4.7 Noise and Vibration

4.7.1 Introduction to Resources and Regulatory Requirements

4.7.1.1 Noise and Vibration Basics

Noise

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

There are two primary noise measurement descriptors that are used to assess noise impacts from traffic and transit projects, the Leq and the Ldn, described below:

Leq: The equivalent sound level (Leq) is the level of a constant sound for a specified period of time that has the same sound energy as an actual fluctuating noise over the same period of time. The peak-hour Leq is used for all traffic and light rail noise analyses at locations with daytime use, such as schools and libraries.

Ldn: The day-night sound level (Ldn) is an Leq over a 24-hour period, with 10 dBA added to nighttime sound levels (between 10 p.m. and 7 a.m.) as a penalty to account for the greater sensitivity and lower background sound levels during this time. The Ldn is the primary noise-level descriptor for light rail noise at residential land uses. Exhibit 4.7-1 is a graph of typical Ldn noise levels and residential land use compatibility. More detail on noise and noise descriptors are provided in the *Noise and Vibration Technical Report* (Appendix H2).

In addition to the Leq and Ldn. there is also a descriptor called the Lmax. The Lmax is the loudest 1 second over a measurement period and is used in many local and state ordinances for noise coming from private land uses and for construction impact evaluation.

Vibration

Travel of light rail trains on trackways and guideways associated with the East Link Project would result in vibration that may be felt on adjacent properties. The project was analyzed for two types of vibration impacts:

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

Ground-borne vibration can be described in terms of displacement, velocity, or acceleration for evaluating impacts from transit projects. Ground-borne noise occurs as a perceptible rumble and is caused by the noise radiated from the vibration of room surfaces. Vibration above certain levels can damage buildings, disrupt sensitive operations, and cause annoyance to humans within buildings.

The response of humans, buildings, and equipment to vibration is most accurately described using velocity or acceleration. Vibration velocity is used in this

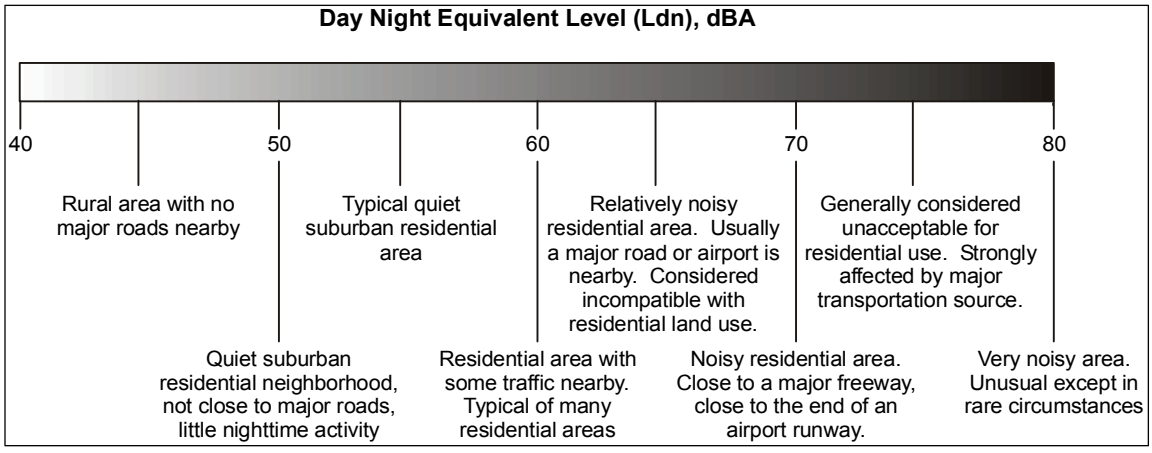


EXHIBIT 4.7-1
Typical 24-hour Ldn Noise Levels and Land Use Compatibility

analysis as the primary measurement to evaluate the effects of vibration.

Exhibit 4.7-2 illustrates typical ground-borne vibration velocity levels for common sources as well as thresholds for human and structural response to ground-borne vibration. As shown, the range of interest is from approximately 50 vibration velocity decibels (VdB) to 100 VdB (i.e., from imperceptible background vibration to the threshold of damage). Although the threshold of human perception to vibration is approximately 65 VdB, annoyance does not usually occur unless the vibration exceeds 70 VdB.

