LINK LIGHT RAIL OPERATIONS AND MAINTENANCE SATELLITE FACILITY

DRAFT ENVIRONMENTAL IMPACT STATEMENT

APPENDIX E.2

Noise and Vibration Technical Report

May 2014

SOUNDTRANSIT

CENTRAL PUGET SOUND
REGIONAL TRANSIT AUTHORITY

U.S. Department of Transportation
Federal Transit Administration

NOISE AND VIBRATION TECHNICAL REPORT

LINK LIGHT RAIL OPERATIONS AND MAINTENANCE SATELLITE FACILITY
DRAFT ENVIRONMENTAL IMPACT STATEMENT

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Contract # AE 0089-10
HZI Contract # 15105001
MMA-001.00

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May 2014

Contents

List of Tables iii
List of Figures iv
List of Acronyms and Abbreviations v

Chapter 1 Introduction 1-1
1.1 Project Alternatives 1-1
1.1.1 No Build Alternative 1-2
1.1.2 Lynnwood Alternative 1-2
1.1.3 BNSF Alternative 1-3
1.1.4 BNSF Modified Alternative 1-3
1.1.5 SR 520 Alternative 1-3
1.2 Analysis Requirements 1-3
Chapter 2 Introduction to Noise and Vibration 2-1
2.1 Introduction to Noise 2-1
2.1.1 General Acoustical Rules 2-3
2.2 Introduction to Vibration 2-4
Chapter 3 Noise and Vibration Impact Criteria 3-1
3.1 FTA Noise Criteria 3-1
3.2 FTA Vibration Criteria 3-3
3.3 Construction Vibration 3-5
3.4 Washington Administrative Code 3-6
3.4.1 Washington State Construction Noise Regulations 3-7
3.5 City of Lynnwood Noise Regulations 3-8
3.6 City of Bellevue Noise Regulations 3-8
Chapter 4 Existing Land Use Noise Levels 4-1
4.1 Lynnwood Alternative 4-1
4.2 BNSF Alternative and BNSF Modified Alternative 4-2
4.3 SR 520 Alternative 4-7
Chapter 5 Impact Assessment Approach 5-1
5.1 Noise Assessment Approach 5-1
5.2 Light Rail Vibration Assessment Approach 5-3
Chapter 6 Impact Assessment 6-1
6.1 No Build Alternative 6-1
6.2 Lynnwood Alternative 6-1
6.2.1 Design Options C1 and C2 6-1
6.2.2 Design Option C3 6-4
6.2.3 BNSF Storage Tracks 6-5

6.3 BNSF Alternative ... 6-5
6.3.1 Noise Impacts ... 6-6
6.3.2 Vibration Impacts ... 6-6
6.4 BNSF Modified Alternative ... 6-7
6.4.1 Noise Impacts ... 6-7
6.4.2 Vibration Impacts ... 6-8
6.5 SR 520 Alternative ... 6-8
6.5.1 Noise Impacts ... 6-8
6.5.2 Vibration Impacts ... 6-9
6.6 Construction Impacts ... 6-9
6.6.1 Construction Noise ... 6-9
6.6.2 Construction Vibration ... 6-12
Chapter 7 Mitigation ... 7-1
7.1 No Build Alternative ... 7-1
7.2 Lynnwood Alternative ... 7-1
7.2.1 Design Options C1 and C2 ... 7-1
7.2.2 Design Option C3 ... 7-3
7.3 BNSF Alternative, BNSF Modified Alternative, and SR 520 Alternative ... 7-3
7.4 Construction Mitigation ... 7-3
7.4.1 Equipment Noise Mitigation ... 7-4
7.4.2 Construction Methods Noise Mitigation ... 7-4
7.4.3 Construction Vibration Mitigation ... 7-5
Chapter 8 Cumulative Analysis ... 8-1
8.1 Lynnwood Alternative ... 8-1
8.1.1 Design Options C1 and C2 ... 8-1
8.1.2 Design Option C3 ... 8-1
8.2 BNSF Alternative ... 8-2
8.3 BNSF Modified Alternative ... 8-2
8.4 SR 520 Alternative ... 8-2
Chapter 9 References ... 9-1

Attachment A. Cumulative Noise Level Tables

Tables

Page

Table 3-1. FTA Vibration Impact Criteria for Frequent Events* 3-5

Table 3-2. Effects of Construction Vibration 3-6

Table 3-3. Washington State Noise Ordinance 3-7

Table 4-1. Lynnwood Alternative Measurement Results 4-2

Table 4-2. BNSF Alternative and BNSF Modified Alternative Noise Measurement Results 4-4

Table 4-3. SR 520 Alternative Noise Measurement Results 4-7

Table 6-1. Noise Impacts for the Lynnwood Alternative, Design Options C1 and C2 6-2

Table 6-2. Noise Impacts for the Lynnwood Alternative, Design Option C3 6-5

Table 6-3. Noise Impacts for the BNSF Alternative 6-6

Table 6-4. Noise Impacts for the BNSF Modified Alternative 6-7

Table 6-5. Noise Impacts for the SR 520 Alternative 6-9

Table 6-6. Construction Equipment List, Use, and Maximum Noise Levels 6-10

Table 6-7. Maximum Noise Levels for Typical Construction Phases 6-11

Table 6-8. Vibration Levels for Typical Construction Equipment 6-13

Table 7-1. Noise Impacts and Mitigation for Lynnwood Alternative, Design Options C1 and C2 7-3

Figures

Page

Figure 2-1. Typical A-Weighted Sound Levels....2-2

Figure 2-2. Typical Ldn Levels....2-3

Figure 2-3. Typical RMS Vibration Levels....2-5

Figure 3-1. FTA Noise Impact Criteria....3-3

Figure 4-1. Lynnwood Alternative—Land Use and Monitoring Locations....4-3

Figure 4-2. BNSF Alternative—Land Use and Monitoring Locations....4-5

Figure 4-3. BNSF Modified Alternative—Land Use and Monitoring Locations....4-6

Figure 4-4. Land Use and Monitoring Locations—SR 520 Alternative Site....4-8

Figure 6-1. Lynnwood Alternative, Design Options C1 and C2— Noise Impact Locations....6-3

Figure 7-1. Lynnwood Alternative, Design Options C1 and C2—Noise Mitigation Measures....7-2

Acronyms and Abbreviations

ANSI	American National Standards Institute
BCC	Bellevue City Code
CFR	Code of Federal Regulations
dB	decibel
dBA	decibel with A-weighting
DNL	day-night equivalent sound level (see also Ldn)
DNR	Department of Natural Resources
EDNA	Environmental Designation for Noise Abatement
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HUD	Department of Housing and Urban Development
Hz	hertz
I-5	Interstate 5
in/sec	inches per second
Ldn	24-hour, time-averaged, A-weighted sound level (day-night)
Leq	equivalent continuous sound level
LMC	Lynnwood Municipal Code
mph	miles per hour
NAC	Noise Abatement Criteria
NEPA	National Environmental Policy Act
NIST	National Institute of Standards and Technology
SEPA	State Environmental Act
Sound Transit	Central Puget Sound Regional Transit Authority
SR	State Route
ST2	Sound Transit 2: A Mass Transit Guide, The Regional Transit System Plan for Central Puget Sound
WAC	Washington Administrative Code

Chapter 1
Introduction

1.1 Project Alternatives

Four build alternatives were identified by the Sound Transit Board for evaluation in the Sound Transit Link Light Rail Operations and Maintenance Satellite Facility (OMSF) Draft Environmental Impact Statement (EIS). The EIS discusses the potential environmental impacts that may result from construction and operation of the proposed project under each of these build alternatives. In addition, the potential environmental impacts that may result from the No Build Alternative, the conditions that would exist if the proposed project were not implemented, are also discussed to provide a baseline for comparing the potential impacts of the build alternatives.

All four build alternatives would involve construction and operation of the following site features:

- An enclosed light rail vehicle (LRV) maintenance building containing service bays for maintaining LRVs that would include the following activities and equipment.
    - Exterior LRV washing area
    - Interior LRV cleaning area
    - General service, inspection, and repair bays
    - Wheel truing
    - Equipment and parts storage
    - Shipping and receiving
    - Electronics shop
    - Welding and fabrication shop
    - Brake and coupler shop
- Office space attached to the shop building containing the following items.
    - Individual offices and workspaces
    - Conference rooms
    - Training room
    - Fitness room
    - Lunch/break room
    - Lockers
    - Restrooms
- Track, switches, catenary power lines, a traction power substation, and signals to support movement of LRVs to and from the mainline and around the facility through the LRV maintenance building and LRV storage area.
- Lead track to provide access between the OMSF and light rail system mainline.

1.1.1 No Build Alternative

Under the No Build Alternative, an OMSF would not be built. The operations and maintenance support needs for the existing and currently planned and funded Link light rail system would be served by the existing Forest Street Operations and Maintenance Facility (OMF) south of downtown Seattle. The Forest Street OMF has the capacity to maintain up to 104 LRVs, 76 fewer than the minimum number of LRVs needed to operate the system at planned service levels.

1.1.2 Lynnwood Alternative

Under the Lynnwood Alternative, Sound Transit would construct the OMSF north of Interstate 5 (I-5) and east of 52nd Avenue W/Cedar Valley Road in the City of Lynnwood. The Lynnwood OMSF site is approximately 24 acres with approximately nine to thirteen acres at the site that would remain for redevelopment, and is located along the proposed Lynnwood Link Extension alignments being evaluated as build alternatives in the *Lynnwood Link Extension Draft EIS* (Sound Transit 2013). A Lynnwood Link Extension alternative has yet to be selected; therefore, the Lynnwood Alternative for the OMSF includes three design options, each connecting to one of the three build alternatives being evaluated in the *Lynnwood Link Extension Draft EIS* (Sound Transit 2013).

- **Design Option C1.** Design Option C1 would include lead track connecting to Lynnwood Link Extension Alternative C1. Under Lynnwood Link Extension Alternative C1, the light rail alignment is located in the middle of I-5, and under Lynnwood Link Extension Alternative C1 the alignment is located along the west side of I-5, between the freeway and nearby homes.
- **Design Option C2.** Design Option C2 would include lead track connecting to Lynnwood Link Extension Alternative C2. Under Lynnwood Link Extension Alternative C2, the light rail alignment is located in the middle of I-5, and under Lynnwood Link Extension Alternative C2 the alignment is located along the west side of I-5, between the freeway and nearby homes.
- **Design Option C3.** Design Option C3 would include lead track connecting to Lynnwood Link Extension Alternative C3. Under Lynnwood Link Extension Alternative C3, the light rail alignment is located in the middle of I-5, and under Lynnwood Link Extension Alternative C3 the alignment is located along the west side of I-5, between the freeway and nearby homes.

Because of operational constraints involved with moving LRVs serving the area east of Lake Washington from the Forest Street OMF in Seattle or from an OMSF north of Seattle, LRV storage, operator report facilities, and interior cleaning functions for up to 32 LRVs would be needed at a secure location on the Eastside. As currently designed, East Link includes overnight storage and operator report facilities for up to 16 LRVs located within the Sound Transit-owned Eastside Rail Corridor north of NE 12th Avenue and south of State Route (SR) 520 in the City of Bellevue. Additional LRV storage and ancillary facilities associated with the Lynnwood Alternative would be located in the same Eastside Rail Corridor in Bellevue to provide morning service to the east side. The site is approximately 11 acres, including 10 acres to remain for redevelopment.

1.1.3 BNSF Alternative

Under the BNSF Alternative, Sound Transit would construct the OMSF on property located between the Eastside Rail Corridor on the west and 120th Avenue NE on the east, south of SR 520 and north of NE 12th Street in the City of Bellevue. This OMSF site is approximately 23 acres with approximately four surplus acres available for redevelopment, and is located along the adopted East Link revenue line northwest of the 120th Avenue NE station. OMSF infrastructure would occupy most of the site leaving the southern portion available for other development.

1.1.4 BNSF Modified Alternative

Under the BNSF Modified Alternative, Sound Transit would construct the OMSF on both sides of the Eastside Rail Corridor off of 120th Avenue NE on the east, south of SR 520 and north of NE 12th Street in the City of Bellevue. This site is located along the adopted East Link revenue line and is approximately 24 acres with an additional approximately 8 acres that would remain for future redevelopment. The storage tracks would be concentrated on the western portion of the site, west of the rail corridor. Other OMSF facilities would be located adjacent to the east side of the rail corridor, leaving the frontage area along 120th Avenue NE available for other development.

1.1.5 SR 520 Alternative

Under the SR 520 Alternative, Sound Transit would construct the OMSF south of SR 520 and north of Northup Way/NE 20th Street, east of 130th Avenue NE and west of 140th Avenue NE in the City of Bellevue. This site is located along the adopted East Link revenue line and is approximately 25 acres.

1.2 Analysis Requirements

This noise and vibration analysis of the proposed OMSF was prepared as required by the FTA for any federal funded component of a major transportation project. The analysis was performed using the methods provided in the *Transit Noise and Vibration Impact Assessment manual* (Federal Transit Administration 2006) (hereafter referred to as the FTA manual) and is part of an environmental impact statement (EIS) for the proposed project.

Chapter 2
Introduction to Noise and Vibration

The following sections include background information on noise and vibration. This information is necessary in order to fully understand the noise and vibration impact criteria provided in Section 3 along with the results of the noise and vibration impact assessment and mitigation measures.

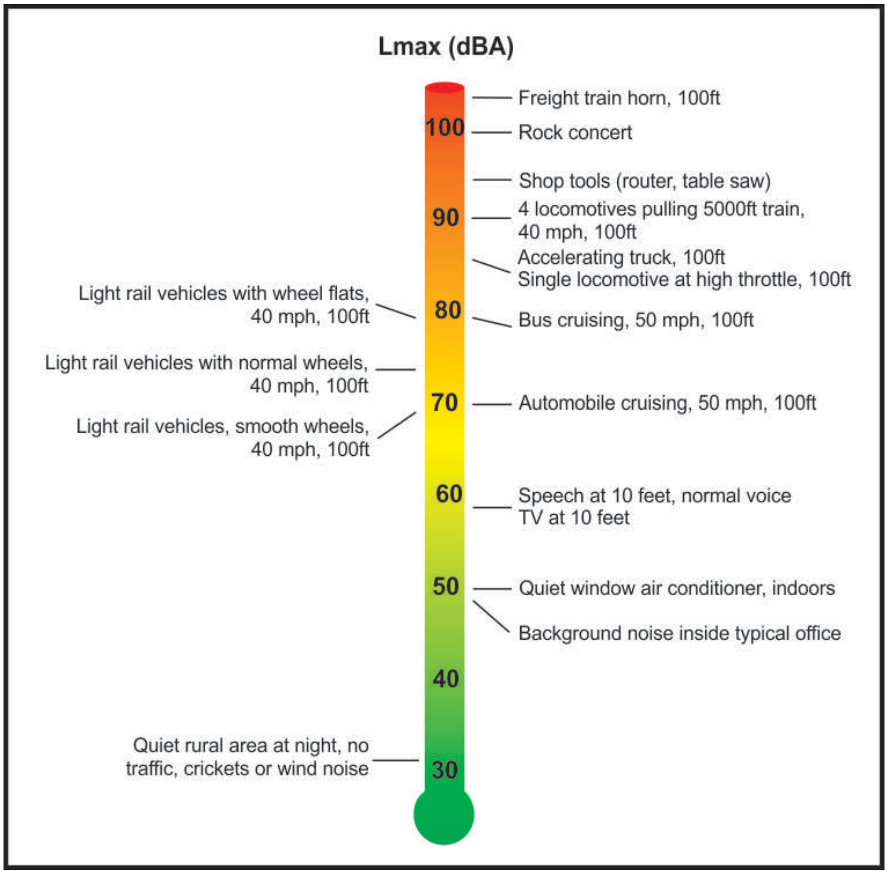
2.1 Introduction to Noise

What we hear as sound is a series of continuous air pressure fluctuations superimposed on the atmospheric pressure that surrounds us. The amplitude of fluctuation is related to the energy carried in a sound wave; the greater the amplitude, the greater the energy and the louder the sound. The full range of sound pressures encountered in the world is so great that it is more convenient to compress the range by using a logarithmic scale, resulting in the fundamental descriptor used in acoustics, the sound pressure level, in decibels (dB). When sounds are unpleasant, unwanted, or disturbingly loud, we tend to classify them as noise.

