of the fueling facility building. The fuel tanks are proposed to be aboveground and double-walled for easier observation and maintenance purposes as well as for easier removal should the fleet be converted to an alternative fuel source in the future.

2.2 Utilities and site access

The site would be equipped with an oil/water separator that would be connected to all sanitary sewer elements serving vehicle maintenance areas and where otherwise required by the Washington State Department of Ecology's (Ecology's) *Stormwater Management Manual for Western Washington* (Ecology 2019) and the Alderwood Water & Wastewater District. This would include floor and trench drains in maintenance areas as well as the chassis wash areas. The bus washer system would be connected to a water reclaim system to reduce the water supply required for that function. Water and sanitary services would be tied to the Alderwood Water & Wastewater District services located along 20th Avenue SE.

Stormwater would be collected underground and detention would be provided in an on-site underground vault. Low-impact development practices, consistent with the Ecology's *Stormwater Management Manual for Western Washington* (Ecology 2019), would be accommodated as space and site conditions allow. Stormwater would ultimately tie into the City of Bothell system via the adjacent ditches.

Communications and natural gas services for the site would be tied into utilities currently available in 20th Avenue SE. Electrical service would be coordinated with the local electrical service provider—the Snohomish County Public Utility District—who would extend service to the site, most likely along the southern portion of the property. While the use of battery-electric buses is being considered for the future, it is not currently planned for the initial construction at this facility. To accommodate battery-electric buses on-site, it is anticipated that the area initially used to accommodate the aboveground fuel tanks (shown in **Figure 2-1** would be removed and that area would be used for a small substation and battery area to provide the on-site power generation and storage needed to charge the bus batteries. It is anticipated that this area would be fenced for safety purposes.

Two site driveways/entrances would be provided from 20th Avenue SE to separate the bus and personal vehicle traffic. The primary fire department access would be through the bus entrance driveway. A secondary fire access would be provided through the employee parking entrance with an access point prior to the ramp up to the employee parking deck, as shown in **Figure 2-1** To allow turns into and out of the facility from both driveways, the raised median that separates the northbound and southbound lanes of 20th Avenue SE would be modified, including providing a break in the median for the employee entrance and shortening the median on the south end to allow buses to exit the facility. Required sidewalks would be provided along the site street frontage.

2.3 Site work

Prior to construction, the site would be cleared and grubbed to remove existing vegetation not intended to be protected (i.e., outside of wetland areas that would not be filled and the stream buffer area shown on **Figure 2-1** as being fenced). The site would also be graded as needed to properly support the development and provide adequate drainage for the site.

Reinforced concrete paving would be used for all driveways and bus and large maintenance vehicle parking areas. Limited areas of asphalt paving could be provided in areas trafficked by personal vehicles. Depending upon existing soil conditions, paving may be installed over a treated subbase, such as lime or cement stabilized soil.

The site would be equipped with lighting as required to support the 24-hour-per-day operations and as needed for security. Landscaping would be provided in designated areas and in accordance with local ordinances. Vegetation would be low maintenance and provided with irrigation. The entire yard area would be secured by fencing with control gates at access and egress points. While fencing materials could vary around the site, all fencing would be affixed at the base via concrete. Gates and access points would be equipped with a key card system, provided with intrusion detection, and would also comply with the City of Bothell's requirements for fire and life safety access. Closed-circuit television cameras are anticipated to be used on the site.

Landscaping would be provided on the perimeter of the site in designated areas and in accordance with local ordinances. Existing trees would be preserved around the perimeter of the site where possible, and vegetation/landscaping would be provided in accordance with Sound Transit's design standards and would be low maintenance and provided with irrigation where needed.

2.4 Operations

The BBN facility would operate 24 hours per day, seven days per week. The facility would house general maintenance functions, including inspections; tire, brake, paint, and body work; parts distribution; and detail cleaning. Transit vehicle maintenance personnel would work in three shifts. Maintenance activities would be performed during all shifts. During the evening shift, personnel would primarily service vehicles through the fuel and wash cycle; however, during all shifts it is possible for any of the different maintenance activities to be performed. **Table 2-1** lists the typical times when buses and maintenance staff would arrive and depart the site for daily operations.

Table 2-1 Typical daily operations – arrivals and departures

Time of day	Daily operations – Arrivals and departures
4:00 a.m.	Transit operators and operations staff arrive
4:30 a.m.	Buses start to leave the facility at approximately 10-minute intervals
7:00 a.m.	Majority of buses off the site
8:00 a.m.	First shift for vehicle maintenance begins/third shift for vehicle maintenance ends
11:00 a.m.	Buses return to site during off-peak hours
2:00 p.m.	Transit operators and operations staff arrive
2:30 p.m.	Buses start to leave the facility at approximately 10-minute intervals
4:00 p.m.	Majority of buses off the site/second shift for vehicle maintenance begins
5:00 p.m.	First shift for vehicle maintenance ends
10:00 p.m.	Third shift for vehicle maintenance begins
12:00 a.m.	Second shift for vehicle maintenance ends

SOURCE: Sound Transit 2019

3 METHODOLOGY

3.1 Noise and vibration fundamentals

The following provides information on some fundamental concepts and terminology used in this noise and vibration assessment.

3.1.1 Noise

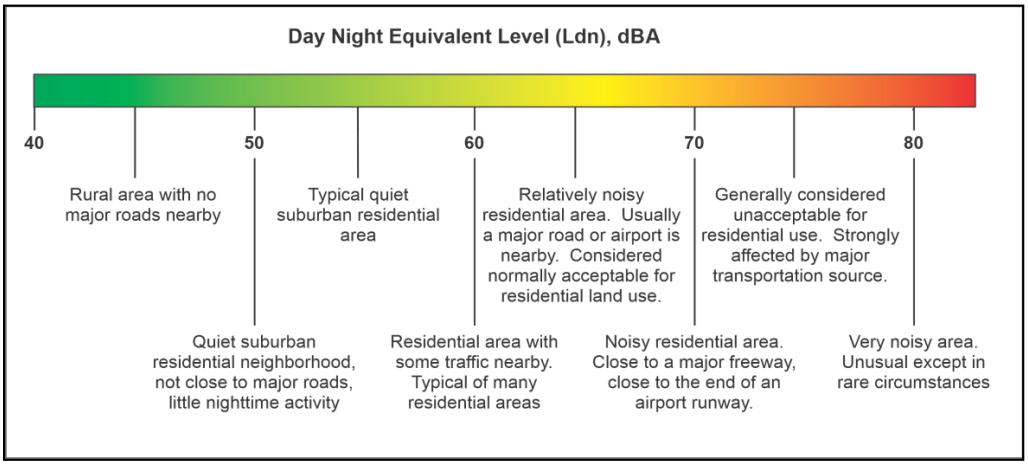
Noise is defined as unwanted sound; it is measured in terms of sound pressure level and is usually expressed in decibels (dB). The human ear is less sensitive to higher and lower frequencies than it is to midrange frequencies. To provide a measurement meaningful to humans, a weighting system was developed that reduces the sound level of higher and lower frequency sounds, similar to what the human ear does. This filtering system is used in virtually all noise ordinances. Measurements taken with this "A-weighted" filter are referred to as "dBA" readings.