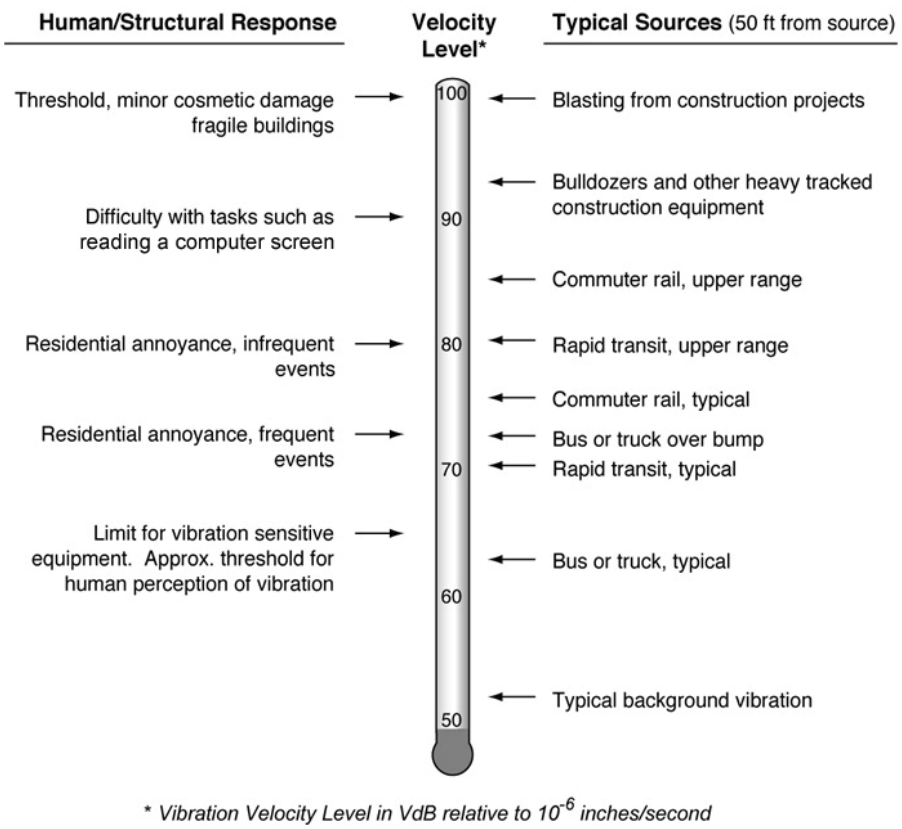


EXHIBIT 4.7-2
Examples of Ground-Borne Vibration Levels and Human/Structural Response

4.7.1.2 Noise and Vibration Impact Criteria

The following sections provide an overview of the criteria used for evaluating East Link Project noise and vibration impacts, which are defined by the Federal Transit Administration (FTA) for transit-related noise and vibration and by the Federal Highway Administration (FHWA) for traffic-related noise. The FTA and FHWA analyses are performed based on actual land use, not land use zoning. Therefore, if a residence is located in an area that has been zoned commercial, the analysis still considers that location to be a residential land use.

Transit Noise Criteria

Noise impacts for the East Link Project are based on the criteria defined in the FTA guidance manual *Transit Noise and Vibration Impact Assessment*. The FTA noise impact criteria are founded on well-documented research of community reaction to noise and are based on changes in noise levels using a sliding scale. Although more transit noise is allowed in neighborhoods with high levels of existing noise, as existing noise levels increase, smaller increases in total noise exposure are allowed than in areas with lower existing noise levels.

The FTA Noise Impact Criteria group noise-sensitive land uses into the following three categories:

- **Category 1**: Buildings or parks where quiet is an essential element of their purpose.
- **Category 2**: Residences and buildings where people normally sleep, including residences, hospitals, and hotels where night-time sensitivity is assumed to be important.
- **Category 3**: Institutional land uses with primarily daytime and evening use, including schools, libraries, churches, and active parks.

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 two levels of impact included in the FTA criteria. The interpretation of these two levels of impact is summarized below:

- **Severe Impact:** Project-generated noise in the severe impact range can be expected to cause a substantial 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 noise level, the predicted 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.

Exhibit 4.7-3 shows graphically the noise impact criteria as well as the existing noise exposure and the additional noise exposure from a 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 a transit project.