Another aspect of sound is the quality described as its pitch. Pitch is established by frequency, which is a measure of how rapidly a sound wave fluctuates as measured in cycles per second or Hertz (Hz). Most sounds are a composite of many individual frequencies. When a sound is analyzed, its energy content at individual frequencies is displayed over the frequency range of interest, usually the range of human audibility, from about 20 Hz to about 20,000 Hz. This display is called a frequency spectrum.

Sound is measured using a sound level meter with a microphone designed to respond accurately to all audible frequencies. The human hearing system does not respond equally to all frequencies. Low frequency sounds below about 400 Hz are progressively and severely attenuated, as are high frequencies above 10,000 Hz. To approximate the way humans interpret sound, a filter circuit with frequency characteristics similar to the human hearing mechanism is built into sound level meters. Measurements with this filter enacted are called A-Weighted Sound Levels (dBA). Community noise is usually characterized in terms of the A-weighted sound level. Figure 2-1 illustrates the A-weighted levels of common sounds. When sounds exceed 110 dBA, there is a potential for hearing damage, even with relatively short exposures. In quiet suburban areas far from major freeways, the noise levels during the late night hours will drop to about 30 dBA. Outdoor noise levels lower than this only occur in isolated areas where there is a minimum of natural noises such as leaves blowing in the wind, crickets, or flowing water.

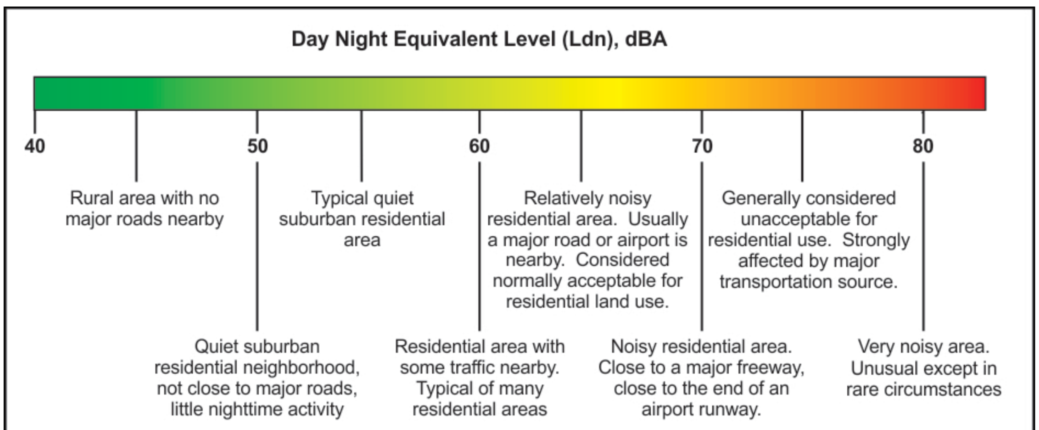
Figure 2-1. Typical A-Weighted Sound Levels



Another characteristic of environmental noise is that it is constantly changing. The noise level increase when a train passes is an example of a short-term change. The lower average noise levels during nighttime hours, when human activities are at a minimum, and the higher noise levels during daytime hours are daily patterns of noise level fluctuation. The instantaneous A-weighted sound level is insufficient to describe the overall acoustic "environment." Thus, it is common practice to condense the fluctuating noise levels into a single number, called the “equivalent” sound level (Leq). Leq can be thought of as the steady sound level that represents the same sound energy as the varying sound levels over a specified time period (typically 1 hour or 24 hours). Often the Leq values over a 24-hour period are used to calculate cumulative noise exposure in terms of the Day-Night Equivalent Sound Level (Ldn, also abbreviated DNL), which is defined as the 24-hour Leq but with a 10-dB penalty assessed to noise events occurring at night (defined as 10:00 p.m. to 7:00 a.m.). The effect of this penalty is that any event during the nighttime hours is equivalent to ten events during the daytime hours. This strongly weights Ldn toward nighttime noise to reflect the fact that most people are more easily annoyed by noise during the nighttime hours, when background noise is lower and most people are sleeping.

Environmental impact assessments for high capacity transit projects in the United States typically use Ldn to describe the community noise environment. Studies of community response to a wide variety of noises indicate that Ldn is a good measure of noise environment. Efforts to derive measures that are better correlated to community response have not been successful, although there are still efforts in the acoustical community to develop improved measures. Figure 2-2 defines typical community noise levels in terms of Ldn. Most urban and suburban neighborhoods will be in the range of Ldn 50 to 70 dBA. An Ldn of 70 dBA is a relatively noisy environment that might be found at buildings on a busy surface street, close to a freeway or near a busy airport. It would usually be considered unacceptable for residential land use without special measures taken to enhance outdoor-indoor sound insulation. Residential neighborhoods that are not close to major sound sources will usually be in the range of Ldn 55 to 60 dBA. If there is a freeway or moderately busy arterial nearby, or any nighttime noise, Ldn is usually in the range of 60 to 65 dBA. In recent times, many urban developments have combined retail, light commercial and other non-residential uses with residential uses in a mixed-use environment. Because of these mixed-use developments, ambient noise levels in some urban environments may be slightly higher than the levels provided in Figure 2-2.

Figure 2-2. Typical Ldn Levels



Source: FTA 2006

2.1.1 General Acoustical Rules

The following list contains some general rules for community noise:

- A 3 dB change is the minimum most people will notice in most environments.
- Under free-field conditions, where there are no reflections or additional attenuations, a point sound source is known to decrease at a rate of 6 dB for each doubling of distance. This is commonly known as the inverse square law. For example, a sound level of 70 dB at a distance of 100 feet would decrease to 64 dB at 200 feet. However, traffic on roadways and LRVs are considered line sources, and reduce at approximately 3 dB for each doubling of distance.
- Sounds such as sirens, bells, and horns are more noticeable than broadband noise sources, such as traffic.
- A 10 dB increase in sound level is perceived as an approximate doubling of the loudness of the sound and represents a substantial change in loudness.

- An important factor to recognize is that noise is measured on a decibel scale, and combining two noises is not achieved by simple addition. For example, combining two 60 dBA noises does not give 120 dBA (which is near the pain threshold), but yields 63 dBA, which is lower than the volume at which most people listen to their TVs.

2.2 Introduction to Vibration

Groundborne vibration consists of oscillatory waves that propagate from the source through the ground to adjacent buildings. On steel-wheel/steel-rail train systems, groundborne vibration is created by the interaction of the steel wheels rolling on the steel rails. Although the vibration is sometimes noticeable outdoors, it is almost exclusively an indoor problem. Additionally, trains operating at the build alternative sites would not produce sufficient vibration even to cause minor cosmetic damage to nearby buildings.

The primary concern is that the vibration and radiated noise can be intrusive and annoying to building occupants. The building vibration caused by groundborne vibration may be perceived as motion of building surfaces; rattling of windows, items on shelves, or pictures hanging on walls; or as a low-frequency rumbling noise, which is referred to as groundborne noise. Factors that influence the amplitudes of groundborne vibration include vehicle suspension parameters, condition of the wheels and rails, type of track, track support system, type of building foundation, and the properties of the soil and rock layers through which the vibration propagates. Use of continuously welded rails eliminates wheel impacts at rail joints and results in notably lower vibration levels than with jointed rails.

Groundborne vibration is not a widespread environmental problem, and it is generally limited to localized areas near rail systems, construction sites, and some industrial operations. Road traffic rarely creates perceptible groundborne vibration except when there are bumps, potholes or other discontinuities in the road surface. When traffic causes phenomena such as rattling of windows, the cause is more likely to be "acoustic excitation" rather than groundborne vibration. The unusual situations where traffic or other existing sources are causing intrusive vibration can be an indication of geologic conditions that would result in higher than normal levels of train vibration.

Low-frequency noise caused by sound radiated from vibrating room surfaces is referred to as groundborne noise. Groundborne vibration and groundborne noise are really the same phenomenon; they only differ in the manner in which they are perceived by the building occupants. It is extremely rare for train-generated groundborne vibration to be of sufficient amplitude to cause even minor cosmetic building damage. The main concern is that building occupants will find the vibration intrusive, particularly late at night or early in the morning when they are trying to sleep. Although all vehicular traffic causes groundborne vibration, the vibration is not usually perceptible because of the vibration isolation characteristics of the pneumatic tires and the suspension systems.

Vibration is an oscillatory motion that can be described in terms of the displacement, velocity, or acceleration of the oscillations. Groundborne vibration is usually characterized in terms of the vibration velocity because, over the frequency range relevant to groundborne vibration (about 1 to 200 Hz); both human and building response tends to be more proportional to velocity than either displacement or acceleration. Vibration velocity is usually given in terms of either inches per second or decibels.

The following equation defines the relationship between vibration velocity in inches per second and decibels.

Lv = 20 x log (V/Vref);

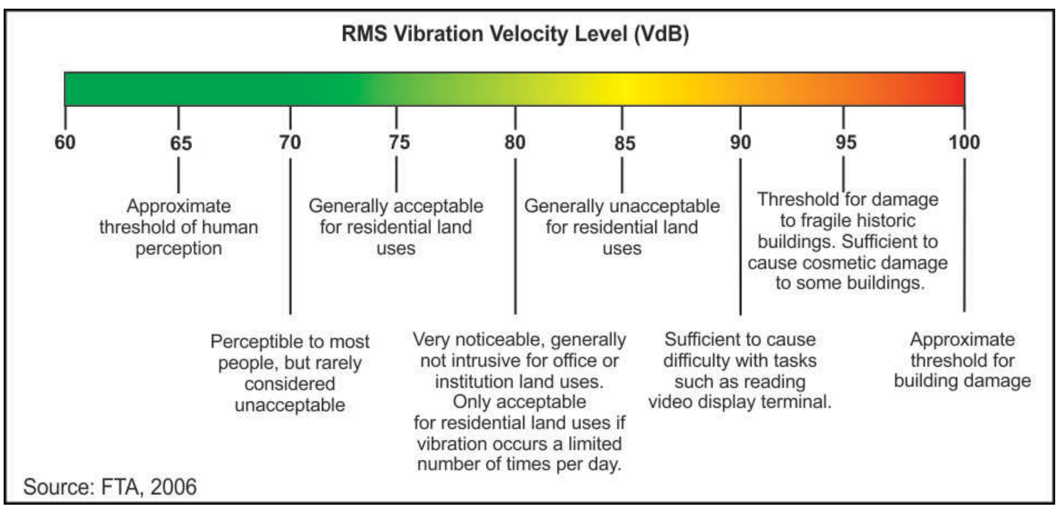
where V is the velocity amplitude in inches/second, Vref is 10-6 inches/second, Lv is the velocity level in decibels.

Vibration decibels (VdB) are abbreviated in this report, to minimize confusion with sound decibels.

Train vibration is virtually always characterized in terms of the root-mean-square (RMS) amplitude. RMS is a widely used but sometimes confusing method of characterizing vibration and other oscillating phenomena. It represents the average energy over a short time interval; typically, a one second interval is used to evaluate human response to vibration. RMS vibration velocity is considered the best available measure of potential human annoyance from groundborne vibration.

Figure 2-3 gives a general idea of human and building response to different levels of vibration. Existing background building vibration is usually in the range of 40 to 50 VdB, which is well below the range of human perception. Although the perceptibility threshold is about 65 VdB, human response to vibration is usually not bothersome unless the RMS vibration velocity level exceeds 70 to 75 VdB. This is a typical level 50 feet from a rapid transit or light rail system. Buses and trucks rarely create vibration that exceeds 70 VdB unless there are large bumps or potholes in the road.

Figure 2-3. Typical RMS Vibration Levels



Chapter 3
Noise and Vibration Impact Criteria

Several different criteria were evaluated for applicability to the OMSF noise and vibration analysis. These include the FTA manual, WAC, and local criteria from the City of Bellevue and the City of Lynnwood. As required by the FTA, if the light rail project includes any modifications to existing roadways that change the vertical or horizontal alignment, add new lanes, or includes a new roadway, the project must consider potential traffic noise impacts in accordance with the Federal Highway Administration (FHWA) standards and regulations. There are no roadway modifications planned as part of the proposed project, and therefore no discussion of the FHWA standards is necessary. All other applicable noise and vibration criteria and methods used for the noise studies are provided in the following sections.

3.1 FTA Noise Criteria

Transit noise impacts for this project are determined based on the criteria defined in the FTA guidance manual. The FTA noise impact criteria are based on documented research on community reaction to noise. The criteria for noise impacts is based on a sliding scale, which uses the existing noise levels as a basis for setting the actual impact level. Although more transit noise is allowed in neighborhoods with high levels of existing noise, as the existing noise levels increase, a smaller increase in the total noise exposure is allowed when compared to areas with lower existing noise levels. The FTA noise impact criteria also groups noise-sensitive land uses into the following three categories.

- **Category 1.** Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use. Also included in this category are recording studios and concert halls.
- **Category 2.** Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
- **Category 3.** Institutional land uses with primarily daytime and evening use. This category includes 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 considered to be in this category. Certain historical sites and parks are also included.

The FTA guidance manual provides details on how parks are analyzed for noise in Chapter 3, Section 2, Application of Noise Impact Criteria, of the manual. The FTA assumes that parks are a special case, and how they are used and where they are located should be considered when considering whether or not a particular park, or an area in a park, is considered noise-sensitive. Parks that are used for outdoor recreation are typically not considered noise-sensitive. This includes parks with baseball diamonds, soccer fields, basketball courts, football fields, and other active recreation areas.

Parks that are noise-sensitive would be those where quiet is an essential element in their intended purpose or places where it is important to avoid interference with activities such as speech, meditation, and reading. The existing noise levels at a park can provide some indication of the sensitivity of its use.