The two primary noise measurement descriptors used to assess noise impacts from traffic and transit projects, the $L_{eq,}$ and L_{dn}, are defined as:

- L_{eq}: The equivalent sound level (L_{eq}) is the level of a constant sound for a specified period of time that has the same sound energy as an actual fluctuating noise over the same period of time. The peak-hour L_{eq} is used for all traffic and transit noise analyses at locations with daytime use, such as schools and libraries. The Washington State Administrative (WAC) Maximum Environmental Noise Levels specifies a maximum noise-level descriptor, which is interpreted to mean a 1-hour L_{eq}.

- L_{dn}: The day-night sound level (L_{dn}) is an L_{eq} over a 24-hour period, with 10 dBA added to nighttime sound levels (between 10 p.m. and 7 a.m.) as a penalty to account for the greater sensitivity and lower background noise levels during this time.

The L_{dn} and L_{eq} are the primary noise-level descriptors for the assessment of Federal Transit Administration (FTA) transit noise at sensitive noise receivers. Typical L_{dn} A-weighted noise levels are presented in **Figure 3-1**. The L_{eq} is the primary noise-level descriptor for the Washington State Administrative assessment.



SOURCE: FTA 2018

Figure 3-1 Typical L_{dn} A-weighted sound levels

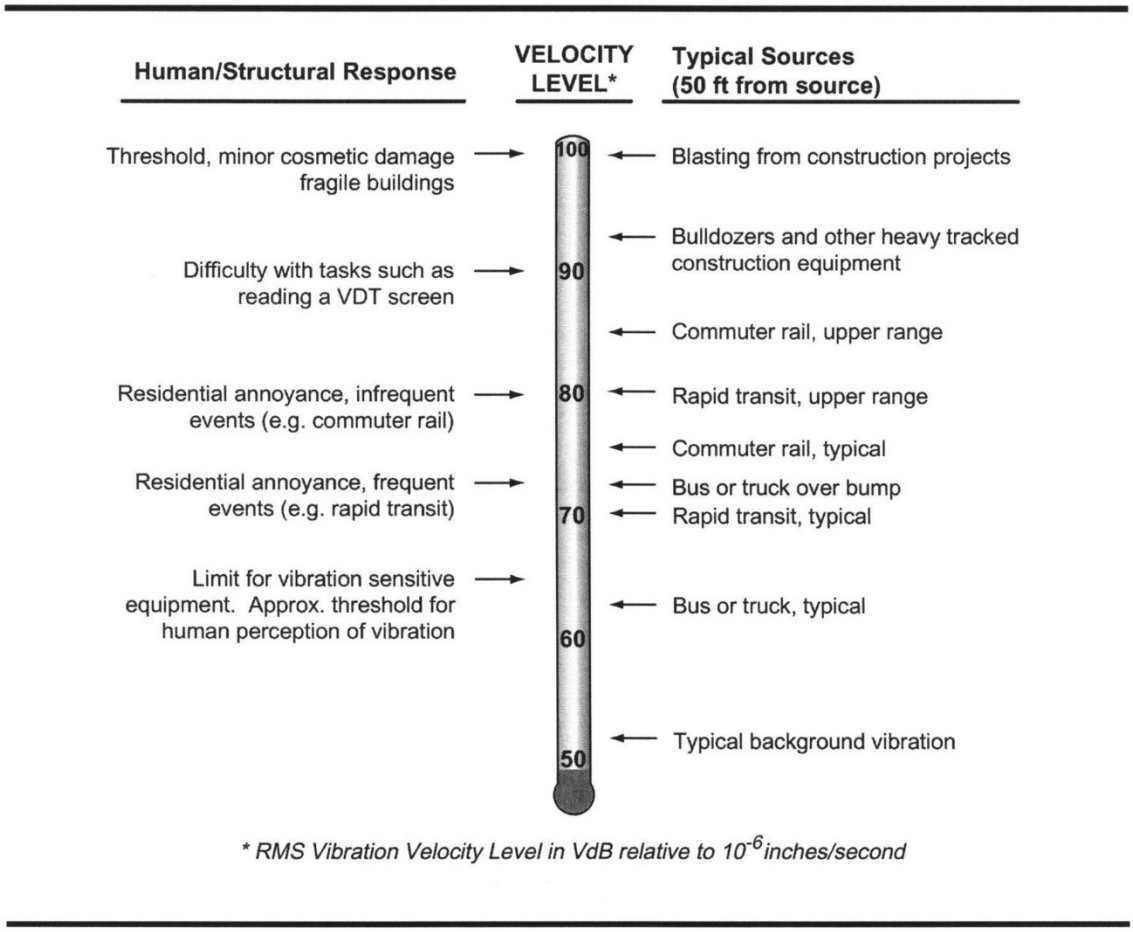
3.1.2 Vibration

Because the rubber tires and suspension systems of buses provide vibration isolation, it is unusual for them to cause noticeable groundborne vibration or groundborne noise. With bus-related vibration, such as rattling of windows, the cause is almost always airborne noise and directly related to running surface conditions such as potholes, bumps, expansion joints, or other discontinuities in the road surface (usually resolved by smoothing the discontinuities). The two types of vibration impacts that may occur when buses operate over poor road surface conditions are:

- Groundborne vibration: The movement of the ground (vibration can be experienced either outdoors or indoors)
- Groundborne noise: Noise generated by the movement of room surfaces, such as walls, resulting from vibration of a building (groundborne noise can only be experienced indoors)

Groundborne vibration can be described in terms of displacement, velocity, or acceleration when evaluating impacts from transit projects. Groundborne noise occurs as a perceptible rumble and is caused by the noise radiated from the vibration of room surfaces. Vibration above certain levels can damage buildings, disrupt sensitive operations, and cause annoyance to humans within buildings. The response of humans, buildings, and equipment to vibration is most accurately described using velocity or acceleration. Vibration velocity is used by the FTA as the primary measurement to evaluate the effects of vibration.

Figure 3-2 illustrates typical groundborne vibration velocity levels for common sources as well as thresholds for human and structural response to groundborne vibration. As shown, the range of interest is from approximately 50 vibration velocity decibels (VdB) to 100 VdB (i.e., from imperceptible background vibration to the threshold of damage to structures). Although the threshold of human perception to vibration is approximately 65 VdB, annoyance does not usually occur unless the vibration exceeds 70 VdB.



SOURCE: FTA 2018

Figure 3-2 Typical levels of ground vibration

3.2 Regulatory context

The guidance presented in the FTA 2018 Transit Noise and Vibration Impact Assessment is used to predict and assess the potential noise and vibration effects of the BBN. Since there are no federal approvals for the BBN, the WAC Maximum Environmental Noise Levels (WAC 173-60) and the BMC noise limits are also used to demonstrate compliance for BBN operation and construction noise.