Traffic Noise Criteria

The criteria for highway noise impacts are taken from the FHWA Procedures for Abatement of Highway Traffic Noise and Construction Noise, Title 23, Code of Federal Regulation (CFR) Subchapter H, Section 772 (1982). The traffic noise abatement criteria are listed in Table 4.7-1. A noise impact occurs if predicted noise levels approach the levels for specific land use categories listed in Table 4.7-1 or substantially exceed existing noise levels, as defined by the Washington State Department of Transportation (WSDOT). Per these regulations, only projects that include construction of new highway, reconstruction of existing highways with a substantial change in the horizontal alignment or vertical profile, or an increase in the number of through traffic lanes require a traffic noise analysis. If impacts are identified, noise abatement must be considered.

WSDOT is responsible for implementing the FHWA regulations in Washington. Under WSDOT policy, a traffic-noise impact occurs if predicted noise levels are within 1 dB of the FHWA criteria shown in Table 4.7-1; therefore, a residential impact occurs at 66 dBA Leq, and a commercial impact occurs at 71 dBA Leq. WSDOT also considers a 10-dB increase in noise a substantial impact, regardless of the original noise level.

Transit Vibration Criteria

The FTA ground-borne vibration impact criteria are based on existing land use and planned train frequencies. Table 4.7-2 shows the criteria for a general vibration assessment. There are some buildings, such as concert halls, recording studios, and theaters that can be very sensitive to vibration but do not fit into any of the three categories listed in Table 4.7-2. Due to their sensitivity, these buildings usually warrant special attention during the vibration analysis.

Within the project corridor, these buildings include the theater at Meydenbauer Center, the Bellevue Arts Museum, the Overlake Hospital MRI Unit, the Overlake Hospital Optical Surgery Unit, the new Group Health Medical Center, and proposed Children's Hospital Bellevue Ambulatory Surgery Center (ASC) . Based on consultation with these facilities, the existing sensitive uses have been identified at these locations described below.

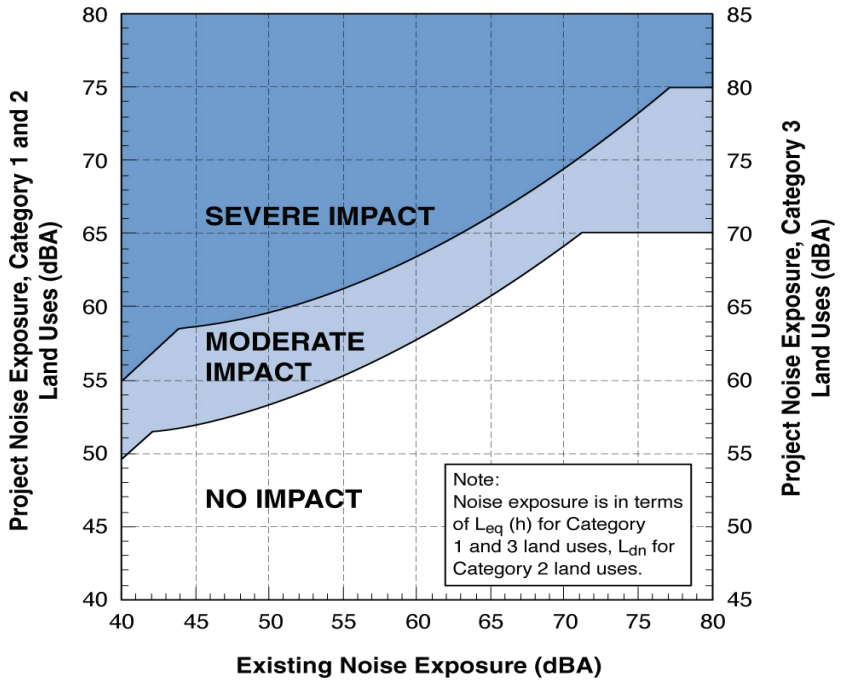


EXHIBIT 4.7-3
FTA Project Noise Impact Criteria

TABLE 4.7-1
FHWA Traffic Noise Abatement Criteria

Land Use Category		Hourly Leq
Type A	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose	57 dBA (exterior)
Type B	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals	67 dBA (exterior)
Type C	Developed lands, properties or activities not included in the above categories	72 dBA (exterior)
Type D	Undeveloped land	—
Type E	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums	52 dBA (interior)

Source: FHWA Procedures for Abatement of Highway Traffic Noise and Construction Noise (23 CFR 772)