All parks along the project corridor were evaluated for consideration under the FTA criteria. Based on the park locations and existing noise levels, no parks, except for Scriber Creek Park, met the requirements for noise sensitivity under the FTA Category 3 criteria. Hours of operation are considered when performing a noise analysis on a park. The City of Lynnwood website has information on parks, and states that this park, along with all other Lynnwood parks, is only open during daylight hours (dusk to dawn).

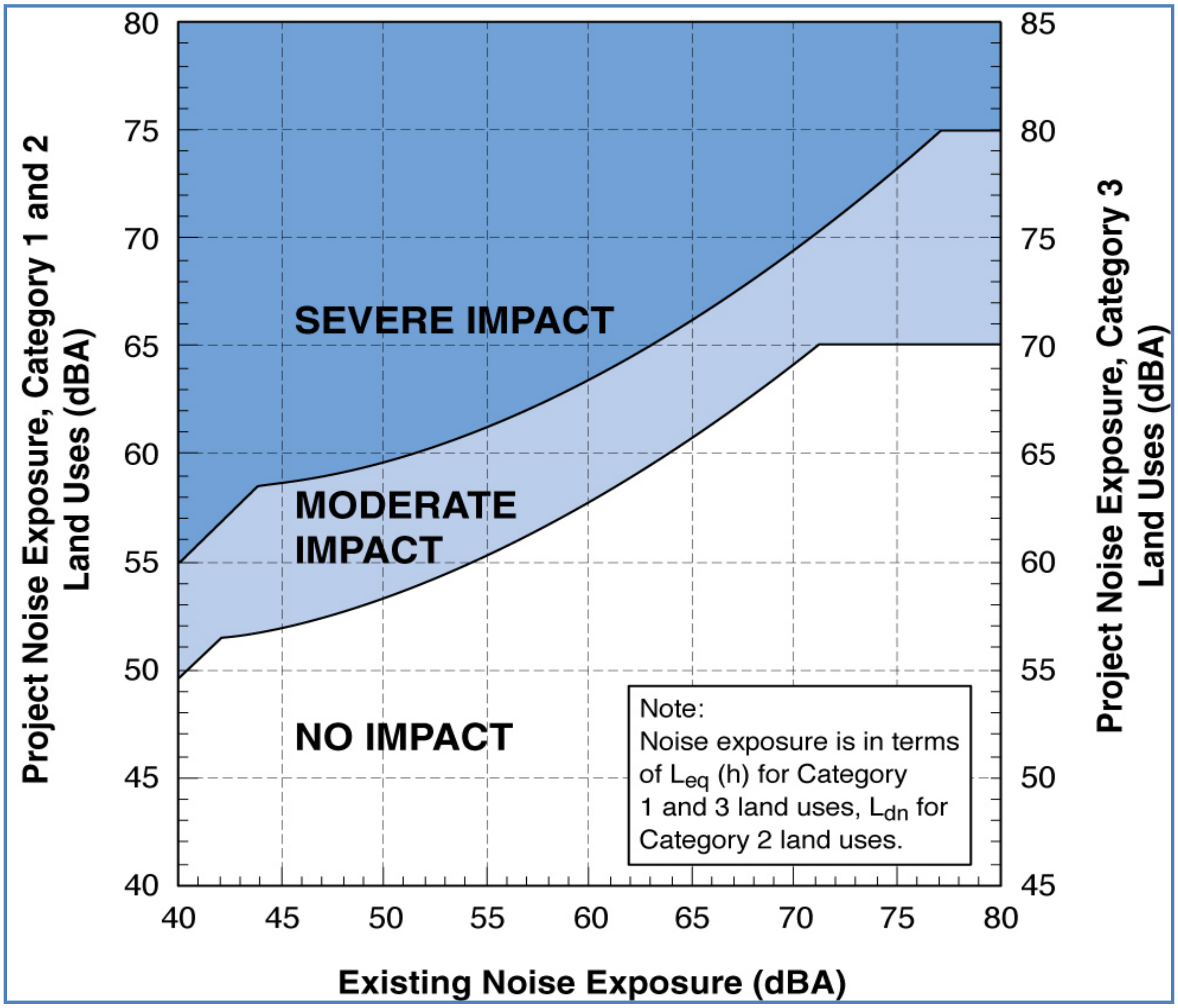
The Ldn is used to characterize noise exposure for residential areas (Category 2). For other noise-sensitive land uses, such as outdoor amphitheaters and school buildings (Categories 1 and 3), the maximum 1-hour Leq during the facility’s operating period is used. There are no noise impact criteria for most commercial and industrial land uses.

There are two levels of impact included in the FTA criteria: severe and moderate, interpreted as follows:

- **Severe Impact.** Project-generated noise in the severe impact range can be expected to cause a large percentage of people to be highly annoyed by the new noise and represents the most compelling need for mitigation. Noise mitigation will normally be specified for severe impact areas unless there are truly extenuating circumstances that prevent it.
- **Moderate Impact.** In this range of noise impact, the change in the cumulative noise level is noticeable to most people but may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These factors include the existing level, the projected level of increase over existing noise levels, the types and numbers of noise-sensitive land uses affected, the noise sensitivity of the properties, the effectiveness of the mitigation measures, community views, and the cost of mitigating noise to more acceptable levels.

The FTA noise impact criteria are summarized in graphical form in Figure 3-1, which shows the existing noise exposure and the additional noise exposure from the transit project that would cause either moderate or severe impact. The future noise exposure would be the combination of the existing noise exposure and the additional noise exposure caused by the transit project.

Figure 3-1. FTA Noise Impact Criteria



Source: Federal Transit Administration 2006.

3.2 FTA Vibration Criteria

FTA has developed impact criteria for acceptable levels of groundborne noise and vibration. Groundborne noise is sometimes associated with subterranean transit projects and is not a concern for the proposed project because the alignment will be elevated or at-grade. Experience with groundborne vibration from rail systems and other common vibration sources suggests that:

- Groundborne vibration from transit trains should be characterized in terms of the RMS vibration velocity amplitude. A one-second RMS time constant is assumed. This is in contrast to vibration from blasting and other construction procedures that have the potential of causing building damage. When looking at the potential for building damage, groundborne vibration is usually expressed in terms of the peak particle velocity (PPV).
- The threshold of vibration perception for most humans is around 65 VdB. Levels in the 70 to 75 VdB range are often noticeable but acceptable, and levels greater than 80 VdB are often considered unacceptable.

- For an operations and maintenance facility, which has train movement throughout the day, evening and nighttime hours, the FTA limit for acceptable levels of residential groundborne vibration is 72 VdB.
- For human annoyance, there is some relationship between the number of events and the degree of annoyance caused by the vibration. It is intuitive to expect that more frequent vibration events, or events that last longer, will be more annoying to building occupants. Because of the limited amount of information available, there is no clear basis for defining this tradeoff. To account for the fact that most commuter rail systems have fewer daily operations than the typical urban transit line, the criteria in the FTA Guidance Manual (ref. 1) include an 8 VdB higher impact threshold if there are fewer than 70 trains per day.
- Groundborne vibration from any type of train operations will rarely be high enough to cause any sort of building damage, even minor cosmetic damage. The only real concern is that the vibration will be intrusive to building occupants or interfere with vibration-sensitive equipment.

The FTA assigns sensitive land uses to the following three categories:

- **Vibration Category 1: High Sensitivity.** This category includes buildings where low ambient vibration is essential for the interior operations in the building. Vibration levels may be below the level of human perception. Typical land uses covered by Category 1 are vibration-sensitive research and manufacturing, hospitals with vibration-sensitive equipment, and university research operations. The degree of sensitivity to vibration will depend on the specific equipment that will be affected by the vibration. Equipment such as electron microscopes and high-resolution lithographic equipment can be very sensitive to vibration, and even normal optical microscopes will sometimes be difficult to use when vibration is well below the human annoyance level. Manufacturing of computer chips is an example of a vibration-sensitive process.
- **Vibration Category 2: Residential.** This category includes residences and buildings where people normally sleep, including private dwellings, hospitals, and hotels where nighttime sensitivity is assumed to be of utmost importance. It is common practice to also use this category as a standard for some special uses such as auditoriums or theaters.
- **Vibration Category 3: Institutional.** This category includes land uses with primarily daytime use including schools, churches, and other institutions and quiet offices that do not have vibration-sensitive equipment. Offices in buildings primarily for industrial use are not included in this category.

Table 3-1 summarizes the FTA impact criteria for groundborne vibration. These criteria are based on previous standards, criteria, and design goals, including ANSI S3.29 and the noise and vibration guidelines of the American Public Transit Association. Land use categories are described in the following paragraph.

Table 3-1. FTA Vibration Impact Criteria for Frequent Events*

Land Use Category	Category Comment	Groundborne Vibration (VdB re 1 micro in/sec)
1	Low interior vibration is essential	65
2	Residential & sleep	72
3	Institutional & daytime	75
--	Concert hall, TV/Recording Studio	65
--	Auditorium	72
--	Theatre	72
--	Office Use for Detailed Analysis	84

* "Frequent" is defined as greater than or equal to 70 events per day.
-- Special buildings and office spaces do not fall into any FTA categories.
Source: Federal Transit Administration 2006.

As shown in Table 3-1, some land use activities are more sensitive to vibration than others. For example, certain research and fabrication facilities, TV and recording studios, and concert halls are more vibration-sensitive than residences and buildings where people normally sleep, which are more sensitive than institutional land uses with primarily daytime use. At those locations where vibration-sensitive equipment is used, such as hospital and medical facilities and high tech manufacturing and testing sites, there may be the potential for additional or more severe ground vibration impacts from transit operations.

3.3 Construction Vibration

The parameter normally used to quantify and assess construction vibration is the peak particle velocity (PPV). The Peak Particle Velocity is the maximum velocity recorded during a particular event, such as the hammering of a jack hammer. Table 3-2 summarizes the levels of PPV vibration and the usual effect on people and buildings. The vibration levels are also presented in terms of VdB. The vibration levels in VdB were derived assuming a reference factor of 1 micro-inch/second and a crest factor of 4 (representing a PPV-rms difference of 12 VdB). Note, however, that there is a considerable variation in reported ground vibration levels from construction activities due to the wide range of soil conditions possible.

Table 3-2. Effects of Construction Vibration

Peak Particle Velocity (in/sec)	Vibration levels in VdB	Effects on Humans	Effects on Buildings
<0.005	<62	Imperceptible	No effect on buildings
0.005–0.015	62–72	Barely perceptible	No effect on buildings
0.02–0.05	74–82	Level at which continuous vibrations begin to annoy in buildings	No effect on buildings
0.1–0.5	88–102	Vibrations considered unacceptable for people exposed to continuous or long-term vibration	Minimal potential for damage to weak or sensitive structures
0.5–1.0	102–108	Vibrations considered bothersome by most people, however tolerable if short-term in length	Threshold at which there is a risk of architectural damage to buildings with plastered ceilings and walls. Some risk to ancient monuments and ruins.
1.0–2.0	108–114	Vibrations considered unpleasant by most people	U.S. Bureau of Mines data indicates that blasting vibration in this range will not harm most buildings. Most construction vibration limits are in this range.
>3.0	>117	Vibration is unpleasant	Potential for architectural damage and possible minor structural damage

Source: FTA, 2006, U.S and Transportation Related Earth-borne Vibrations. Caltrans, Technical Advisory, TAV-02-01-R9601, February 2002.

There are no specific construction related vibration regulations or criteria. The U.S. Department of Transportation (USDOT) has guidelines for vibration levels from construction related to their activities, and recommends that the maximum peak-particle-velocity levels remain below 0.05 inch per second at the nearest structures. Vibration levels above 0.5 inch per second have the potential to cause architectural damage to normal dwellings. USDOT also states that vibration levels above 0.015 inch per second are sometimes perceptible to people, and the level at which vibration becomes annoying to people is 0.64 inch per second.

3.4 Washington Administrative Code

This technical report has been prepared to meet the requirements of the FTA manual. Under the FTA guidance for federally funded high-capacity transportation projects, the noise analysis must be performed in accordance with the FTA guidelines. In addition to meeting the FTA noise impact criteria, maintenance facilities and other related ancillary facilities must also consider any state, city or local noise ordinances and standards that are applicable to the project. In the case of the proposed project the regulations from the Washington Administrative Code (WAC) would be applicable, and therefore are considered in this analysis.

The noise regulations for the noise analysis were taken from Chapter 173-60, WAC, Maximum Environmental Noise Levels, 2000 (WAC 2000). This noise control ordinance provides three environmental designations for noise abatement (EDNA) based on land use, summarized as follows.

- **Class A.** EDNA Class A includes lands where human beings reside and sleep. Typically, Class A EDNAs include single- and multifamily residences, parks, camping facilities and resorts, orphanages, homes for the aged, hospitals, and health and correctional facilities
- **Class B.** EDNA Class B includes uses requiring protection against noise interference with speech. Typically, Class B EDNAs include commercial living accommodations, restaurants, vehicle service centers, retail services, banks and office buildings, miscellaneous commercial services, recreation and entertainment facilities, (theaters, stadiums, fairgrounds, and amusement parks), community services, and educational, religious and governmental facilities.
- **Class C.** EDNA Class C includes lands involving economic activities of such a nature that higher noise levels than experienced in other areas are anticipated. Persons working in these areas are normally covered by the U.S. Department of Labor and Industries noise-control regulations. Also, Class A EDNAs are generally not permitted within a Class C EDNA. Class C EDNAs include farming, storage, warehouse, distribution and industrial properties.

The WAC ordinance, and the corresponding ordinances from the Cities of Lynnwood and Bellevue, are written to define the maximum allowable noise level from one EDNA to another EDNA. For example, noise generated by an EDNA Class C property must be less than 60 dBA at the closest residential property line (EDNA Class A), 65 dBA at the closest commercial use (EDNA Class B) and 70 dBA at the closest industrial use (EDNA Class C). The Washington State noise ordinance is summarized in Table 3-3 and the criteria applicable to the proposed project are shown in bold text.

Table 3-3. Washington State Noise Ordinance

	Maximum Allowable Sound Level (dBA) Property Receiving Noise EDNA		
Property Producing Noise (EDNA)	**Class A EDNA (Residential)**	**Class B EDNA (Commercial)**	**Class C EDNA (Industrial)**
Class A	55	57	60
Class B	57	60	65
Class C	**60**	**65**	**70**

Between 10:00 p.m. and 7:00 a.m., the maximum allowable levels shown in Table 3-3 are reduced by 10 dBA. Therefore, using the above example, the noise generated from an EDNA Class C property must be less than 50 dBA at the closest residential property line (EDNA Class A), 55 dBA at the closest commercial use (EDNA Class B) and 60 dBA at the closest industrial use (EDNA Class C) between the hours of 10:00 p.m. and 7:00 a.m.