3.2.1 Federal

3.2.1.1 FTA noise impact thresholds

FTA's criteria for assessing noise impacts related to transit projects are based on community reactions to noise. The criteria reflect changes in noise exposure using a sliding scale where the higher the level of existing noise, the smaller increase in total noise exposure is allowed. Some land use activities are more sensitive to noise than others, such as parks, churches, and residences, as compared to industrial and commercial uses. FTA's Noise Impact Criteria groups sensitive land uses into the three categories described in **Table 3-1**.

Table 3-1 Land use categories and metrics for transit noise impact criteria

Land use category	Land use type	Noise metric, dBA	Description of land use category
1	High sensitivity	Outdoor L_{eq} (1hr)[1]	Land where quiet is an essential element of its intended purpose. Example land uses include preserved land for serenity and quiet, outdoor amphitheaters and concert pavilions, and national historic landmarks with considerable outdoor use. Recording studios and concert halls are also included in this category.
2	Residential	Outdoor L_{dn}	This category is applicable all residential land use and buildings where people normally sleep, such as houses, apartments, hotels, and hospitals.
3	Institutional	Outdoor L_{eq} (1hr)[1]	This category is applicable to institutional land uses with primarily daytime and evening use. Example land uses include schools, libraries, theaters, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material. Places for meditation or study associated with cemeteries, monuments, museums, campgrounds, and recreational facilities are also included in this category.

SOURCE: FTA 2018
NOTES: [1] L_{eq} (1hr) for the loudest hour of project related activity during hours of noise sensitivity.
dBA = A-weighted decibel; L_{dn} = day/night noise level; L_{eq} = equivalent noise level

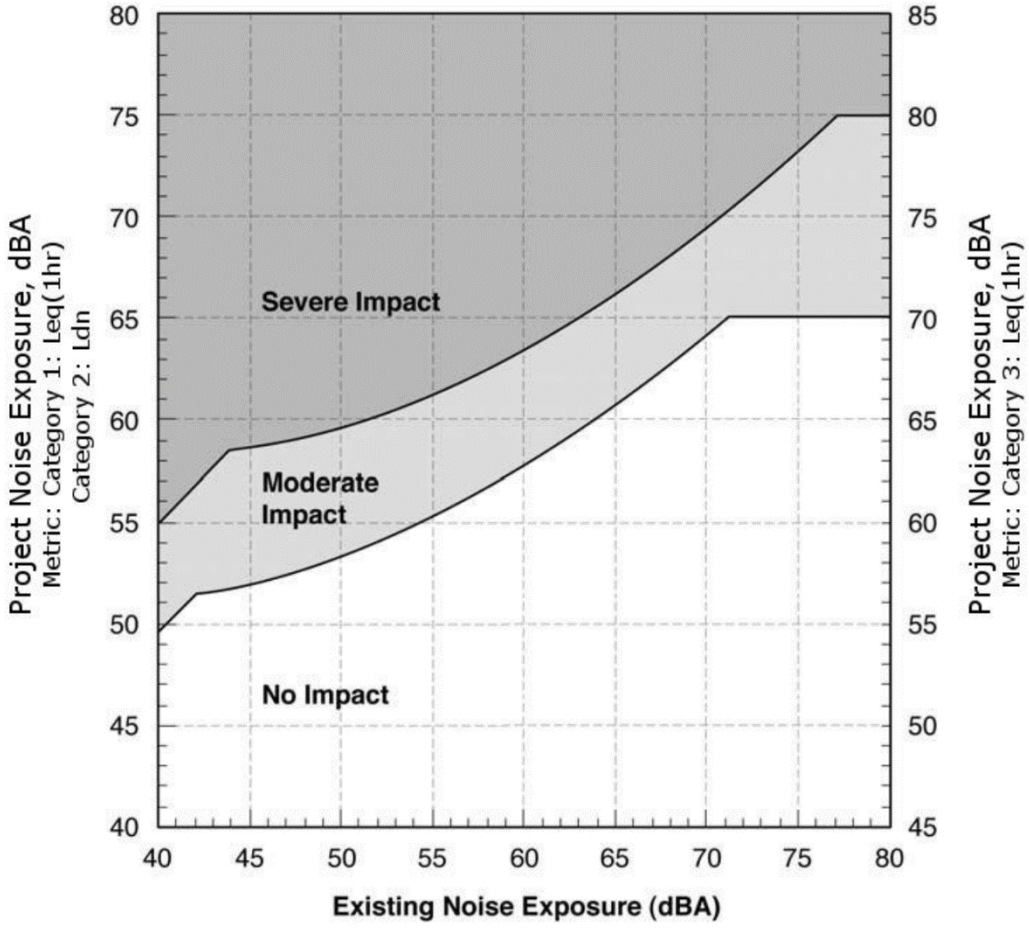
Most commercial or industrial uses are not considered noise sensitive because activities within these buildings are generally compatible with higher noise levels. Business can be considered noise sensitive if low noise levels are an important part of operations, such as sound and motion picture recording studios. Most parks used primarily for active recreation such as sports complexes and bike or running paths are not considered noise sensitive. However, some parks (even in dense urban areas) are primarily used for passive recreation such as reading, conversation, or meditation. These places, which may be valued for low noise levels, are treated as noise sensitive, and are included in land use Category 3. Non-sensitive uses do not require noise impact assessment.

The FTA has defined three levels of impacts for sensitive uses affected by transit projects: no impact, moderate impact, or severe impact. A description of each impact level is shown in **Table 3-2** and are illustrated in **Figure 3-3**.

Table 3-2 Levels of impact

Level of impact	Description
No impact	Project-generated noise is not likely to cause community annoyance. Noise projections in this range are considered acceptable by FTA and mitigation is not required.
Moderate impact	Project-generated noise in this range is considered to cause impact at the threshold of measurable annoyance. Moderate impacts serve as an alert to project planners for potential adverse impacts and complaints from the community. Mitigation should be considered at this level of impact based on project specifics and details concerning the affected properties. In this range, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These other factors may include the predicted increase over existing noise levels, the type and number of noise-sensitive land uses affected, existing outdoor-indoor sound insulation, and the cost effectiveness of mitigating noise to more acceptable levels.
Severe impact	Project-generated noise in this range is likely to cause a high level of community annoyance. The project sponsor should first evaluate alternatives to determine whether it is feasible to avoid severe impacts altogether. In densely populated urban areas, evaluation of alternative locations may reveal a trade-off of affected groups. Projects that are characterized as point sources, such as the BBN, often present greater opportunity for selecting alternative sites. If it is not practical to avoid severe impacts by changing the location of the project, mitigation measures must be considered. Noise mitigation will be specified for severe impact areas unless there is no practical method of mitigating the noise.

SOURCE: FTA 2018



SOURCE: FTA 2018

Figure 3-3 Noise impact criteria for transit projects

The noise impact criteria for transit operations are summarized in **Table 3-3**. The first column shows the existing noise exposure and the remaining columns show the additional noise exposure caused by transit operations that would result in either a moderate or severe impact. As the existing noise exposure increases, the allowable increase in noise exposure decreases. The future noise exposure would be the combination of the existing noise exposure and the additional noise exposure caused by transit operations.