TABLE 4.7-2
Ground-Borne Vibration and Noise Impact Criteria for Light Rail Transit Service Frequency

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro inch/second): Frequent Events	Ground-Borne Noise Impact Levels (dB re 20 micro Pascals): Frequent Events
Category 1: Buildings where low ambient vibration is essential for interior operations	65 VdB[a]	N/A[b]
Category 2: Residences and buildings where people normally sleep	72 VdB	35 dBA
Category 3: Institutional land uses with primarily daytime use	75 VdB	40 dBA

[a] This criterion limit is based on levels that are acceptable for most moderately sensitive equipment, such as optical microscopes. Vibration-sensitive manufacturing or research would require detailed evaluation to define the acceptable vibration levels. Verifying lower vibration levels in a building often requires special design of the heating, ventilation, and air conditioning (HVAC) systems and stiffened floors.

[b] Vibration-sensitive equipment is generally not sensitive to ground-borne noise.

Additional sensitive uses may exist in the future that would require additional analysis. The following criteria apply for these locations:

- Theater at Meydenbauer Center and Bellevue Arts Museum: 72VdB for vibration, 35 dBA for ground-borne noise
- MRI Units at Overlake Hospital, Group Health Medical Center, and Children's Hospital Bellevue ASC: 60 VdB for vibration, no criterion for ground-borne noise because vibration sensitive equipment is not sensitive to ground-borne noise
- Overlake Hospital Optical Surgery Unit: 54 VdB for vibration, no criterion for ground-borne noise because vibration sensitive equipment is not sensitive to ground-borne noise

Table 4.7-2 includes separate FTA criteria for ground-borne noise—the "rumble" that can radiate from the motion of room surfaces in buildings due to ground-borne vibration. The vibration of floors and walls causes them to act like loudspeakers, generating noise due to the movement of the surfaces. Although expressed in dBA, which emphasizes the more audible middle and high frequencies, the criteria are set lower than they are for airborne noise to account for the annoying low-frequency character of ground-borne noise. Because airborne noise often masks ground-borne noise for aboveground transit systems (i.e., at-grade or elevated), ground-borne noise criteria are primarily applied to light rail operations in a tunnel where airborne noise is not a factor. For above-grade transit systems,

ground-borne noise criteria are applied only to buildings that have sensitive interior spaces that are well insulated from exterior noise.

Washington State Noise Criteria

The State of Washington has a noise control ordinance that applies to general construction activities, park-and-ride lots, and maintenance facilities. The Washington State Noise Control Ordinance does not contain a section specific to highway or light rail noise. Highway and light rail operation noise on public roadways and rights-of-way are exempt under the noise ordinance. For noise originating from outside public roadways and rights-of-way, the Washington State Noise Control Ordinance defines three classes of property usage and the maximum noise levels allowable for each (Table 4.7-3). For example, the noise caused by a commercial property must be less than 57 dBA at the closest residential property line. Between 10 p.m. and 7 a.m., the maximum allowable levels shown in Table 4.7-3 are reduced by a 10-dBA "penalty." In addition to the property line noise standards, there are exemptions for short-term noise exceedance based the minutes per hour that the noise limit is exceeded (Table 4.7-4). Local noise limits for construction equipment and specific exceedence exemptions are discussed in Section 4.7.3.5, Impacts during Construction.

4.7.1.3 Methodology

The light rail noise and vibration analysis was performed in accordance with the Transit Noise and Vibration Guidance Manual, FTA revised May 2006. An FTA screening level analysis was performed during initial alternative screening, providing the project team with valuable information on potential noise and vibration impacts to inform the identification of reasonable alternatives to carry forward into the Draft EIS. The noise and vibration analysis that follows was performed using current conceptual project design files and follows the detailed analysis methods described in the FTA manual.

TABLE 4.7-3
Washington State Noise Limits

Property Usage	Maximum Allowable Sound Level (dBA)		
	Residential	Commercial	Industrial
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

TABLE 4.7-4
Washington State Short-Term Noise Exceedance Exemptions

Maximum Minutes per Hour	Adjustment to Allowable Sound Level
15	+5 dBA
5	+10 dBA
1.5	+15 dBA

Light rail noise and vibration impacts were evaluated using actual measured noise and vibration levels from Sound Transit's fleet of light rail vehicles. Detailed noise and vibration prediction models were developed using the methods given in the FTA Manual. Input to the models includes the track type (elevated, at-grade and embedded), distance from LRT tracks to sensitive properties, train speed, number of trains per hour and per day, and the location of any special track work such as switches. In addition, for the vibration analysis, the measured vibration levels were adjusted for ground type using data from propagation tests performed along the project corridor. Outputs from the models were then compared to the FTA's impact criteria, and impacts were identified.