3.4.1 Washington State Construction Noise Regulations

For the purpose of discussing construction noise and potential construction noise impacts, this study used the WAC. Most project construction can be performed within the limits of the WAC noise ordinance if the work is conducted during normal daytime hours (WAC 173-60-050). If construction is performed during the nighttime, the contractor must still meet the WAC noise-level requirements presented in Table 3-3 or obtain a noise variance from the governing jurisdiction. Construction contracts would typically contain sections specific to construction noise and address any site-specific requests for variances or other construction-related noise issues associated with the project.

3.4.1.1 Haul Truck Noise Criteria

Maximum permissible sound levels for haul trucks on public roadways are limited to 86 dBA for speeds of 35 miles per hour (mph) or less, and 90 dBA for speeds over 35 mph when measured at 50 feet (WAC 173-62). For trucks operating at staging areas, the general construction equipment would be used to determine compliance.

3.4.1.2 Back-Up Alarms

Sounds created by back-up alarms are exempt, except on a construction site between 10:00 p.m. and 7:00 a.m. back-up alarms would be required to meet the WAC noise ordinance. However, in most cases, back-up alarms are not typically used during nighttime hours in urban areas and could be replaced with smart back-up alarms, which automatically adjust the alarm level based on the background level, broadband alarms, which use a broadband noise instead of a beeper, or switch off back-up alarms and replace with spotters. This criterion is included because noise from back-up beepers could exceed the WAC nighttime criteria at distances up to 800 feet, or more, from the construction site.

3.5 City of Lynnwood Noise Regulations

The maximum allowable noise levels under the City of Lynnwood noise control ordinance (LMC 10.12) are the same as given for the WAC in Table 3-3. The City of Lynnwood noise ordinance classifies EDNAs based on the zoning designations of the source and receiving properties (LMC 10.12.400). Under the City's ordinance, sounds created by construction are exempt between 7:00 a.m. and 6:00 p.m. on weekdays. Construction between 6:00 p.m. and 7:00 a.m. on weekdays, and on weekends must meet the city code in Table 3-3, or obtain a noise variance from the City.

3.6 City of Bellevue Noise Regulations

In the City of Bellevue, the maximum allowable noise levels in Table 3-3 would apply. The Bellevue City Code (BCC) classifies EDNAs based on the zoning designations of the source and receiving properties (BCC 9.18.025). The City of Bellevue has adopted the WAC with a slight modification to the hours for construction, and is found in BCC 9.18. Under the City of Bellevue noise control ordinance, sounds created by construction and emanating from construction sites are exempt between 7:00 a.m. and 6:00 p.m. on weekdays, and 9:00 a.m. and 6:00 p.m. on Saturdays that are not legal holidays. Construction during nighttime hours (between 6:00 p.m. and 7:00 a.m. on weekdays, and between 6:00 p.m. and 9:00 a.m. on Saturdays) or on Sundays or legal holidays is required to meet the City's noise regulations as given in Table 3-3, unless a noise variance is received from the City. The City of Bellevue has a 5 dB penalty for impulsive or pure tone noise sources.

Chapter 4
Existing Land Use Noise Levels

This chapter provides a summary of the existing land use and existing noise environment near the build alternative sites. For the purpose of defining land use, the FTA categories provided in Section 3.1, FTA Noise Criteria, were used as the primary descriptor. EDNA classifications established by city codes (Sections 3.5, City of Lynnwood Noise Regulations, and 3.6, City of Bellevue Noise Regulations) are used to determine compliance with the local noise control ordinances from the Cities of Lynnwood and Bellevue.

Under the FTA criteria, the noise impact is based on the existing noise levels, and therefore ambient noise monitoring was required. The monitoring was used to establish the existing noise environment at residential land uses near the site. Impacts under the local regulations from the Cities of Bellevue and Lynnwood are property line noise limits that are based on the EDNA classifications of the noise source and noise-receiving properties.

4.1 Lynnwood Alternative

All design options of the Lynnwood Alternative have essentially the same general layout with modified connection that will be based on the selected alternative for the Lynnwood Link Extension. Land use near the Lynnwood Alternative site is mostly residential along the west side of 52nd Avenue W. East of 52nd Avenue W, adjacent to I-5, there is one single-family residence (20909 52nd Avenue W), and then land uses transition to commercial and industrial. Near 50th Avenue W are a warehouse and distribution facility and the Interurban Trail. East of 52nd Avenue W are several vacant parcels, state and private office buildings, and Scriber Creek Park. Other land uses near the Lynnwood Alternative site include the Park Five Apartments at 20104 48th Avenue W and the 76-unit Cedar Creek Condominiums at 4800-4920 200th Street SW.

As stated in the FTA regulations, how a park is used and where it is located is considered when determining noise sensitivity. Based on the park location, uses and existing noise levels, Scriber Creek Park was evaluated under the FTA Category 3 criteria. Scriber Creek Park is open during daylight hours (dusk to dawn).

Existing noise levels in this area were characterized with four monitoring sites. One measurement site was near I-5, two measurement sites were along 52nd Avenue W and two additional monitoring sites were at the Park Five Apartments, near Scriber Creek Park and at the Cedar Creek Condominiums, also near Scriber Creek Park. Noise levels along 52nd Avenue W are highest near I-5, where noise levels near the 52nd Avenue W overpass are near 70 dBA Leq during peak hours, with an Ldn of approximately 72 dBA. Farther north, on 52nd Avenue W, away from I-5, noise levels gradually reduce with peak hour Leq noise levels ranging from 57 to 64 dBA and Ldn noise levels ranging from 64 to 65 dBA.

Noise levels near Scriber Creek Park, the Park Five Apartments, and the Cedar Creek Condominiums range from 58 to 62 dBA Leq during peak hours, with Ldn noise levels ranging from 57 to 62 dBA. Major noise sources in this area include traffic on I-5, commercial and industrial activities, and traffic on other arterial roadways. The monitoring results for sites M-1 through M-5 used to characterize the existing noise levels near the Lynnwood Alternative site are provided in Table 4-1. Figure 4-1 provides an overview of the proposed Lynnwood Alternative site, monitoring locations, noise levels, access tracks, and area land use. Because there are three design options for this site, the connections to each of the Lynnwood Link Extension alternatives are provided and noted in the figure.

Table 4-1. Lynnwood Alternative Measurement Results

Site Number	Address	Land Use Type	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)
M-1	20929 53rd Avenue W	FTA Cat 2 EDNA Class A	70	72
M-2	20706 52nd Avenue W	FTA Cat 2 EDNA Class A	57	64
M-3	20526 52nd Avenue W (Cedar Valley Grange)	FTA Cat 2,3 EDNA Class A	64	65
M-4	20128 48th Avenue W, Bldg. C, Apt. #30 (Park Five Apartments)	FTA Cat 2 EDNA Class A	62	62
M-5	4900 200th Street SW, Bldg. C (Cedar Creek Condominiums)	FTA Cat 2 EDNA Class A	58	57

Monitoring sites and land use shown in Figures 4-1.

4.2 BNSF Alternative and BNSF Modified Alternative

The BNSF Alternative and BNSF Modified Alternative sites are both located in a primarily commercial and industrial area, north of NE 12th Street and south of SR 520 along the Eastside Rail Corridor. Land use north and east of the sites is commercial and industrial. West of the alternative sites, along 116th Avenue NE, land use includes the Seattle Children's Hospital: Bellevue Clinic and Surgery Center, which has a planned expansion to the east for a new surgical center and parking area, several commercial and office spaces and several single-family residences. There are also several converted single-family homes that are now used as offices on 116th Avenue NE near NE 20th Street.

Figure 4-1. Lynnwood Alternative—Land Use and Monitoring Locations

The City of Bellevue has approved a Master Development Plan for 36 acres in the Bel-Red subarea from the current industrial use to a transit-oriented urban village, referred to as the Spring District. The Spring District will be a mixed-use development that will contain office space, retail, housing, hotels, parks, and a new road system with the necessary infrastructure. The current plan includes construction of 29 buildings following demolition of the existing industrial structures. The entire redevelopment is planned over a 15-year period with seven construction phases. The proposed redevelopment is located south of the BNSF Alternative and BNSF Modified Alternative sites. The two Spring District residential structures and the hotel nearest to the BNSF Alternative and BNSF Modified Alternative sites are shown in Figures 4-2 and 4-3. Construction of the hotel is planned for 2022–2024, Phase 4 of the project. Construction of residential structures nearest to 120th Avenue NE and 124th Avenue NE are planned for 2024–2026 (Phase 5) and 2026–2028 (Phase 6).

There are no proposed parks or recreational resources in the Spring District near the BNSF Alternative site, BNSF Modified Alternative site, or BNSF Storage Tracks.

Existing noise levels near the BNSF Alternative and BNSF Modified Alternative sites are dominated by traffic noise from I-405, NE 12th Street, 116th Avenue NE and other arterial roadways in addition to the commercial and industrial activities. Farther north, the noise levels would be dominated by SR 520 and arterial roadways near SR 520, including Northrup Way. Noise levels near the remaining single-family residences along 116th Avenue NE were characterized with monitoring site M-6, where noise levels were measured at 58 dBA Leq and 58 dBA Ldn. Noise levels at the Children's Hospital, just south of M-6, are predicted to be similar. Current noise levels near the Spring District are predicted to be in the mid to upper 60-dB range due to traffic on NE 12th Street and other nearby arterial roads. Noise monitoring at the Spring District site was not performed because it would not produce accurate results due to the ongoing construction and industrial activities.

Under both the BNSF Alternative and BNSF Modified Alternative, a set of storage tracks would be required along the existing BNSF right-of-way, north of NE 12th Street in Bellevue. Land use and noise levels near the storage tracks would be the same for the BNSF Alternative and BNSF Modified Alternative sites. Table 4-2 provides the noise monitoring results for site M-6, which was used to quantify the existing noise levels near sensitive uses for the BNSF Alternative and BNSF Modified Alternative.

Table 4-2. BNSF Alternative and BNSF Modified Alternative Noise Measurement Results

Site Number	Address	Land Use Type	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)
M-6	1815 116th Avenue NE	FTA Cat 2 EDNA Class B	58	58

Monitoring sites and land use shown in Figures 4-2 and 4-3.

Figures 4-2 and 4-3 provide overviews of the BNSF Alternative and BNSF Modified Alternative, respectively. Both figures also show the noise monitoring locations, noise levels, access tracks to and from the mainline, and area land use for these alternatives. Spring District is outlined and the nearest residential buildings and hotel in the Spring District are shown for reference.

Figure 4-2. BNSF Alternative—Land Use and Monitoring Locations

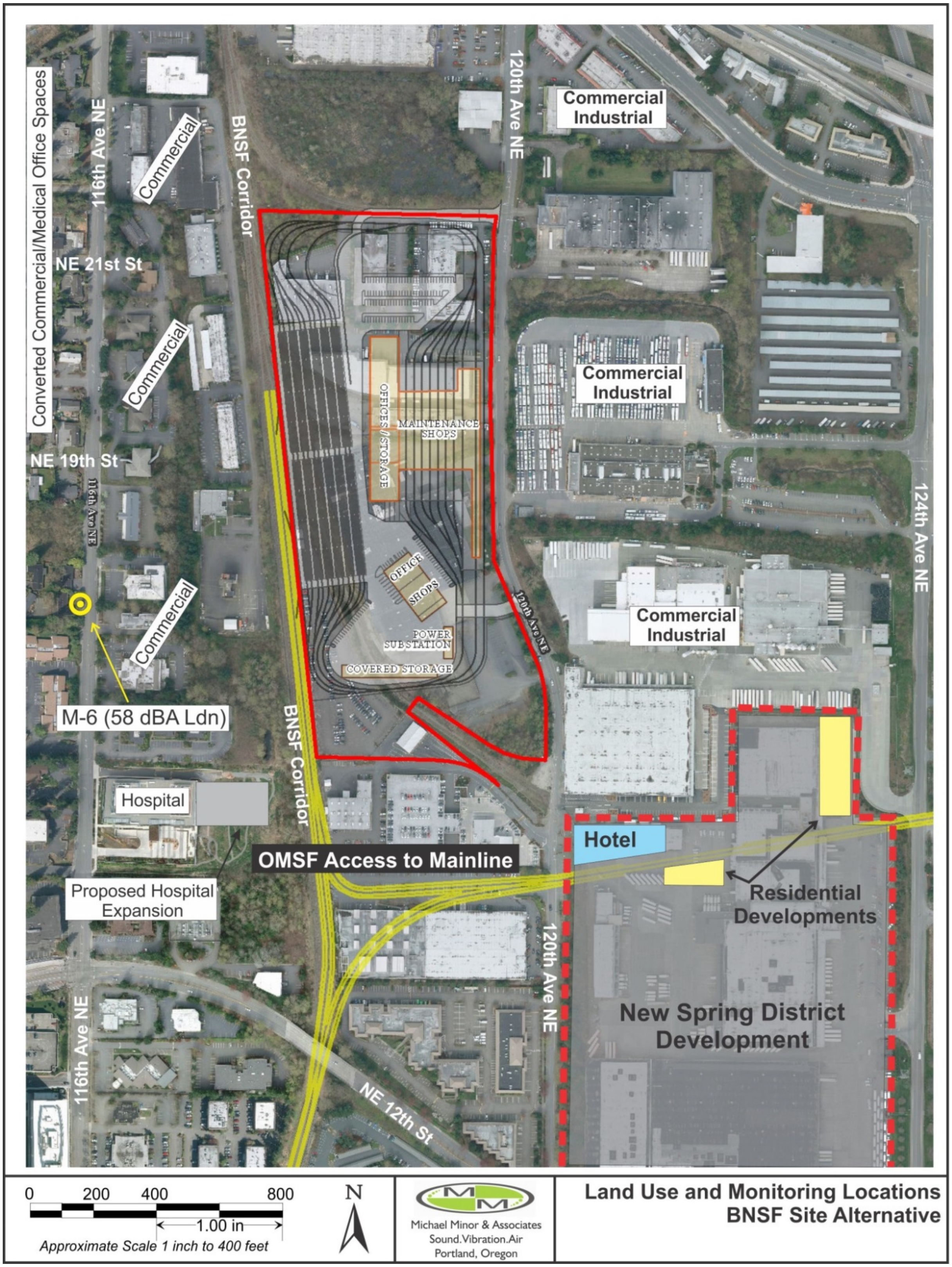
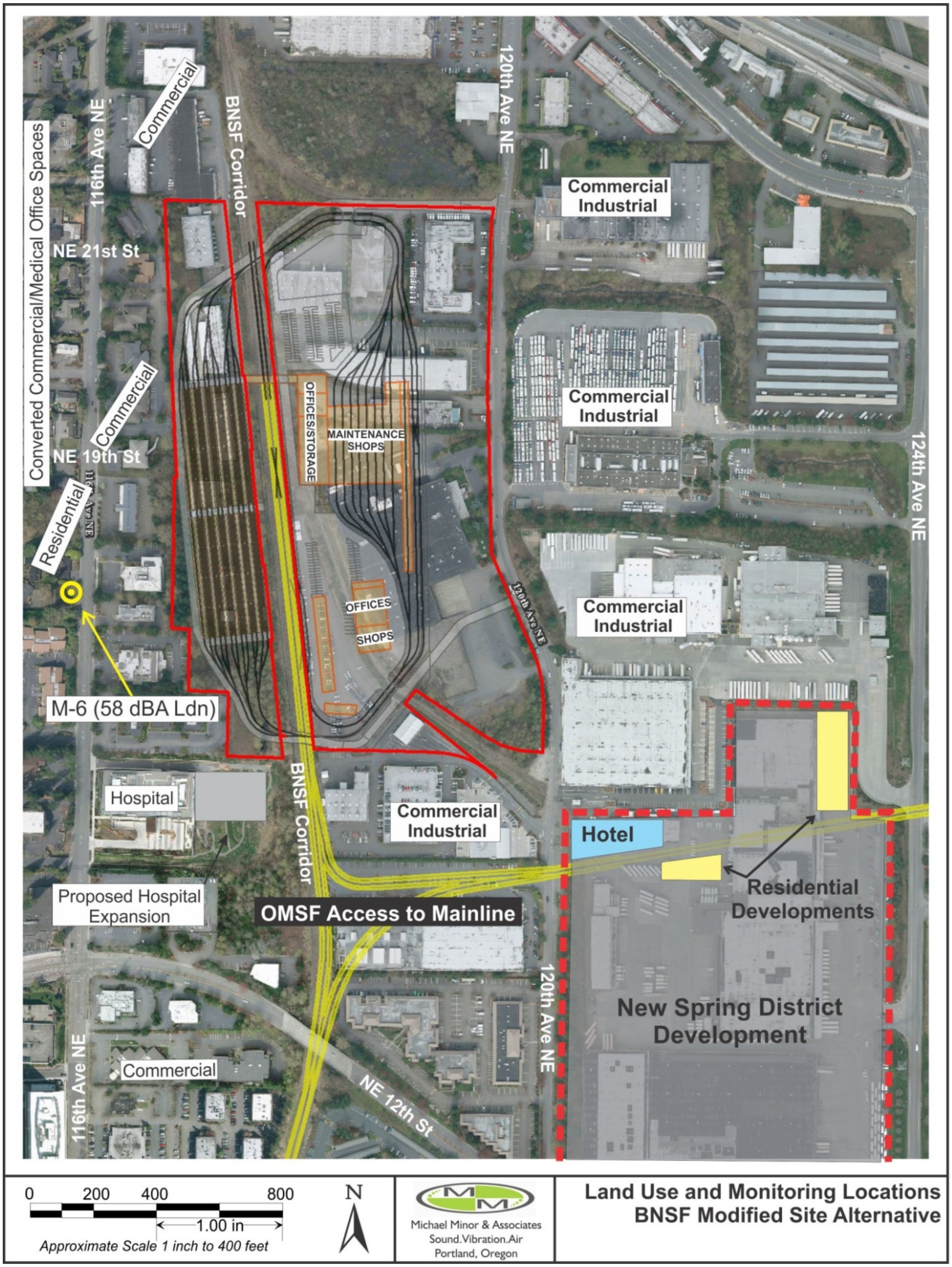