Since there are no FTA standardized criteria for assessing construction noise impacts, the criteria developed for the BBN is based on BMC Chapter 8.26. The code regulates both noise levels and construction noise hours within the City of Bothell.

Table 3-3 Noise impact criteria for transit operations

Existing noise exposure L_{eq} or L_{dn} (dBA)	Project noise impact exposure, L_{eq} (h) or L_{dn} (dBA)					
	Category 1 or 2 Sites			Category 3 Sites		
	No impact	Moderate impact	Severe impact	No impact	Moderate impact	Severe impact
<43	< Ambient + 10	Ambient + 10 to 15	>Ambient + 15	< Ambient + 15	Ambient + 15 to 20	>Ambient + 20
43	<52	52-58	>58	<57	57-63	63
44	<52	52-58	>58	<57	57-63	63
45	<52	52-58	>58	<57	57-63	63
46	<53	53-59	>59	<58	58-64	64
47	<53	53-59	>59	<58	58-64	64
48	<53	53-59	>59	<58	58-64	64
49	<54	54-59	>59	<59	59-64	64
50	<54	54-59	>59	<59	59-64	64
51	<54	55-60	>60	<59	59-65	65
52	<55	55-60	>60	<60	60-65	6
53	<55	55-60	>60	<60	60-65	65
54	<55	55-61	>61	<60	60-66	66
55	<56	55-61	>61	<61	61-66	66
56	<56	56-62	>62	<61	61-67	67
57	<57	57-62	>62	<62	62-67	67
58	<57	57-62	>62	<62	62-67	67
59	<58	58-63	>63	<63	63-68	68
60	<58	58-63	>63	<63	63-68	68
61	<59	59-64	>64	<64	64-69	69
62	<59	59-64	>64	<64	64-69	69
63	<60	60-65	>65	<65	65-70	70
64	<61	61-65	>65	<66	66-70	70
65	<61	61-66	>66	<66	66-71	71
66	<62	62-67	>67	<67	67-72	72
67	<63	63-67	>67	<68	68-72	72
68	<63	63-68	>68	<68	68-73	73
69	<64	64-69	>69	<69	69-74	74
70	<65	65-69	>69	<70	70-74	74
71	<66	66-70	>70	<71	71-75	75
72	<66	66-71	>71	<71	71-76	76

Existing noise exposure L_{eq} or L_{dn} (dBA)	Project noise impact exposure, L_{eq} (h) or L_{dn} (dBA)					
	Category 1 or 2 Sites			Category 3 Sites		
	No impact	Moderate impact	Severe impact	No impact	Moderate impact	Severe impact
73	<66	66-71	>71	<71	71-76	76
74	<66	66-72	>72	<71	71-77	77
75	<66	66-73	>73	<71	71-78	78
76	<66	66-74	>74	<71	71-79	79
77	<66	66-74	>74	<71	71-79	79
>77	<66	66-75	>75	<71	71-80	80

SOURCE: FTA 2018
NOTES: Category 1 sites use Leq while category 2 and 3 sites use L_{dn}.
dBA = A-weighted decibel; L_{dn} = day/night noise level; L_{eq} = equivalent noise level

3.2.1.2 FTA vibration impact thresholds

FTA has developed impact criteria for acceptable levels of groundborne noise and vibration. These criteria, as summarized in **Table 3-4,** are based on standards, criteria, and design goals, including vibration guidelines from the American National Standards Institute and the American Public Transit Association.

Table 3-4 Groundborne vibration and groundborne noise impact criteria for general assessment

Land use category	Groundborne vibration impact levels (VdB, 1 micro-inch/sec)			Groundborne noise impact levels (dBA, 20 micro pascals)		
	Frequent events[1]	Occasional events[2]	Infrequent events[3]	Frequent events[1]	Occasional events[2]	Infrequent events[3]
Category 1: Buildings where vibration would interfere with interior operations.[4]	65	65	65	N/A	N/A	N/A
Category 2: Residences and buildings where people normally sleep.	72	75	80	35	38	43
Category 3: Institutional land uses with primarily daytime use.	75	78	83	40	43	48

SOURCE: FTA 2018
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. Some commuter trunk lines have this number of events.
3 "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes commuter rail branch lines.
4 This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes.
dBA = A-weighted decibel; N/A = not applicable; VdB = decibel notation

To evaluate potential annoyance or interference with vibration-sensitive activities caused by construction vibration, the criteria for general assessment shown in **Table 3-4** can be applied. However, short-term annoyance during construction is not considered a significant impact. In most cases, the primary concern regarding construction vibration relates to potential damage effects. Vibration damage criteria are provided in **Table 3-5** for various structural categories.

Table 3-5 Construction vibration damage risk criteria

Building category	PPV (inches/second)
I. Reinforced concrete, steel, or timber (no plaster)	0.5
II. Engineered concrete and masonry (no plaster)	0.3
III. Non-engineered timber and masonry buildings	0.2
IV. Buildings extremely susceptible to vibration damage	0.12

SOURCE: FTA 2018
NOTES: PPV = peak particle velocity; peak particle velocity is a measure of vibration related to construction activities.

3.2.2 State

3.2.2.1 Washington state noise criteria

In Chapter 173-60 of the WAC, the Department of Ecology has adopted Maximum Environmental Noise Levels for residential, commercial, industrial and construction areas. However, WAC 173-60-110 states that:

> *The department conceives the function of noise abatement and control to be primarily the role of local government and intends actively to encourage local government to adopt measures for noise abatement and control. Wherever such measures are made effective and are being actively enforced, the department does not intend to engage directly in enforcement activities.*

Washington Administrative Code

The state of Washington has a noise control ordinance that applies (together with local noise regulations) to construction, industrial, commercial, and residential noise sources. State law exempts mobile noise sources, including freight rail, aircraft in flight, and vehicles traveling in public right-of-way, as well as safety warning devices (e.g., bells). For stationary land uses with noises originating from outside public roadways and rights-of-way, the Washington State Noise Control Ordinance defines three different Environmental Designations for Noise Abatement (EDNAs) based on land use, which can be summarized as residential, commercial, and industrial. The WAC noise regulations are in Chapter 173-60, WAC, Maximum Environmental Noise Levels, 2000 (WAC 2000). The ordinance is then written to define the maximum allowable noise level from one EDNA to another EDNA, as shown in **Table 3-6**.

The WAC property line noise standards are used to assess the potential impacts from park-and-ride lots and other stationary noise sources adjoining residential land uses. The FTA noise criteria and Federal Highway Administration Noise Abatement Criteria are used for the bus and traffic operation noise.