For those locations where project construction required a substantial movement of the horizontal alignment or vertical profile of existing roadways, a traffic noise analysis was also performed. The traffic noise projections were performed using the FHWA's Traffic Noise Model (TNM) and follow the FHWA methods for predicting traffic noise levels. Traffic noise impacts were identified using the WSDOT traffic noise abatement criteria. Detailed information on the models and model inputs are provided in Section 4.7.3, Environmental Impacts.

4.7.2 Affected Environment

This section provides a summary of land uses along the project corridor as well as existing noise and vibration levels measured for the East Link analysis. Exhibits 4.7-4 and 4.7-5 show where existing noise and vibration were measured. More detailed maps showing the locations of the noise-monitoring sites and planned land uses are provided in the *Noise and Vibration Technical Report* (Appendix H2).

4.7.2.1 Noise- and Vibration-Sensitive Land Uses

While a more detailed presentation of land use can be found in Section 4.3, Land Use, of this Draft EIS, the following land uses are summarized for their potential sensitivity to noise and vibration. Most identified land uses are sensitive to both noise and vibration. The exceptions include outdoor parks, which may be noise sensitive depending on usage, but are not vibration sensitive, and vibration-sensitive equipment (such as MRI equipment in a hospital), which is not sensitive to noise. It is important to note that the discussion on land use is based on the actual use and not the zoning. For example, if a residence is legally located in an area that has rezoned for commercial use, the property would still be considered as a residence for the analysis.

For most of the project corridor, land use and zoning appear to match. Areas that are in transition include the southern end of Downtown Bellevue, the area near Lake Bellevue, and some areas along the BNSF railroad tracks in Redmond. Other areas where zoning is planned to change and may not match land uses in the future include the Bel-Red corridor and the Overlake neighborhood. Long-term monitoring locations were measured for 24 hours, while short-term monitoring locations were measured for 20 minutes. Table 4.7-5 provides a summary of the noise levels at these monitoring locations as measured in February and March 2007. A discussion of land use and noise levels by segment is given below.

Segment A

Land use near the connection to the existing transit tunnel is mainly commercial; however, there are multifamily residences on the upper floors of the Uwajimaya Grocery Store at 6th Avenue S and South Lane Street, where the route is in the existing transit tunnel. The route continues eastbound along the D2 Roadway, remaining in the existing Interstate 90 (I-90) corridor to the Mt. Baker Tunnel. Land use along this section of the route is mainly commercial until it reaches 12th Avenue S, where there is a large group of single-family and multifamily residences. The route transition's from the tunnel to the floating bridge, through an area that is primarily single-family residential.

Land use along Mercer Island is primarily single-family residential with multifamily apartment buildings near the Mercer Island Station. At the eastern end of Mercer Island, land use is primarily single-family residential with some office buildings to the south of the highway.

Five locations were monitored in Segment A, one long-term and four short-term. Existing noise levels along Segment A are dominated by traffic noise from area highways, including I-5, I-90, and major arterial roadways. The measured existing Ldn near Segment A in the Seattle area was 69 dBA. Peak-hour noise levels were measured at two different representative locations between 4 and 5 p.m. and ranged from 67 to 68 dBA Leq.