Figure 4-3. BNSF Modified Alternative—Land Use and Monitoring Locations



4.3 SR 520 Alternative

The SR 520 Alternative site is located along the south side of SR 520, between 130th Avenue NE and 136th Place NE and north of NE 20th Street. There are no residences within 700 feet of the site boundaries. The closest residences are located north of SR 520 off NE 24th Street, approximately 725 feet north of the site, and on 127th Avenue NE, also north of SR 520, approximately 825 feet from the site. Land use to the west of the site includes commercial and industrial uses, including retail and storage. Along NE 20th Street, south of the site, land use continues to be commercial, light industrial and retail. East of the site, near 136th Place NE, land use is primarily retail and also includes office spaces and other commercial uses.

Noise levels near the SR 520 Alternative site are dominated by traffic on SR 520, NE 20th Street, 130th Avenue NE, along with noise from existing commercial and light industrial activities. Noise levels in this area are taken from a short-term measurement at a multifamily residence on NE 21st Place, M-7 approximately 1,000 feet west of the site, where peak-hour noise levels of 72 dBA Leq were due to traffic on SR 520. Noise levels were measured for 24 hours, north of SR 520, at 2311 127th Avenue NE (M-8) during the SR 520 project. The noise levels at this site varied from 71 dBA Leq during peak hours to 60 dBA Leq during nighttime hours, for a 24-hour Ldn of 72 dBA.

Table 4-3 has the measured noise levels for sites M-7 and M-8 that were used to characterize noise levels at the SR 520 Alternative site. Figure 4-4 provides an overview of the SR 520 Alternative and also shows the noise monitoring locations and noise levels, access tracks to and from the mainline land uses surrounding this build alternative.

Table 4-3. SR 520 Alternative Noise Measurement Results

Site Number	Address	Land Use Type	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)
M-7	12628 Northup Way	FTA Cat 2 EDNA Class C	72	70
M-8	2311 127th Avenue NE	FTA Cat 2 EDNA Class A	71	72

Monitoring sites and land use shown in Figures 4-2 and 4-3.

Figure 4-4. Land Use and Monitoring Locations—SR 520 Alternative Site

Chapter 5
Impact Assessment Approach

Noise and vibration from OMSF operations was modeled using the methods described in the FTA Manual (2006). The proposed OMSF would enable Sound Transit to provide service and inspection functions for supporting a fleet of approximately 88 additional LRVs with the assumption that the Forest Street OMF would continue to provide inspection, heavy repair, and overhaul services. The OMSF would be used to store, maintain, and dispatch vehicles for daily service. Activities at the OMSF would include preventative maintenance inspections, light maintenance, emergency maintenance, interior vehicle cleaning, and exterior vehicle washing.

The facility is needed to accommodate additional administrative and operations functions and would be used as a report base for LRV operators. The proposed OMSF would have space for employee parking, operations staff offices, maintenance staff offices, dispatcher workstations, an employee report room, and areas with lockers, showers, and restrooms for both operators and maintenance personnel.

The following sections provide the assumptions that will be used to predict noise and vibration levels associated with the project.

5.1 Noise Assessment Approach

The noise impact assessment includes the analysis of noise from general maintenance operations, cleaning of trains, and the arrival and departure of trains at the OMSF, vehicle movement in the yard and ancillary equipment, including power substation. All four build alternatives would involve construction and operation of storage tracks, offices and an enclosed LRV maintenance building containing service bays for maintaining LRVs. The OMSF would include the following activities and equipment which may produce noise.

- LRV washing area.
- General service, inspection, and repair bays, wheel truing, brake and coupler shop and a welding and general fabrication shop.
- Track, switches, catenary power lines, a traction power substation, and signals to support movement of LRVs to and from the mainline and around the facility through the LRV maintenance building and LRV storage area.
- Lead track to provide access between the OMSF and light rail system mainline.

The analysis uses reference noise levels for operation of a maintenance base taken from the FTA Manual (2006). The operational analysis assumes that the OMSF would operate 24 hours a day. Major operational assumptions include the following.

- The OMSF would store and maintain up to approximately 88 LRVs with storage for an additional 8 spare vehicles. All 88 LRVs would depart the OMSF before 7:00 a.m., with some LRVs returning to the OMSF during midday service and departing the OMSF for PM peak service, returning again as service is reduced during evening and nighttime hours. The remaining LRVs would return to the OMSF at the end of revenue service. Noise levels for trains accessing the OMSF were projected using measured noise levels from Sound Transit's existing LRV fleet and the calculation methods provided in the FTA Manual (2006).

- The LRV wash area would be enclosed with openings on each end for LRV access. Blowers would be used to strip water off the vehicles; the blowers would be located inside the end of the LRV wash structure. The noise sources associated with the LRV wash and blowers would include a vacuum system and an air compressor. Based on measurements of similar wash facilities, the sound level at a distance of 50 feet is assumed to be 71 dBA, assuming the blowers are located at the end of the wash bay, directly adjacent to the exit, and the door to the wash bays are open. The LRV wash would typically be used for 50 to 60 minutes per day. This is based on the wash cycle for a four-car train taking approximately 10 minutes and approximately four to five four-car trains washed each day (approximately 25% the fleet stored at the OMSF). As a worst case, this analysis assumes the loudest 1-hour of LRV washing operations, and also assumes that the operations would occur during nighttime hours when regulations are the most stringent.
- Manufacturers of LRV wash systems were contacted to determine design options that could be used to reduce noise from the blowers. There are typically eight to 10 blowers, each producing 15 horsepower, drawing approximately 15 amps of current. Because the systems are only circulating air to move water off the vehicles, back pressure on the blowers is typically not an issue. Therefore, it is possible to extend the length of the wash facility to enclose the blowers within the wash bays, and add an automated door system that only opens once the blowers have completed their task and shut down. The installation of the blowers and addition of an automated door would reduce noise from the blowers by 10 to 15 dB, depending on the type of doors used. For the purpose of this analysis, it is assumed that the bays would be extended approximately 100 feet and noise-reducing automated doors would be used, providing a reduction of 12 dB to the blower motors. Based on this assumption and information from the wash blower manufacturers, the sound level from the wash would be 59 dBA at 50 feet from the wash bay exit doors with the doors closed.
- Sound Transit would perform limited outdoor testing of horns and only during the daytime.
- Although wheel squeal can be an issue, due to the low speed limit of no more than 8 mph for LRV operating in the OMSF yard, it is not predicted to be an issue of concern. Any wheel squeal on the curves into and out of the storage tracks would be resolved with lubrication or other means. Wheel squeal was not included in the noise model for the OMSF.
- The slow speed on the storage tracks would also reduce any impact noise associated with crossovers at the OMSF. Only the crossovers on the access tracks were included in the analysis.
- Noise from general maintenance activities inside the shop building would include use of hand tools, continuous operation of compressors and other mechanical equipment, and intermittent operation of equipment such as overhead cranes, vehicle lifts, and the wheel trues. The equipment would all be located inside the maintenance shop. The predictions of the noise that would be emitted from the shop are based on measurements at the existing Sound Transit Operations and Maintenance Base in Seattle and measurements at the Los Angeles Metro Green Line Yard in California. For this analysis, it was assumed that bay doors would be left open for ventilation, making this a worst-case analysis and the typical sound level would be 65 dBA at 50 feet outside the work bays with the bay doors open. With the doors closed, the noise from general maintenance activities would not affect the overall noise from the facility.

- Some equipment in the shop, such as the vehicle lifts and overhead cranes, may be equipped with alarms to alert workers before they are used. In the design of the shop facility, the use of these alarms would be minimized and any alarms used would be designed to provide appropriate warning for shop personnel and to be inaudible beyond the maintenance yard property line.
- There would be limited vehicle movements inside the yard. Once trains enter a storage yard and are parked, they would usually stay in place until they went back into revenue service. Movements within the yard would include shuttling vehicles to the shop and through the LRV wash, and cleaning station.
- The noise from the traction power substations in the maintenance yard would be a maximum of 49 dBA at 50 feet. This is based on measurements of Metro Gold Line in South Pasadena.
- Activities at the cleaning station would include vacuuming and hand cleaning of the vehicle interior. This is assumed to be an insignificant noise source.

Using the above assumptions, the 24-hour Ldn, peak nighttime hourly Leq, was calculated and used to predict potential noise impacts. The 24-hour Ldn was compared to the appropriate FTA noise criteria from Section 3.1, FTA Noise Criteria. The peak hour Leq was used to show compliance with the local noise control ordinance. The worst-case nighttime hours are during the deployment of the 88 LRVs and during a full hour of normal operation of the wash systems with blowers.

5.2 Light Rail Vibration Assessment Approach

Light rail vibration was predicted using information from the vibration sections of the *East Link Project Final EIS* (Sound Transit 2012) and the *Lynnwood Link Extension Draft Vibration Technical Report* (Sound Transit 2013). Based on these documents and including track type adjustments for ballast and tie, direct fixation and aerial guideway alignment types, vibration impacts could only occur at FTA Category 2 structures located within 70 feet of the Lynnwood Alternative tracks, and within 100 feet of the BNSF Alternative, BNSF Modified Alternative, and SR 520 Alternative tracks, as well as the BNSF Storage Tracks. The larger impact distance for these build alternatives would be due to the different vibration propagation characteristics of the soils at the different sites.

The distances from nearby structures were measured using AutoCAD design drawings with high resolution aerial photos to determine the number of type of uses that would be within the distances for potential vibration impacts. Adjustments for track type and any mitigation proposed as part of the East Link project and Lynnwood Link Extension were included in the model. Based on the results of the analysis, the corridor was examined for potential vibration impacts.

Chapter 6
Impact Assessment

This section provides the results of the noise and vibration impact analysis. It also includes a construction noise and vibration analysis as well as a review of potential indirect noise impacts. Cumulative noise and vibration impacts are discussed in Chapter 8, Cumulative Analysis.

6.1 No Build Alternative

Under the No Build Alternative, noise and vibration levels would continue to be dominated by traffic on nearby major highways, commercial and industrial activities and local traffic on nearby arterial roadways.

With the construction of the Lynnwood Link Extension, noise levels along the preferred alternative would see a slight increase related to the construction and operation of the light rail alignment. For example, under Design Options C1 and C2, noise levels along 52nd Avenue W would also include noise from the construction and operation of the new light rail extension. Other noise sources in the area, including I-5, 200th Street SW, 52nd Avenue W, and other arterial roadways along with nearby commercial and industrial activities would dominate the noise levels in most areas near the Lynnwood Alternative site.

With the construction of East Link, a new noise source would be added to the general area proposed for the BNSF Alternative, BNSF Modified Alternative, and SR 520 Alternative sites. However, these alternative sites are 400 to 500 feet from the East Link mainline; therefore, operation of East Link is not predicted to affect noise levels near any of the BNSF Alternative, BNSF Modified Alternative, and SR 520 Alternative sites. Other noise sources in the area, including I-405, SR-520, NE 12th Street, 116th and 120th Avenues NE and Northup Way along with other arterial roadways along with nearby commercial and industrial activities would dominate the noise levels in most areas near the sites.

6.2 Lynnwood Alternative

The Lynnwood Alternative includes three design options (C1, C2, and C3), each connecting to one of the three build alternatives being evaluated in the *Lynnwood Link Extension Draft EIS* (Sound Transit 2013). Noise analysis for the site was evaluated using both the FTA criteria and the local noise control ordinance from the City of Lynnwood. The City of Lynnwood ordinance classifies EDNAs based on zoning designations (LMC 10.12.400). The Lynnwood Alternative site is an EDNA Class C (industrial) property. Properties adjacent to the Lynnwood Alternative site are classified as EDNA Class A (residential and park/public) and Class B (commercial).

6.2.1 Design Options C1 and C2

There would be two noise impacts and no vibration impacts under the Lynnwood Alternative, with Design Option C1 or C2. Details on the impacts are provided in the following sections.