Table 3-6 Washington state noise control regulation

EDNA source of noise	EDNA receiver of noise (maximum allowable sound level in dBA[1])		
	Residential	Commercial	Industrial
Class A Residential	55	57	60
Class B Commercial	57	60	65
Class C Industrial	60	65	70

SOURCE: Washington Administrative Code Chapter 173-60-040
NOTES: [1] Between 10 p.m. and 7 a.m., the levels given above are reduced by 10 dBA in Class A EDNAs. Maximum allowable noise levels are interpreted to mean a 1-hour L_{eq}.
dBA = A-weighted decibel

Although the WAC does not define the maximum noise-level descriptor, the EDNA allowable noise levels are interpreted to mean a 1-hour L_{eq}. For example, the noise caused by a private parking garage or public park-and-ride lot, both considered commercial property, must be less than L_{eq} = 57 dBA at the closest residential property line. From 10 p.m. to 7 a.m., the allowable maximum sound levels shown in **Table 3-6** are reduced by 10 dBA in Class A EDNAs (residential zones). The WAC contains short-term exemptions to the property line noise standards shown in **Table 3-6** based on the minutes per hour that the noise limit is exceeded. These exceedances are outlined in **Table 3-7**.

Table 3-7 Washington state exemptions for short-term noise exceedances

Minutes per hour	Adjustment to maximum sound level
15	+5 dBA
5	+10 dBA
1.5	+15 dBA

SOURCE: Washington Administrative Code Chapter 173-60-040
NOTE: dBA = A-weighted decibel

Sounds received in Class A EDNAs that originate from construction sites are exempt from the limits of the WAC regulations during normal daytime hours (7 a.m. to 10 p.m.). If construction is performed during the nighttime, the contractor must still meet the WAC noise-level requirements for sounds received in Class A EDNAs, as presented in **Table 3-6**, or get a noise variance from the governing jurisdiction.

The WAC also contains a set of construction-specific allowable noise-level limits. These construction noise regulations are organized by type of noise and, among other things, include criteria for haul trucks and backup safety alarms.

Construction noise is exempt from the WAC noise limits, except at residential land uses during nighttime hours (10 p.m. to 7 a.m.). If construction is performed during nighttime hours, the contractor must still meet the WAC noise-level requirements or obtain a noise variance from the governing jurisdiction.

Maximum permissible sound levels for haul trucks on public roadways are limited to 86 dBA for speeds of 35 miles per hour or less, and 90 dBA for speeds over 35 miles per hour when measured at 50 feet (Chapter 173-62, WAC).

Sounds created by backup alarms are exempt, except between 10 p.m. and 7 a.m. when "beep-beep" backup alarms are essentially prohibited by the WAC in urban areas and would be replaced with smart backup alarms, which automatically adjust the alarm level based on the background level or switch off backup alarms and replace with spotters. This criterion is included because, as with noise from construction activities, noise from backup beepers would exceed the WAC nighttime criteria, even with the allowable exceedance, at large distances from the construction site.

3.2.2.2 Vibration

There are no state vibration regulations.

3.2.3 Local

3.2.3.1 Noise ordinances and regulations

BMC Chapter 8.26 regulates noise in the City of Bothell, including construction noise. The code regulates both noise levels and construction noise hours. BMC 8.26.040 sets maximum permissible noise levels consistent with WAC 173-06-040. BMC 8.26.060 identifies sounds that are defined to be a public nuisance, which includes sound made by construction that is not consistent with the city's noise construction hours. Construction noise within allowed hours are not considered a public nuisance but would still be subject to the maximum permissible noise levels.

BMC 8.26.090 establishes a process to request a variance to the noise-level requirements of BMC 8.26.040. A variance to the maximum allowable noise levels may be made by the community development director if it is determined that the requirements cannot be achieved because of special circumstances, such as economic or physical factors, encroachment upon an existing noise source, or because of non-availability of feasible technology or control methods. The variance decision is a Type I action under BMC 11.04.003.

BMC 8.26.065, Construction Noise Hours, outlines regulations to control construction noise. Construction noise is limited to Monday through Friday between 7 a.m. and 8 p.m. and Saturday from 9 a.m. to 6 p.m. Construction noise is prohibited on Sunday and major holidays. Certain construction noise activities are exempt from this section, including freeway, highway, or arterial construction and improvements. BMC 8.26.065.D allows the community development director to authorize the extension of construction noise hours for Monday through Friday and Saturday for certain types of construction activities.

The BMC refers to WAC 173-60-040 for the maximum permissible noise levels from the operation of the BBN.

3.2.3.2 Vibration

There are no local vibration regulations.

3.3 Noise and vibration analysis

3.3.1 Noise

3.3.1.1 Construction

Construction of the BBN project would require the use of heavy equipment that generates relatively high noise levels. The assessment of construction noise is prepared using the FTA Construction Noise Assessment. The assessment predicts construction noise levels for a variety of construction operations based on a compilation of empirical data and the application of acoustical propagation formulas. The FTA uses a database of noise levels for common pieces of construction equipment that would be expected to be used during construction of the BBN facility (refer to **Table 5-1** in Section 5.1.1). Variables that can be adjusted are distance from equipment to receiver, shielding, and equipment usage rates. Construction noise levels were assessed as they would typically occur at the closest residential receivers.

3.3.1.2 Long-term/operational

The project would generate operational noise associated with bus activity at BBN. An analysis of operational noise levels at the closest sensitive land uses (refer to **Figure 4-1** in Section 4.1) was completed using the FTA General Noise Assessment. The measured existing 24-hour noise level was compared to the predicted bus base noise levels to determine if an impact would occur. The predicted nighttime bus base noise levels were also compared to the WAC maximum noise levels. The following is a summary of the noise and vibration sources evaluated in this study:

- **Bus operations**: This is the normal noise from buses entering and leaving the BBN. These include noise from tires, propulsion motors, air conditioning, and other auxiliary equipment on the vehicles.

- **Parking facility**: Parking would be provided for employees. Typical parking lot sources of noise are vehicle idling, opening and closing of car doors, and people talking.

Maintenance and storage facility: The BBN would accommodate daily servicing and cleaning, inspection and repairs, and storage of buses. Associated noise sources would include repair areas that would produce noise associated with the use of hand tools and mechanical equipment, blowers associated with the enclosed car wash, the vacuum system and an air compressor associated with the vehicle blow down facility, horn testing, wheel squeal, employee vehicle trips, and bus movements within the site.

The project would not increase the capacity of or widen adjoining roadways. Roadway traffic noise is not anticipated to change and, therefore, was not considered as part of the noise assessment. Traffic noise generated by BBN activities along local streets are not considered by FTA.

3.3.2 Vibration

3.3.2.1 Construction

Construction would require the use of heavy equipment that generates groundborne vibration. The FTA guidance provides an analytical/empirical construction vibration prediction model used to estimate vibration level propagation from construction equipment to vibration-sensitive locations. The vibration model is based on a combination of previous works, including measured equipment vibration emission data from the FTA's Guidance Manual (FTA 2018). The fundamental equation used in the model is based on propagation relationships of vibration through average soil conditions and distance, as follows:

$$PPV_{receiver} = PPV_{ref} * \left(25 / Dist_{receiver} \right)^{n}$$

where:

$PPV_{receiver}$ = predicted PPV at the receiver

PPV_{ref} = reference PPV of equipment at 25 feet

$Dist_{receiver}$ = distance from the receiver to the equipment in feet

n = 1.5 (the vibration attenuation rate through the soil)

The suggested value for "n" in the FTA Guidance Manual is 1.5. The value for "n" can lie between 1.0 and 2.0, and a value of 1.5 is commonly used in general vibration prediction models. Equipment vibration emission levels used for the predictions are shown in **Table 3-8**.