6.2.1.1 Noise Impacts

Under the Lynnwood Alternative Design Options C1 and C2, there would be no noise impacts under the FTA criteria. There would be two noise impacts on EDNA Class A (residential) land uses under the City of Lynnwood noise control ordinance. The two noise impacts, which would result from the mainline track access crossovers, would be at front-line residences along 52nd Avenue W. Both residences would be near the crossover and exit doors of the wash bays, and would also receive some added noise from general OMSF operations (maintenance bays and access tracks). Table 6-1 provides the results of the noise analysis. Locations of the noise impacts are shown in Figure 6-1.

Table 6-1. Noise Impacts for the Lynnwood Alternative, Design Options C1 and C2

	Lynnwood Analysis	FTA Analysis			
Address[a]	**Peak Hour Leq[b]**	**Existing Ldn[c]**	**Project Ldn[d]**	**FTA Criteria[e]**	**Impact Type and Criteria Exceeded[f]**
5211 208th St SW	48	64	46	61	None
20706 52nd Ave W	42	64	42	61	None
20628 52nd Ave W	42	64	41	61	None
20624 52nd Ave W	42	64	41	61	None
20618 52nd Ave W	45	64	43	61	None
5210 206th St SW	48	64	47	61	None
20504 52nd Ave W	**50**	64	50	61	1 SFR with LMC Leq impact from new crossover
20430 52nd Ave W	**50**	64	50	61	1 SFR with LMC Leq impact from new crossover
20416 52nd Ave W	48	64	48	61	None
20410 52nd Ave W	46	64	46	61	None
20406 52nd Ave W	46	64	46	61	None
20505 53rd Ave W	44	62	44	59	None
20511 53rd Ave W	45	63	45	60	None
20517 53rd Ave W	45	63	45	60	None

Note: Values in bold text meet or exceed the project noise impact criteria.

[a] Address of representative parcel used in modeling.

[b] Lynnwood noise criteria for EDNA Class C (industrial) next to an ENDA Class A (residential) is 60 dBA Leq (daytime) and 50 dBA Leq (nighttime). Details are provided in Section 3.5, City of Lynnwood Noise Regulations.

[c] Existing Ldn.

[d] 24-hour Ldn noise from ingress and egress of trains.

[e] FTA moderate impact criteria for 24-hour Ldn for Category 2 land uses.

[f] Number and type of noise impacts from facility.

SFR = single-family residence; LMC = Lynnwood Municipal Code.

Figure 6-1. Lynnwood Alternative, Design Options C1 and C2— Noise Impact Locations

Noise levels in Scriber Creek Park (FTA Category 3, EDNA Class A) would only be of concern during daytime hours, since the park closes at dusk (9:30 p.m. during summer months) and opens at sunrise. The park would be located on the north side of the OMSF, and would be shielded from the maintenance bays and the LRV wash area by intervening structures and offices. There would be an access track along the southern side of the park and a shop facility that would be approximately 500 feet from the park trails.

During peak hours, trains entering or leaving the OMSF would produce noise levels at the nearest edge of Scriber Creek Park of 58 dBA Leq. This prediction is based on four train sets accessing the mainline tracks during peak hours to accommodate the increased headways. These levels are below the FTA criteria of 62 dBA Leq for a moderate noise impact at a Category 3 use with an existing Leq of 58 dBA.

Furthermore, the levels of 58 dBA Leq is also below the City of Lynnwood daytime criteria of 60 dBA for an EDNA Class A use. Therefore, no noise impacts were identified at the Scriber Creek Park under the Lynnwood Alternative, Design Options C1 and C2.

6.2.1.2 Vibration Impacts

The distance from the OMSF tracks to the nearest residences would be over 130 feet from any of the OMSF tracks; therefore, no vibration impacts are projected under Design Options C1 or C2.

6.2.2 Design Option C3

Noise analysis for the Lynnwood Alternative Design Option C3 was evaluated using both the FTA criteria and the local noise control ordinance from the City of Lynnwood. The City of Lynnwood ordinance classifies EDNAs based on zoning designations (LMC 10.12.400).

6.2.2.1 Noise Impacts

Under Design Option C3, there are no noise impacts under the FTA criteria or the City of Lynnwood noise control ordinance. Design Option C3 would not result in any noise impacts because the mainline track access crossovers would be located near I-5, away from the residences. Conversely, under Design Options C1 and C2, the crossovers would be located along 52nd Avenue W, near the residential area. Therefore, there are no noise impacts to any of the residential (FTA Category 2, EDNA Class A) uses along 52nd Avenue W under the FTA criteria or the Lynnwood Code. Table 6-2 provides the results of the noise analysis.

Noise levels at Scriber Creek Park (FTA Category 3, EDNA Class A) would be slightly lower than Design Options C1 or C2, by 3 to 5 dB, due to the locations of the access tracks being moved over next to I-5 and; therefore, no noise impacts are projected at the park under Design Option 3.

Table 6-2. Noise Impacts for the Lynnwood Alternative, Design Option C3

	Lynnwood Analysis	FTA Analysis			
Address[a]	Peak Hour Leq[b]	Existing Ldn[c]	Project Ldn[d]	FTA Criteria[e]	Impact Type and Criteria Exceeded[f]
20624 52nd Ave W	41	64	51	61	None
20618 52nd Ave W	42	64	52	61	None
5210 206th St SW	44	64	54	61	None
20504 52nd Ave W	49	64	59	61	None
20430 52nd Ave W	48	64	58	61	None
20416 52nd Ave W	45	64	55	61	None
20410 52nd Ave W	44	64	54	61	None
20406 52nd Ave W	43	64	53	61	None
20511 53rd Ave W	45	63	55	60	None
20517 53rd Ave W	45	63	55	60	None

Note: Values in bold text meet or exceed the project noise impact criteria.
[a] Address of representative parcel used in modeling.
[b] Lynnwood noise criteria for EDNA Class C (industrial) next to an ENDA Class A (residential) property is 60 dBA Leq (daytime) and 50 dBA Leq (nighttime). Details are provided in Section 3.5, City of Lynnwood Noise Regulations.
[c] Existing Ldn.
[d] 24-hour Ldn noise from ingress and egress of trains.
[e] FTA moderate impact criteria for 24-hour Ldn for Category 2 land uses.
[f] Number and type of noise impacts from facility.

6.2.2.2 Vibration Impacts

The distance from the OMSF tracks to the nearest residences would be over 130 feet from any of the OMSF tracks; therefore, no vibration impacts are projected.

6.2.3 BNSF Storage Tracks

Under the Lynnwood Alternative, the BNSF Storage Tracks would be installed and maintained along the BNSF right-of-way in Bellevue. The tracks would be used to store trains overnight in preparation for the morning commute. LRVs on these storage tracks would be restricted to the speed for auxiliary tracks of 10 mph. In addition, the LRV operator would also be required to sound the low bell during initial movement back to service. The combination of noise from the slow-moving LRV and bells were not predicted to result in any noise impacts due to the distance between the receivers and the storage tracks (greater than 300 feet).

6.3 BNSF Alternative

Noise analysis for the BNSF Alternative was evaluated using both the FTA criteria and the local noise control ordinance from the City of Bellevue. The City of Bellevue ordinance classifies EDNAs based on zoning designations (BCC 9.18.025). There would be no noise impacts or vibration impacts predicted with the BNSF Alternative. Details on the analysis are provided below.

6.3.1 Noise Impacts

Under the BNSF Alternative, no noise impacts would occur as identified under the FTA or City of Bellevue noise criteria. The majority of land use surrounding the facility would be commercial and industrial.

The Seattle Children's Hospital: Bellevue Clinic and Surgery Center (FTA Category 2 and EDNA Class B), which has planned improvements to expand to the east toward the BNSF Alternative site, is the nearest noise-sensitive use to the BNSF Alternative site. The new building would be approximately 410 feet southwest of the BNSF Alternative site and 250 feet west of the access tracks. This site was evaluated using FTA Category 2 and EDNA Class B. The analysis concluded that there would be no noise impacts under either the FTA or the City of Bellevue noise control ordinance criteria at the Seattle Children's Hospital: Bellevue Clinic and Surgery Center.

Residential buildings in the Spring District, which is consider EDNA Class B under the Bellevue Code, would be located 850 to 1,100 feet from the BNSF Alternative site, and the nearest hotel would be approximately 550 feet from the BNSF Alternative site. No noise impacts would occur at any structures in this new development. The only other residences near the site are single-family residences along the west side of 116th Avenue NE (FTA Category 2 and EDNA Class B), which would be over 650 feet away and well shielded from the OMSF by existing structures. Table 6-3 provides the results of the noise analysis.

Table 6-3. Noise Impacts for the BNSF Alternative

	Bellevue Analysis	FTA Analysis			
Address[a]	Peak Hour Leq[b]	Existing Ldn[c]	Project Ldn[d]	FTA Criteria[e]	Impact Type and Criteria Exceeded[f]
Children's Hospital 1500 116th Ave NE	47	65	48	61	None
Commercial Use West of the OMSF	51	N/A[b]	N/A[b]	N/A[b]	None
King County Transit Bus Maintenance Base (industrial use east of OMSF)	52	N/A[b]	N/A[b]	N/A[b]	None
Safeway Distribution Center (industrial use east of OMSF)	52	N/A[b]	N/A[b]	N/A[b]	None

Note: Values in bold text meet or exceed the project noise impact criteria.
[a] Address of representative parcel used in modeling.
[b] Bellevue noise criteria for EDNA Class C (industrial) next to an ENDA Class A (residential) is 60 dBA Leq (daytime) and 50 dBA Leq (nighttime). Details are provided in Section 3.6, City of Bellevue Noise Regulations.
[c] Existing Ldn.
[d] 24-hour Ldn noise from ingress and egress of trains.
[e] FTA moderate impact criteria for 24-hour Ldn for Category 2 land uses.
[f] Number and type of noise impacts from facility (City of Bellevue and WAC criteria are the same for this purpose).

6.3.2 Vibration Impacts

The distance from the OMSF tracks to the Children's Hospital, the closest vibration-sensitive use, is approximately 250 feet, which is well beyond the 100-foot distance for potential vibration impact at FTA Category 2 uses. Therefore, no vibration impacts are projected.

6.4 BNSF Modified Alternative

Noise analysis for the BNSF Modified Alternative site was evaluated using both the FTA criteria and the BCC, which classifies EDNAs based on zoning designations (BCC 9.18.025). There are no noise or vibration impacts predicted under the BNSF Modified Alternative. Details on the analysis are provided below.

6.4.1 Noise Impacts

No noise impacts would occur under the BNSF Modified Alternative. The majority of land use surrounding the BNSF Modified Alternative site is classified EDNA B (commercial) and EDNA C (industrial). The Seattle Children's Hospital: Bellevue Clinic and Surgery Center (FTA Category 2 and EDNA Class B) is approximately 200 feet southwest of the site, and 250 feet west of the access tracks. Residences near the site are along the west side of 116th Avenue NE (FTA Category 2 and EDNA Class B), are over 400 feet away and would be well shielded from the OMSF by existing structures. Residential buildings at the proposed Spring District (FTA Category 2 and EDNA Class B) would be 700 to 925 feet from the BNSF Modified Alternative site, with the hotel 700 feet from the BNSF Modified Alternative site, which is outside the potential distance for noise impacts. No noise impacts were identified at any of these structures. Noise levels were projected for the Seattle Children's Hospital: Bellevue Clinic and Surgery Center (FTA Category 2 and EDNA Class B) and several commercial and industrial sites near the BNSF Modified Alternative site. No noise impacts were identified under the FTA or BCC. The results are provided in Table 6-4.

Table 6-4. Noise Impacts for the BNSF Modified Alternative

	Bellevue Analysis	FTA Analysis			
Address[a]	**Peak Hour Leq[b]**	**Existing Ldn[c]**	**Project Ldn[d]**	**FTA Criteria[e]**	**Impact Type and Criteria Exceeded[f]**
Children's Hospital 1500 116th Ave NE	48	51	61	67	None
Commercial Use West of the OMSF	52	N/A[g]	N/A[g]	N/A[g]	None
King County Transit Bus Maintenance Base (industrial use east of OMSF)	58	N/A[g]	N/A	N/A[g]	None
Safeway Distribution Center (industrial use east of OMSF)	56	N/A[g]	N/A[g]	N/A[g]	None

Note: Values in bold text meet or exceed the project noise impact criteria.

[a] Address of representative parcel used in modeling.

[b] Bellevue noise criteria for EDNA Class C (industrial) next to an ENDA Class A (residential) is 60 dBA. Peak-hour Leq (daytime)for facility operations, typically between 6:00 a.m. and 7:00 a.m. (City of Lynnwood 50 dBA Leq (nighttime), full details are found in Section 3.6, City of Bellevue Noise Regulations).

[c] Existing Ldn.

[d] 24-hour Ldn noise from ingress and egress of trains.

[e] FTA moderate impact criteria for 24-hour Ldn for Category 2 land uses.

[f] Number and type of noise impacts from facility.

[g] There are no FTA noise criteria for commercial or industrial uses.

6.4.2 Vibration Impacts

The distance from the BNSF Modified Alternative site to the Seattle Children's Hospital: Bellevue Clinic and Surgery Center, the closest vibration-sensitive, is approximately 250, which is well beyond the 100-foot distance for potential vibration impact at FTA Category 2 uses. Therefore, no vibration impacts are projected.

6.5 SR 520 Alternative

Noise analysis for the SR 520 Alternative site was evaluated using both the FTA criteria and the local noise control ordinance from the City of Bellevue. The City of Bellevue ordinance classifies EDNAs based on zoning designations (BCC 9.18.025). No noise or vibration impacts were identified under the SR 520 Alternative. Details are provided below.

6.5.1 Noise Impacts

There are no residences or other FTA Category 2 or Category 3 uses within 700 feet of the SR 520 Alternative site; therefore, there were no noise impacts predicted under the FTA noise criteria.

The SR 520 Alternative site is an EDNA Class C (industrial) property. Properties adjacent to the site are classified as EDNA Class B (commercial) and Class C (industrial). EDNA Class A (public park) properties north of the site are over 700 feet from the site, outside the area of potential noise impacts. Therefore, for the analysis under the City of Bellevue noise criteria, noise levels were evaluated for the nearest ENDA Class B (commercial) and Class C (industrial)uses south, east and west of the SR 520 Alternative site. Noise levels from the reconfigured LRV wash system and general OMSF operations are below the City of Bellevue noise control code. Based on the current design drawings, no noise impacts were identified at any nearby structures under the FTA criteria or BCC. Table 6-5 provides the results of the noise analysis.

Table 6-5. Noise Impacts for the SR 520 Alternative

	Bellevue Analysis	FTA Analysis			
Location[a]	Peak Hour Leq[b]	Existing Ldn[c]	Project Ldn[d]	FTA Criteria[e]	Impact Type and Criteria Exceeded[f]
Commercial Use North of the OMSF	40	N/A[g]	N/A[g]	N/A[g]	None
Commercial Use East of the OMSF	48	N/A[g]	N/A[g]	N/A[g]	None
Commercial Use West of the OMSF	47	N/A[g]	N/A[g]	N/A[g]	None
Commercial Use South of the OMSF	53	N/A[g]	N/A[g]	N/A[g]	None

[a] Address of representative parcel used in modeling.
[b] Bellevue noise criteria for EDNA Class C (industrial) next to an ENDA Class A (residential) is 60 dBA. Peak-hour Leq (daytime)for facility operations, typically between 6:00 a.m. and 7:00 a.m. (City of Lynnwood 50 dBA Leq (nighttime). Details are provided in Section 3.6, City of Bellevue Noise Regulations.
[c] Existing Ldn
[d] 24-hour Ldn noise from ingress and egress of trains.
[e] FTA moderate impact criteria for 24-hour Ldn for Category 2 land uses.
[f] Number and type of noise impacts from facility.
[g] There are no FTA noise criteria for commercial or industrial uses.
Note: Values in bold text meet or exceed the project noise impact criteria.

6.5.2 Vibration Impacts

The distance from the SR 520 Alternative site to the closest commercial use, is approximately 100 feet, which is beyond the for potential vibration impact at vibration-sensitive daytime uses. This is based on the measured vibration data from the FTA Manual (2006) that shows that vibration levels will be below 70 VdB at 100 feet from a typical LRV traveling at 50 mph. Therefore no vibration impacts are projected.

6.6 Construction Impacts

This analysis considers the temporary noise effects that construction would cause in the build alternative sites. These effects would end when project construction is completed. Project construction related to noise and vibration are considered in this section.

6.6.1 Construction Noise

Equipment required to complete the proposed project includes normal construction equipment that is used for many roadway and structural construction projects. Table 6-6 provides a typical list of the types of equipment used for this type of project, the activities they would be used for, and the corresponding maximum noise level as measured at 50 feet, under normal use.

Table 6-6. Construction Equipment List, Use, and Maximum Noise Levels

Equipment	Typical Expected Project Use[a]	Typical Noise Level at 50 feet in dBA[b]
Air Compressors	Used for pneumatic tools and general maintenance	81
Backhoe	General construction and yard work	80
Concrete Pump	Pumping concrete	82
Concrete Saws	Concrete removal, utilities access	75–80
Crane	Materials handling, removal and replacement,	83–88
Excavator	General construction and materials handling	82–88
Fork Lifts	Staging area work and hauling materials	72
Generators	Lighting and staging area	78–81
Pavement Grinder	Remove top coat of pavement for resurfacing	88
Haul Trucks	Materials handling, general hauling	86–88
Jack Hammers	Pavement removal	88
Loader	General construction and materials handling	85
Paver	Apply pavement overlay	89
Power Plants	General construction use, nighttime work	72
Pumps	General construction use, water removal	76
Pneumatic Tools	Miscellaneous construction work	85
Service Trucks	Repair and maintenance of equipment	72
Tractor Trailers	Material removal and delivery	82–86
Utility Trucks	General project work	72
Vibratory equipment	Soil compacting	82–88
Welders	General project work, track welds	76

[a] Typical project uses.
[b] Typical maximum noise level under normal operation as measured at 50 feet from the noise source, FTA 2006.

Several phases would be required to complete construction of the proposed project. The analysis assumes the worst-case noise levels based on three major types of construction described in this section and as shown in Table 6-7. The actual noise levels experienced during construction would be generally lower than those given in this report. The noise levels presented here are for short periods of maximum construction activity and would occur for a limited period of time. For the majority of time, construction of the proposed project would be similar to the construction of any commercial office building or other major development.

Table 6-7. Maximum Noise Levels for Typical Construction Phases

Scenario[a]	Equipment[b]	Lm[c]	Leq[d,e]
Demolition base preparation and utilities relocation and installation	Air compressors, backhoe, concrete pumps, crane, dozers excavator, forklifts, haul trucks, loader, pumps, power plants, service trucks, tractor trailers, utility trucks, vibratory equipment	94 dBA	82 dBA
Structures and buildings, track installation, paving activities and connection to mainline	Air compressors, backhoe, cement mixers, concrete pumps, crane, forklifts, haul trucks, loader, pavers, pumps, power plants, service trucks, tractor trailers, utility trucks, vibratory equipment, welders	94 dBA	83 dBA
Miscellaneous activities	Air compressors, backhoe, crane, forklifts, haul trucks, loader, pumps, service trucks, tractor trailers, utility trucks, welders	91 dBA	78 dBA

[a] Operational conditions under which the noise levels are projected.
[b] Normal equipment in operation under the given scenario.
[c] Lm (dBA) is an average maximum noise emission for the construction equipment under the given scenario; for this type of equipment and activities, the Lm is slightly less than the Lmax.
[d] Combined worst-case noise levels for all equipment at a distance of 50 feet from work site.
[e] Leq (dBA) is an energy average noise emission for construction equipment operating under the given scenario.

6.6.1.1 Demolition, Site Preparation, and Utilities Relocation

Major noise-producing equipment used during the construction preparation stage could include dozers, concrete pumps, cranes, excavator, haul trucks, loader, tractor-trailers, and vibratory equipment. Maximum noise levels could reach 82 to 94 dBA within 50 to 100 feet during heavy construction activities. Other, less notable noise-producing equipment expected during this phase includes backhoes, air compressors, forklifts, pumps, power plants, service trucks, and utility trucks.

6.6.1.2 Structures Construction, Track Installation, and Paving Activities

The loudest noise sources in use during this phase of construction would include cement mixers, concrete pumps, cranes, pavers, haul trucks, and tractor-trailers. The cement mixers, cranes, and concrete pumps would be required for construction of shops, buildings and the light rail alignment for facility access. The pavers and haul trucks would be used to provide the final surface on roadways and parking areas. Maximum noise levels could exceed 90 dBA at 50 feet for short periods.

6.6.1.3 Miscellaneous Activities

Following the heavy main facility construction, general supporting construction such as installation of rails, and overhead power systems, shop and LRV wash facility components along with other general construction activities would still need to occur. These less intensive activities are not expected to produce noise levels above 78 dBA at 50 feet except during rare occasions, and even then only for short periods of time.

6.6.1.4 Pile Driving

There is a potential for pile driving at all of the build alternative sites. Pile foundations or drilled piers would likely be required in the northern and eastern parts of the Lynnwood Alternative site. At the BNSF Storage Tracks, BNSF Alternative site, and BNSF Modified Alternative site, pile foundations or drilled piers may be necessary to support elevated structures and bridges or where substantial depth of fill placement would occur. Pile foundations may be necessary to support structures at the SR 520 Alternative site where substantial deep fill placement would occur or where the light rail access lines would cross over underground oil pipelines. Average maximum noise levels from pile driving would typically range from 98 to 105 dBA Lmax at 50 feet. Due to the high noise levels, pile driving would be typically limited to daytime hours, and any pile driving would be required to meet the applicable construction noise regulations.

6.6.1.5 Lynnwood Alternative

For the Lynnwood Alternative, there are residences along 52nd Avenue W that are closer than 100 feet from the Lynnwood Alternative site, there are brief periods of time where noise levels could reach maximum levels of 92 dBA; however, this is unlikely to occur except when the construction is directly adjacent to 52nd Avenue W. The highest noise levels would occur during the first two phases of construction (Table 6-7). Once those phases are completed, the final phase of light construction would not be expected to produce noise levels notably above the existing ambient during the majority of time.

6.6.1.6 BNSF Alternative, BNSF Modified Alternative, and SR 520 Alternative

Under the BNSF Alternative and BNSF Modified Alternative, construction noise is not predicted to be a major concern, as the majority of nearby land uses are commercial or industrial. All residential land uses are shielded from the site and the Seattle Children's Hospital: Bellevue Clinic and Surgery Center is over 300 feet from most construction activities. However, during the first two phases, noise from construction would be noticeable at the hospital and many of the surrounding businesses.

Under the SR 520 Alternative, noise from facility construction would be noticeable at most nearby businesses. Construction noise of the OMSF would be similar to the construction noise that occurred during construction of most of the nearby commercial structures. There are no residences that are predicted to experience adverse effects during the construction of the OMSF along SR 520.

6.6.1.7 Nighttime Construction

Given the location of the proposed build alternative sites, it is unlikely that substantial nighttime construction would be required. Construction activities might be required during nighttime hours because of the nature of the construction. In order to perform construction at night, a noise variance from the local jurisdictions would be required and Sound Transit and/or the contractor would be required to obtain any necessary noise variance specific to project construction.

6.6.2 Construction Vibration

Construction related vibration would be essentially the same under all alternatives and design options. Vibration associated with general construction activities can result in short-term increased vibration levels at nearby structures. Project-related vibration sources include soil compactors, dozers, excavators, haul trucks, flat bed tractor-trailers, backhoes, cranes and jackhammers. The vibration sources associated with the project, even though they are likely to be noticeable to residents when construction is nearby, are not expected to cause any structural damage.

Vibration levels for construction activities are projected to be the highest during demolition activities and soil compacting. Major construction equipment that would be used during demolition includes excavators, haul trucks, backhoes, jackhammers, and cranes. Based on information from the U.S. Bureau of Mines, it typically takes vibration levels in excess of 0.5 inches per second (in/sec) to cause cosmetic damage to plaster walls, and 0.75 in/sec for cosmetic damage to drywall. Vibration levels from project construction are projected to remain below 0.5 inches per second (in/sec) at residences along the project corridor due to the distance between the work zones and structures. Based on this projection, there is only a minimal potential for any structural damage during construction, and only for structures located within 25 to 50 feet from the work zones Table 6-8 provides vibration levels for several different common pieces of construction equipment.

Table 6-8. Vibration Levels for Typical Construction Equipment

Equipment	Conditions	Peak Particle Velocity at 25 feet (in/sec)	Vibration Level in VdB at 25 feet (re 1 micro-in/sec)
Large Bulldozer	Normal operations	0.089	87
Loaded haul trucks	Normal operations	0.076	86
Jackhammer	Normal operations	0.035	79
Small Bulldozer	Normal operations	0.003	58
Vibratory Roller	Normal operations	0.210	94

Source: Federal Transit Administration 2006.
in/sec = inches per second; VdB = velocity decibels.

Chapter 7
Mitigation

This section describes the potential noise and vibration mitigation measures that could be used for the build alternatives. However, if during final design Sound Transit determines that the relevant noise criterion could be achieved by a less costly means, or that the noise or vibration impact at that location would not occur even without mitigation, then the potential mitigation measure(s) might be eliminated or modified as needed. Conversely, if any additional noise impacts are identified during final design, then Sound Transit would provide mitigation that is consistent with the Sound Transit Noise Mitigation Policy (Sound Transit 2004).

7.1 No Build Alternative

Under the No Build Alternative, there would be no project and no noise mitigation would be required.

7.2 Lynnwood Alternative

This section provides the recommended noise mitigation measures for each of the design options for the Lynnwood Alternative.

7.2.1 Design Options C1 and C2

Under Design Options C1 and C2, noise impacts were identified at two EDNA Class A residences under the City of Lynnwood noise control ordinance. These impacts are located along 52nd Avenue W, and are due to the new access crossover. The standard crossover, which is used as the base level for this analysis, along with all other crossovers associated with the mainline access will be replaced with a special noise reducing crossover, which will reduce noise from the wheels traveling across the gap, reduce noise levels and eliminate the noise impact.

The noise levels would be reduced by an additional 6 to 8 dBA at the two receivers near the crossover, and also at several nearby residences that don't have impacts, but would receive a benefit from the low noise crossover. It is also important to note that the crossovers along this segment are behind noise walls that will be installed as part of the Lynnwood Link Extension mitigation package, and the noise reducing effects of that noise wall is included in this analysis. The locations of the special trackwork crossovers that will be installed are shown in Figure 7-1. Noise levels for the two impacts, with and without mitigation are shown on Table 7-1.

Figure 7-1. Lynnwood Alternative, Design Options C1 and C2—Noise Mitigation Measures

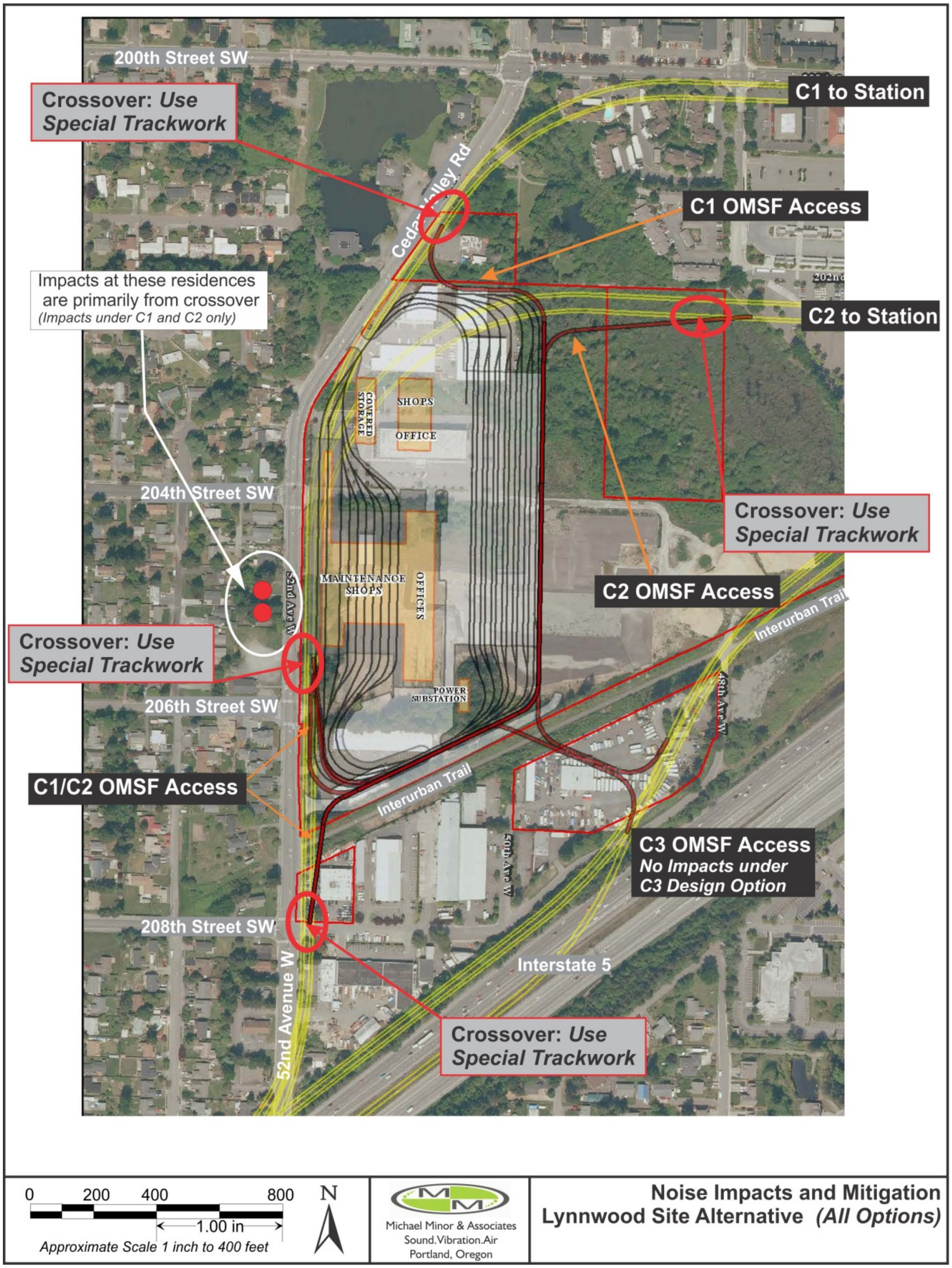


Table 7-1. Noise Impacts and Mitigation for Lynnwood Alternative, Design Options C1 and C2

Address[a]	Project Noise (Leq in dBA)[b]	Noise Impacts[c]	Project w/Mitigation (Leq in dBA)[d]	Impacts w/Mitigation[e]	Mitigation Methods[f]
20504 52nd Ave W	**50**	1	42	0	Special Trackwork for new crossover
20430 52nd Ave W	**50**	1	42	0	Special Trackwork for new crossover

a. Sites shown in Figure 3.8-8 of the Draft EIS.
b. Lynnwood criteria for EDNA Class A (residential) noise levels is 60 dBA Leq (daytime) and 50 dBA Leq (nighttime).
c. Number of homes with noise levels above the criteria.
d. Project noise levels with proposed noise mitigation measures.
e. Number of homes with noise levels above the criteria with noise mitigation measures.
f. Type of mitigation proposed for the project impact.