Table 3-8 Equipment vibration emission levels

Equipment		Vibration level at 25 feet (in/sec PPV)
Pile driver (impact)	Upper range	1.518
	Typical	0.644
Large bulldozer		0.089
Caisson drilling		0.089
Small bulldozer		0.003
Jack hammer		0.035
Hoe ram		0.089
Loaded truck		0.076
Vibratory roller		0.210

SOURCE: FTA, 2018
NOTES: in/sec = inches per second; PPV = peak particle velocity

3.3.2.2 Long-term/operational

Because the rubber tires and suspension systems of buses provide vibration isolation, it is unusual for buses to cause noticeable groundborne vibration or groundborne noise problems, either along roadways or from a specific site. For most issues with bus-related vibration, such as rattling of windows, the cause is almost always airborne noise and directly related to running surface conditions such as potholes, bumps, expansion joints, or other discontinuities in the road surface (usually resolved by smoothing the discontinuities). These effects are typical of all buses operating along roadways. For operational vibrations, a screening-level assessment was conducted at the closest vibration-sensitive receiver to the bus base. The screening distances are as follows:

- FTA Vibration Category 1: 100 feet for buildings where vibration would interfere with interior operations that may be well below those associated with human annoyance
- FTA Vibration Category 2: 50 feet for residences and buildings where people normally sleep
- FTA Vibration Category 3: No critical distance for institutional land uses with primarily daytime use

The closest buildings to the BBN site are a bus and vehicle maintenance facility for the Northshore School District and the City of Bothell to the north, and multi-story office buildings and a large warehouse/manufacturing facility to the south. These existing buildings are FTA Vibration Category 3, 65 feet from the BBN site, which are not considered by FTA as vibration sensitive and would not be affected by the operation of the BBN. The closest vibration-sensitive receivers are the future site of the proposed Canyon Park Apartments approximately 150 feet from the bus base site and the residences at 214th Street SE, 730 feet from the bus base. At these distances, vibration from operations within the BBN and bus movements is not predicted to result in a vibration impact. No further assessment of BBN vibrations impacts is needed.

4 EXISTING CONDITIONS

4.1 Noise

Noise-sensitive land uses were identified using Geographic Information System (GIS), assessor's parcel maps and aerial photos, and were verified through field work. A noise monitoring location was selected to best represent existing noise-sensitive conditions at the closest residential receiver to the BBN site.

The BBN is located on a vacant lot at the intersection of 214th Street SE and 20th Avenue SE, in Bothell. The area is in the center of a light industrial/office park. The land uses closest to the BBN site (65 feet), a FTA Land Use Category 3, are multi-story office buildings and a large warehouse/manufacturing facility. The nearest existing residences are located 730 feet to the west on 214th Street SE and 930 feet to the north on 23rd Avenue SE, which are a FTA Land Use Category 2. The 220 Towns at Canyon Park residential development is currently under construction, located 325 feet southeast of the BBN site.

There is a walking trail, North Creek Trail, located 135 feet to the west of the BBN. The North Creek Trail is a regional multi-purpose trail through an industrial/commercial area that is adjacent to 20th Avenue SE. It is an active use recreational facility and is not noise sensitive in this location.

Figure 4-1 shows the location of the BBN, land use in the area, and the location of the two 24-hour noise measurements taken in the area: Site 1 at the walking trail 135 feet from the west side of the proposed facility and 720 feet from its center, and Site 2 at the 2020 Towns at Canyon Park site. At Site 1, the peak-hour existing ambient daytime $L_{eq}(h)$ of 65 dBA was measured at 1:00 to 2:00 p.m. and a peak-hour nighttime $L_{eq}(h)$ of 63 dBA was measured at 6:00 to 7:00 a.m.; the L_{dn} for the measurement period was 68 dBA. At Site 2, the peak-hour existing ambient daytime $L_{eq}(h)$ of 61 dBA was measured at 3:00 to 4:00 p.m. and a peak-hour nighttime $L_{eq}(h)$ of 55 dBA was measured at 6:00 to 7:00 a.m.; the L_{dn} for the measurement period was 59 dBA.

The 24 one-hour noise levels are shown on **Figure 4-2**. A 15-minute daytime noise sampling measurement was taken at Site A, the residences on 23rd Avenue SE and compared to the measurements conducted at the walking trail, Site 1. The existing noise levels at these two locations are within 2 dB of each other, which would indicate that the measured existing L_{dn} at the walking trail is representative of the existing levels at the 23rd Avenue SE residences.