No vibration impacts were projected for Design Options C1 and C2, and no vibration mitigation is recommended, although the special crossovers will also reduce vibration levels from the track along this segment of the corridor.

7.2.2 Design Option C3

No noise impacts would occur under the Lynnwood Alternative, Design Option C3as identified by any of the criteria and no noise mitigation is recommended. No vibration impacts were projected for Design Option C3; therefore, no vibration mitigation is recommended.

7.3 BNSF Alternative, BNSF Modified Alternative, and SR 520 Alternative

There were no FTA noise or vibration impacts identified under the BNSF Alternative, BNSF Modified Alternative, or SR 520 Alternative. There are also no noise impacts projected under the City of Bellevue noise control ordinance under any of the alternatives. Therefore, no noise or vibration mitigation is necessary.

7.4 Construction Mitigation

Under Sound Transit's Light Rail Noise Mitigation Policy, Sound Transit would seek to limit construction noise levels and meet applicable noise regulations and ordinances. Typical mitigation measures that could be applied are discussed below. Contractors would be required to meet the criteria of Cities of Lynnwood and Bellevue noise ordinances.

Several noise-mitigation measures could be implemented to reduce construction noise levels to within the required limits. Sound Transit would, as practical, limit construction activities that produce the highest noise levels during daytime hours, or when disturbance to sensitive receivers would be minimized. For operation of construction equipment that could exceed allowable noise limits during nighttime hours (between 10:00 p.m. and 7:00 a.m.) or on Sundays or legal holidays, Sound Transit would obtain the appropriate noise variance from the City of Lynnwood or the City of Bellevue.

Noise-control mitigation could include the following measures, as necessary, to meet required noise limits.

7.4.1 Equipment Noise Mitigation

1. Ensure that pneumatic impact tools and equipment used at the construction site have intake and exhaust mufflers recommended by the manufacturers thereof, to meet relevant noise ordinance limitations.
2. Construction equipment, both stationary and mobile, should be of recent manufacture and incorporate effective noise-suppression design, including features such as shrouds, baffles, and mufflers or as recommended by the manufacturers.
3. Locate stationary equipment that generates noise away from sensitive receptors and shield with a noise-attenuating barrier or shroud.
4. Line or cover storage bins and chutes with sound-deadening material.
5. Ensure all vehicles engaged in loading on-site have lined truck beds.
6. Provide mufflers or shield paneling for other equipment, including internal combustion engines, recommended by manufacturers thereof.
7. As required to meet the noise limits specified in this section, use alternative procedures of construction and selection of proper combination of techniques that generate least overall noise and vibration. Such alternative procedures include the following:
    a. Use electric welders powered from utility main lines instead of internal combustion powered generators/welders.
    b. Mix concrete off-site instead of on-site.
    c. Employ prefabricated structures instead of assembling on-site.
    d. Drilled pile installation methods.
8. Use construction equipment manufactured or modified to dampen noise and vibration emissions, such as:
    a. Use electric instead of diesel-powered equipment.
    b. Use hydraulic tools instead of pneumatic impact tools.
    c. Use electric instead of air- or gasoline-driven saws.

7.4.2 Construction Methods Noise Mitigation

1. Operate equipment and cranes so as to minimize banging, clattering, buzzing, and other annoying types of noises, especially near residential areas.
2. To the extent feasible, configure the construction site in a manner that keeps noisier equipment and activities as far as possible from noise sensitive locations and nearby buildings.
3. Minimize noise-intrusive impacts during most noise sensitive hours.

4. Plan noisier operations during times of highest ambient noise levels.
5. Keep noise levels relatively uniform; avoid excessive and impulse noises.
6. Turn off idling equipment.
7. Phase in start-up and shut-down of site equipment.
8. Avoid simultaneous activities that both generate high noise levels.
9. Use construction truck routes for excavation disposal as shown on the Contract Drawings.
10. Conduct truck loading, unloading and hauling operations so noise and vibration are kept to a minimum.
11. Limit the time that steel decking or plates for covering excavated areas are in use.
12. Grade surface irregularities on construction sites to minimize the generation of impact noise and ground vibrations by passing vehicles.
13. Use warning broadband backup alarms on all equipment in operation at the site, at all times.
14. Limit the use of annunciators or public address systems, except for emergency notifications.
15. Install noise abatement measures in locations specified in the Contract Specifications as required to meet the noise limits specified.

The contract specifications will contain a section specific to construction related noise and also provide the actual construction noise limits, mitigation measures, and operational methods that will be used to maintain reasonable construction noise levels. The construction specifications will also provide requirements for construction noise monitoring, reporting and any construction log or hotline to be associated with this project.

The construction contract specifications will also contain a section specific to vibration that could require vibration monitoring of all activities that may produce vibration levels at or above 100 VdB or 0.5 in/sec whenever there are structures located near the construction activity. This would only be required for construction activities that have the potential to cause high levels of vibration. There is virtually no effective method to reduce vibration effects from construction; however, by restricting and monitoring vibration-producing activities, vibration effects from construction could be kept to a minimum.

7.4.3 Construction Vibration Mitigation

The construction contract specifications could also contain a section specific to vibration that could require vibration monitoring of all activities that may produce vibration levels at or above 100 VdB or 0.5 in/sec whenever there are structures located near the construction activity. This would only be required for construction activities that have the potential to cause high levels of vibration. Vibration effects from construction can be kept to a minimum by restricting and monitoring vibration-producing activities.

Chapter 8
Cumulative Analysis

This chapter provides a summary of the cumulative noise levels expected once the light rail extension and OMSF facilities are completed. For example, under the Lynnwood Alternative, Design Options C1 and C2, this analysis provides the total noise from light rail operations along 52nd Avenue W in combination with the noise from the operations of the OMSF, providing cumulative future noise levels. The cumulative analysis also assumes that any noise mitigation measures proposed for the East Link and Lynnwood Link Extension projects would be constructed with the project.

8.1 Lynnwood Alternative

8.1.1 Design Options C1 and C2

Under the Lynnwood Alternative, Design Options C1 and C2, the cumulative noise levels at residences along 52nd Avenue W, between 208th Street and 204th Street, are predicted to range from 58 to 70 dBA Ldn prior to noise mitigation. There are nine moderate and 13 severe noise impacts predicted in this area from the Lynnwood Link Extension, and the two noise impacts under the Lynnwood Alternative for the proposed OMSF project are included in those noise impacts. The impacts identified using FTA criteria would be due to the noise from the Lynnwood Link Extension, and not from operations of the OMSF.

The noise mitigation measures for the Lynnwood Link Extension Alternatives C1 and C2 both include the installation of noise walls along the elevated guideway, beginning at I-5 and continuing to the Lynnwood Station. In addition to the mitigation for the mainline corridor, noise mitigation for the OMSF would also include special track work crossovers located at 52nd Avenue W, helping to reduce the overall contribution to the noise environment. Noise levels at all residences along 52nd Avenue W to below the FTA criteria, with future cumulative noise levels ranging from 46 to 59 dBA Ldn. Therefore, all cumulative noise impacts are fully mitigated. Tables summarizing the cumulative analysis for residences along 52nd Avenue W are provided in Attachment A.

Under Design Options C1 and C2, cumulative construction noise generated at the properties near the build alternative sites would be expected to be the same as the standalone OMSF project, as presented in Section 6.2.1, Design Options C1 and C2. There is a potential for some other local construction projects to overlap with the construction of this project. This would only happen if other unrelated construction projects occur simultaneously with this project. However, because the OMSF project's construction noise analysis assumes the worst-case noise levels, the overall maximum noise levels at any one property would remain the same, as presented in Section 6.2.1, Design Options C1 and C2.

8.1.2 Design Option C3

Under Design Option C3, cumulative noise levels would be the same as given for the OMSF in Chapter 6, Mitigation, for properties near the proposed site along 52nd Avenue W, and noise levels along the Lynnwood Link Extension alignment would be the same as provided in the *Lynnwood Link Extension Draft EIS* (Sound Transit 2013). Noise from the OMSF would not contribute to the Lynnwood Link light rail mainline noise because the alignment is over 400 feet south of the OMSF site, is shielded from the 52nd Avenue W residences by existing and future structures and is along I-5. Cumulative construction noise generated at the properties near the Lynnwood Alternative, Design Option C3 would be the same as described for Design Options C1 and C2.

8.2 BNSF Alternative

Under the BNSF Alternative, cumulative noise levels would be the same as given for the OMSF in Chapter 6, Mitigation, for properties near the proposed site, and noise levels along the East Link alignment would be the same as provided in the *East Link Final EIS* (Sound Transit 2011). Noise from the OMSF would not contribute to the mainline East Link light rail noise because the alignment is over 600 feet south of the BNSF Alternative site.

Cumulative construction noise generated at the properties near the BNSF Alternative site would be expected to be the same as the standalone OMSF project. There is a potential for other local construction projects to overlap with the construction of this project; however, the worst-case construction noise levels predicted would also account for any other nearby construction project. In most cases, however, because construction noise would be localized, it would not contribute toward a cumulative noise impact.

8.3 BNSF Modified Alternative

Under the BNSF Modified Alternative, cumulative noise levels would be the same as given for the OMSF in Chapter 6, Mitigation, for properties near the proposed site, and noise levels along the East Link alignment would be the same as provided in the East Link Final EIS. Noise from the OMSF site would not contribute to the mainline East Link light rail noise because the alignment is over 600 feet south of the OMSF site.

Cumulative construction noise generated at the properties near the BNSF Modified Alternative site would be the same as described for the BNSF Alternative.

8.4 SR 520 Alternative

Under the SR 520 Alternative, cumulative noise levels would be the same as given for the OMSF in Chapter 6, Mitigation, for properties near the proposed site, and noise levels along the East Link alignment would be the same as provided in the *East Link Project Final EIS* (Sound Transit 2011). Noise from the SR 520 Alternative site would not contribute to the mainline East Link noise because the alignment is approximately 500 feet southeast of the SR 520 Alternative site.

Cumulative construction noise generated at the properties near the SR 520 Alternative site would be the same as described for the BNSF Alternative.

Chapter 9
References

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Attachment A

Cumulative Noise Level Table

Table A-1. Cumulative Noise Levels for the Lynnwood Alternative with Lynnwood Link Extension Alternative with Design Option C1or C2

		Noise Sources		Cumulative Project Noise and Impacts					Mitigation Measures and Mitigated Cumulative Project Noise Levels		
Address[a]	Ext Ldn[b] (dBA)	LRT Ldn (dBA)[c]	OMSF Ldn (dBA)[d]	Total Ldn (dBA)[e]	FTA Criteria (dBA)[f] Moderate	FTA Criteria (dBA)[f] Severe	Mod Imp[g]	Sev Imp[h]	Mitigation Measures[i]	Project Ldn with Mitigation (dBA)[j]	Residual Impacts[k]
5211 208th St SW	64	70	46	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20706 52nd Ave W	64	70	42	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20628 52nd Ave W	64	70	41	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20624 52nd Ave W	64	70	42	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20618 52nd Ave W	64	70	45	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
5210 206th St SW	64	70	48	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20504 52nd Ave W	64	70	50	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20430 52nd Ave W	64	70	50	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20416 52nd Ave W	64	70	48	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20410 52nd Ave W	64	70	46	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20406 52nd Ave W	64	70	46	70	61	66	--	1	Snd Wall-Fac Mods-Spl Trk	58	0
20403 53rd Ave W	62	62	39	62	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	50	0
20411 53rd Ave W	62	62	40	62	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	50	0
20419 53rd Ave W	62	62	41	62	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	50	0
20425 53rd Ave W	62	62	41	62	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	50	0

	Noise Sources		Cumulative Project Noise and Impacts					Mitigation Measures and Mitigated Cumulative Project Noise Levels		
				FTA Criteria (dBA)[f]						
Address[a]	Ext Ldn[b] (dBA)	LRT Ldn (dBA)[c]	OMSF Ldn (dBA)[d]	Total Ldn (dBA)[e]	Moderate	Severe	Mod Imp[g]	Sev Imp[h]	Mitigation Measures[i]	Project Ldn with Mitigation (dBA)[j]	Residual Impacts[k]
20429 53rd Ave W	62	62	43	62	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	50	0
20505 53rd Ave W	62	62	44	62	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	50	0
20511 53rd Ave W	63	67	45	67	60	66	--	1	Snd Wall-Fac Mods-Spl Trk	55	0
20517 53rd Ave W	63	67	45	67	60	66	--	1	Snd Wall-Fac Mods-Spl Trk	55	0
20523 53rd Ave W	62	61	41	61	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	49	0
20510 53rd Ave W	62	60	39	60	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	58	0
20506 53rd Ave W	62	60	39	60	59	65	1	--	Snd Wall-Fac Mods-Spl Trk	48	0

[a] Address of parcel under analysis
[b] Existing Ldn noise levels in dBA
[c] Noise from light rail operations under designated alternative
[d] Noise from OMSF operations
[e] Total un-mitigated Ldn for light rail transit and OMSF operations combined
[f] FTA noise criteria for residences
[g] Number of structures identified moderate noise impacts
[h] Number of structures identified severe noise impacts
[i] Mitigation Measures: Snd Wall = Sound Walls (either Lynnwood Link Extension or OMSF); Fac Mods = Facility Modifications; Spl Trk = Special Trackwork for Crossovers
[j] Total Project noise, light rail transit and OMSF operations combined, with proposed noise mitigation measures in place
[k] Residual noise impacts with mitigation.