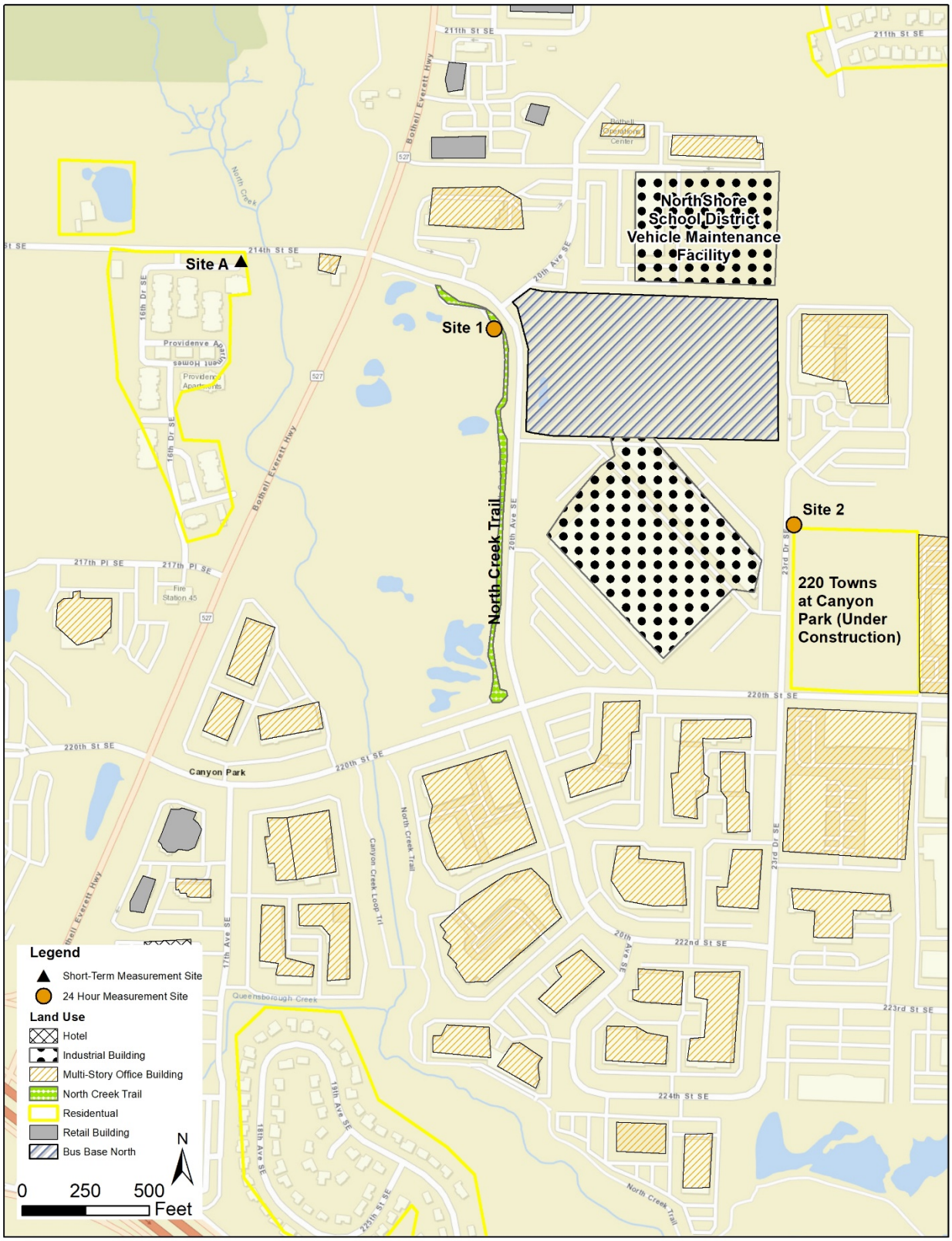


Figure 4-1 24-hour noise measurement locations and area land uses

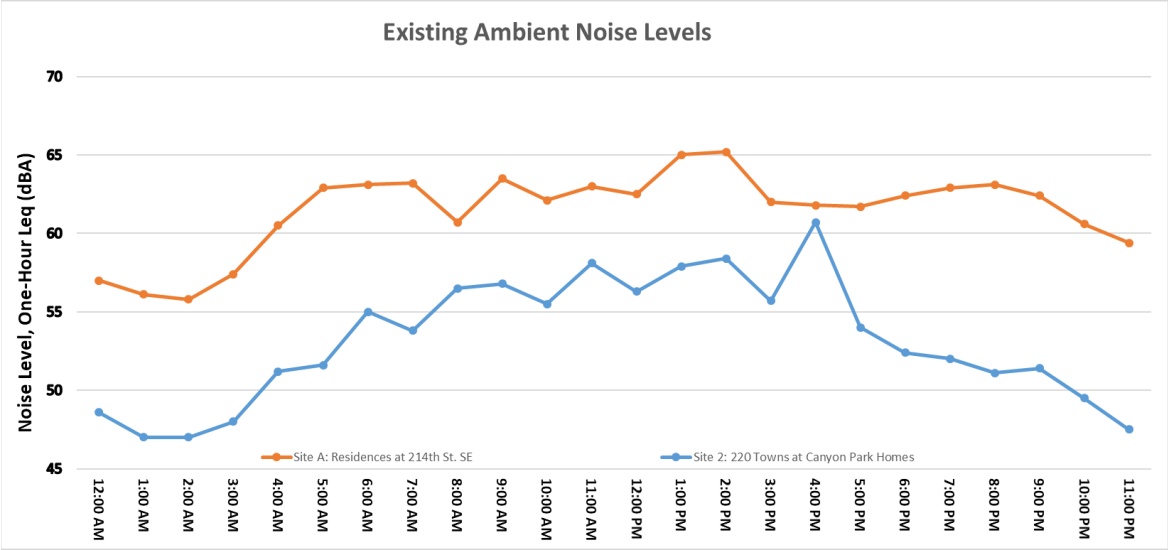


Figure 4-2 Existing ambient 24-hour noise levels at measurement site

4.2 Vibration

Primary existing sources of groundborne vibration include trucks traveling along roadways and construction using heavy equipment. According to FTA guidance, the background VdB levels are expected to range from 50 to 65. Ambient vibration levels were not measured as part of this study since the FTA vibration impact assessment is not based on the ambient levels but rather the FTA Vibration Impact Criteria. These criteria are used to identify vibration-sensitive receivers where potential impacts may occur based on existing land use activities. The only existing vibration-sensitive receivers are the residences on 214th Street SE, a FTA Land Use Category 2. The 220 Towns at Canyon Park residences are currently under construction, and would also be a FTA Land Use Category 2. The North Creek Trail, which is an outdoor land use, is not considered by FTA as vibration sensitive. The closest buildings that would be affected by the construction vibration would be a multi-story office building and a large warehouse/manufacturing facility 65 feet to the west of the BBN site. The damage risk criteria for these buildings would be a 0.5 in./sec PPV.

5 ENVIRONMENTAL IMPACTS

5.1 Construction impacts

5.1.1 Noise

The duration of construction for the proposed BBN project is anticipated to be approximately 24 months. Working hours of construction would vary to meet the type of work being performed. Most construction activities would adhere to Bothell's regulations to control construction noise, BMC 8.26.065, Construction Noise Hours, which limits construction noise to Monday through Friday between 7 a.m. and 8 p.m. and Saturday from 9 a.m. to 6 p.m. Construction noise is prohibited on Sunday and major holidays. However, for some portions of the work, construction at night and on Sundays is likely to occur to accommodate construction scheduling for specific work activities and to reduce potential street closures or disruption of traffic during the day.

The most constant noise source at construction sites is usually engine noise. Mobile equipment generally operates intermittently or in cycles of operation, while stationary equipment, such as generators and compressors, generally operates at constant sound levels. Trucks are present during most phases of construction and are not confined to the project site, so noise from trucks may affect more receivers than other construction noise. Noise levels during the construction period depend on the following:

- The type of construction methods establishes the maximum noise levels.
- The amount of construction activity establishes how often certain construction noises occur throughout the day.
- The location of construction equipment relative to adjacent properties determines the effect of distance in reducing construction noise levels.

The maximum noise levels of construction equipment are expected to be similar to the noise levels presented in **Table 5-1** and typically range from 76 to 88 dBA at 50 feet. The various pieces of equipment are almost never operating simultaneously at full power, and some would be powered off, idling, or operating at less than full power at any time.

Construction noise is allowed from 7:00 a.m. to 10:00 p.m. by the Bothell Noise Ordinance. During this time, the average noise levels from construction would be a 1-hour L_{eq} of 62 dBA at the residence on 214th Street 730 feet from the BBN construction and a 1-hour L_{eq} of 69 dBA at the 2020 Towns at Canyon Park residences currently under construction. Impact pile driving would be prohibited unless Sound Transit's contractor determines there is no feasible technical alternative, but it has been evaluated in case it is required. If impact pile driving is used for construction, a noise level of 85 dBA would occur at the 220 Towns at Canyon Park residences and 78 dBA at the existing residences on 214th Street SE. If the homes at the 220 Towns at Canyon Park are completed and occupied during construction of this project, these levels of noise during construction would be noticeable. Construction activities after 10:00 p.m. and before 7:00 a.m. would require a permit from the city.

Table 5-1 Construction equipment noise emission levels

Equipment	Typical noise level 50 feet from source, dBA
Air compressor	80
Backhoe	80
Compactor	82
Concrete mixer	85
Concrete pump	82
Concrete vibrator	76
Crane, derrick	88
Crane, mobile	83
Dozer	85
Excavator	82
Grader	85
Jack hammer	88
Loader	80
Paver	85
Pile driving (impact)	101
Pneumatic tool	85
Pump	77
Roller	85
Saw	76
Scraper	85
Shovel	82
Truck	84

SOURCE: FTA 2018
NOTES: dBA = A-weighted decibels

5.1.2 Vibration

Construction vibration varies greatly depending on the construction process, type of equipment used, and distance to the closest receivers. Many of these factors are traditionally left to the contractor's discretion, which makes it difficult to accurately estimate levels of construction vibration. Project designers usually try to minimize constraints on how the construction would be performed and what equipment would be used so that contractors can perform construction in the most cost-effective manner. Therefore, construction vibration estimates are approximate at this time, based on best professional judgement. The FTA has provided guidance for assessing construction vibration associated with transit projects. The vibration criteria are based on potential damage risk to buildings (see **Table 3-5** in Section 3.2.1.2). The FTA standards are used in this analysis to assess building damage risk from construction vibrations.

Equipment expected to be used during construction is listed in **Table 5-2** along with the predicted vibration levels at 25 feet.

Table 5-2 Construction vibration levels

Equipment		Vibration level at 25 feet (in/sec PPV)
Pile driver (impact)	Upper range	1.518
	Typical	0.644
Large bulldozer		0.089
Caisson drilling		0.089
Small bulldozer		0.003
Jack hammer		0.035
Hoe ram		0.089
Loaded truck		0.076
Vibratory roller		0.210

SOURCE: FTA, 2018
NOTES: in/sec = inches per second; PPV = peak particle velocity

Impact pile driving would be prohibited unless Sound Transit's contractor determines there is no feasible technical alternative, but it has been evaluated in case it is required. If used, the closest impact pile driving would likely occur at a distance of 50 feet or more from the BBN property boundary resulting in a predicted groundborne vibration level of 0.228 in/sec (PPV), which would not exceed the FTA building damage risk criteria of 0.50 in/sec (PPV). The predicted impact pile driving vibration levels at the 214th Street SE residences and the 220 Towns at Canyon Park residences would be in the range of 0.004 in/sec (PPV) to 0.014 in/sec (PPV), which is substantially lower than the FTA damage risk criteria.

With the exception of impact pile driving, the other vibration-generating activities would not be noticeable at the closest buildings to the BBN site. Construction vibration at any of these locations would not result in risk of building damage during either impact pile driving or other construction activities.

5.2 Long-term impacts

5.2.1 Noise

The predicted noise levels of the BBN based on the FTA General Noise Assessment are presented in **Table 5-3** and **Table 5-4** based on the Washington state assessment.

Table 5-3 Predicted BBN noise levels FTA assessment

Receiver location	FTA land use category	Existing noise level, dBA	Predicted BBN noise levels	FTA noise impact threshold	Impact (Y/N)
Residences at 214th Street SE	2	L_{dn}=68 dBA	L_{dn}=43 dBA	L_{dn}=63 dBA	N
220 Towns at Canyon Park (under construction)	2	L_{dn}=59 dBA	L_{dn}=47 dBA	L_{dn}=58 dBA	N

NOTES: BBN = Bus Base North; dBA = A-weighted decibels; FTA = Federal Transit Administration; L_{dn}= day/night sound level; Y/N = yes/no

Table 5-4 Predicted BBN noise levels Washington state assessment

Receiver location	Existing daytime noise level, dBA	Predicted BBN noise levels	WAC noise impact threshold	Impact (Y/N)
Residences at 214th Street SE	Daytime L_{eq}=65 dBA	Daytime L_{eq}=34 dBA	Daytime L_{eq}=55 dBA	N
	Nighttime L_{eq}=63 dBA	Nighttime L_{eq}=35 dBA	Nighttime L_{eq}=45 dBA	N
220 Towns at Canyon Park (under construction)	Daytime L_{eq}=56 dBA	Daytime L_{eq}=40 dBA	Daytime L_{eq}=55 dBA	N
	Nighttime L_{eq}=50 dBA	Nighttime L_{eq}=41 dBA	Nighttime L_{eq}=45 dBA	N

NOTES: BBN = Bus Base North; dBA = A-weighted decibels, L_{eq}= equivalent noise level; WAC = Washington Administrative Code; Y/N = yes/no

The FTA noise impact thresholds and Bothell daytime and nighttime noise impact thresholds at the closest existing residential receiver on 214th Street SE, and the 2020 Towns at Canyon Park residences under construction, are not predicted to be exceeded. No long-term operational noise impact is predicted at these receivers.

5.2.2 Vibration

Based on the FTA Vibration Screening Assessment, residential receivers that are farther than 50 feet from the bus base would not be impacted by vibrations from the long-term operations of the bus base. No further vibration assessment is needed since the closest sensitive receiver is the future site of the proposed Canyon Park Apartments 150 feet west of the BBN and the 220 Towns Canyon Park Homes, currently under construction, 325 feet to the west of the BBN on 219th Place SE.

6 MITIGATION MEASURES

No measures are anticipated to be needed to mitigate future impacts. The following are noise and vibration control practices that will be implemented as part of the project as summarized below.

6.1 Construction impacts

6.1.1 Noise

Prior to construction as part of final design, Sound Transit would revise the noise and vibration analysis with updated design and construction information. The revised analysis would be presented as part of an updated Noise and Vibration Analysis and Control Plan, which would specify methods that the contractor would implement to minimize construction equipment noise and vibration levels at sensitive receivers.

If the updated analysis indicates a potential exceedance of FTA noise impact guidelines, measures and best practices would be identified in the updated Noise and Vibration Analysis and Control Plan and implemented to minimize noise levels. These measures could include but would not be limited to the following:

- Use low-noise emission equipment
- Use broadband backup warning devices on all vehicles
- Implement noise-deadening measures for truck loading and operations
- Conduct monitoring and maintenance of equipment to meet noise limits
- Use acoustic enclosures, shields, or shrouds for equipment and facilities
- Install high-grade engine exhaust silencers and engine-casing sound insulation
- Minimize the use of generators
- Use movable noise barriers at the source of the construction activity
- Using noise-reducing shrouds on pile drivers
- Using alternative pile driving methods such as vibratory hammers, hydraulic press-in driving, auger, or pre-drilled pile holes

6.1.2 Vibration

Building damage or annoyance from construction vibration is not anticipated from the project due to the type of construction and distance between the site and any nearest receivers. If necessary, mitigation measures would be implemented, such as construction vibration monitoring and low-impact construction equipment and methods.

6.2 Long-term impacts

No mitigation measures would be needed for long-term operational noise or vibration from the BBN project.

7 REFERENCES

Federal Transit Administration (FTA). 2018.*Transit Noise and Vibration Impact Assessment.*

Sound Transit. 2016. *Sound Transit 3 (ST3) System Plan.*

Washington State Administrative Code (WAC), Chapter 173-60 Maximum Environmental Noise Levels.

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