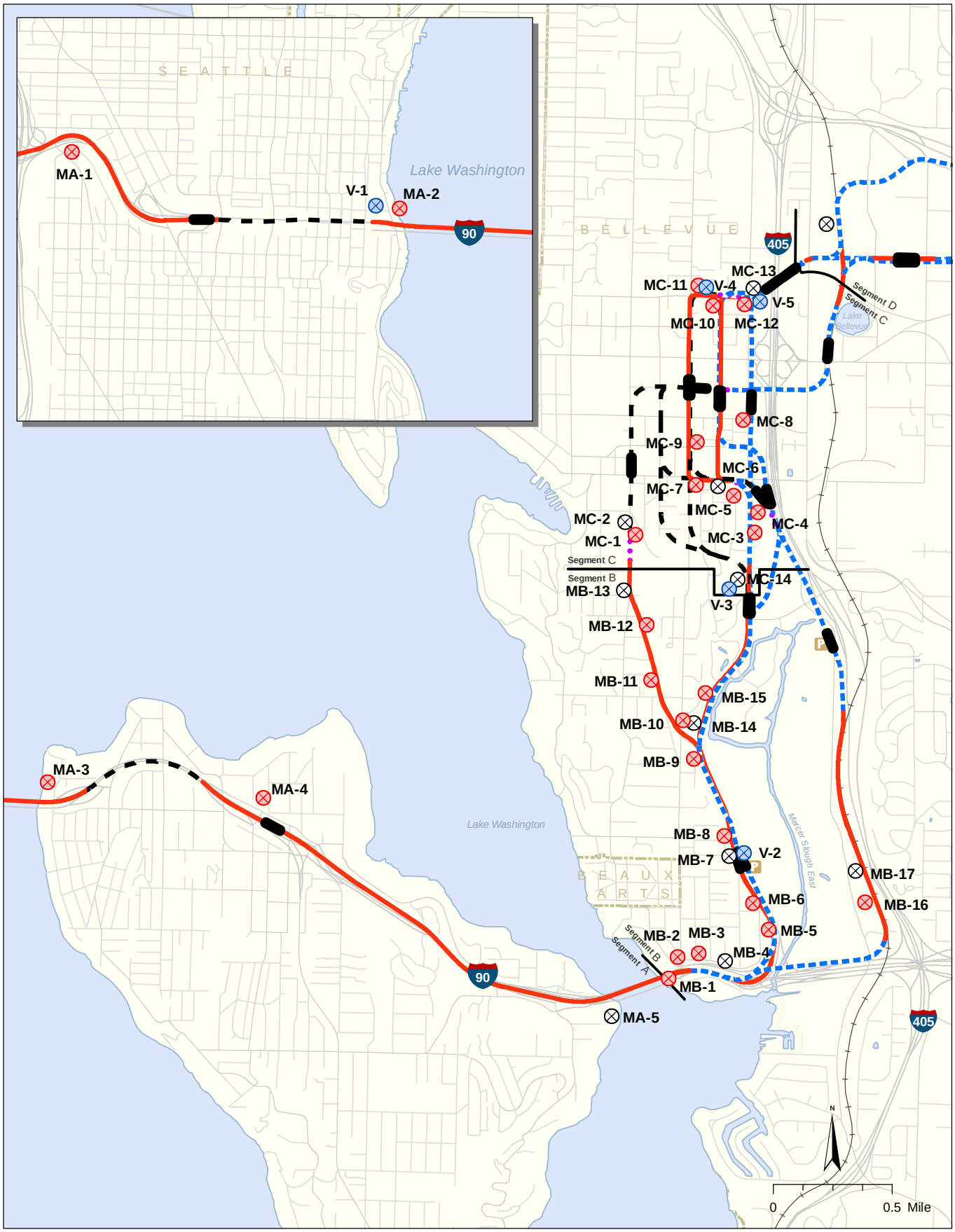
Segment B

Land use in Segment B consists primarily of residences and parks, with some institutional and commercial uses. Land use in the southern end of Segment B, near Lake Washington, includes single-family residences and the Enatai Beach Park. Land use along Bellevue Way is primarily residential from I-90 to Downtown Bellevue, although there are several churches and some commercial structures north of the intersection with 112th Avenue SE. The Frederick Winters House, a historic structure used for non-residential uses, is located along the east side of Bellevue Way adjacent to the Mercer Slough Nature Park. Along the 112th Avenue SE At-Grade (B2A) and Elevated (B2E) alternatives, land use along the west side of the alternatives is entirely single- and multifamily residential, with commercial use on the east side transitioning to mixed commercial and hotel use from SE 8th Street to the boundary with Segment C. Land use along the BNSF Alternative (B7) includes the Mercer Slough Nature Park, multifamily residences, and commercial land use. Major sources of noise in this segment include traffic noise from I-90, I-405, and Bellevue Way.

Eighteen locations were monitored in Segment B: 12 short-term sites and 6 long-term sites. Overall peak-hour noise levels in south Bellevue ranged from 50 to 72 dBA Leq. The highest noise levels were measured at locations near I-90 and along Bellevue Way.

Segment C

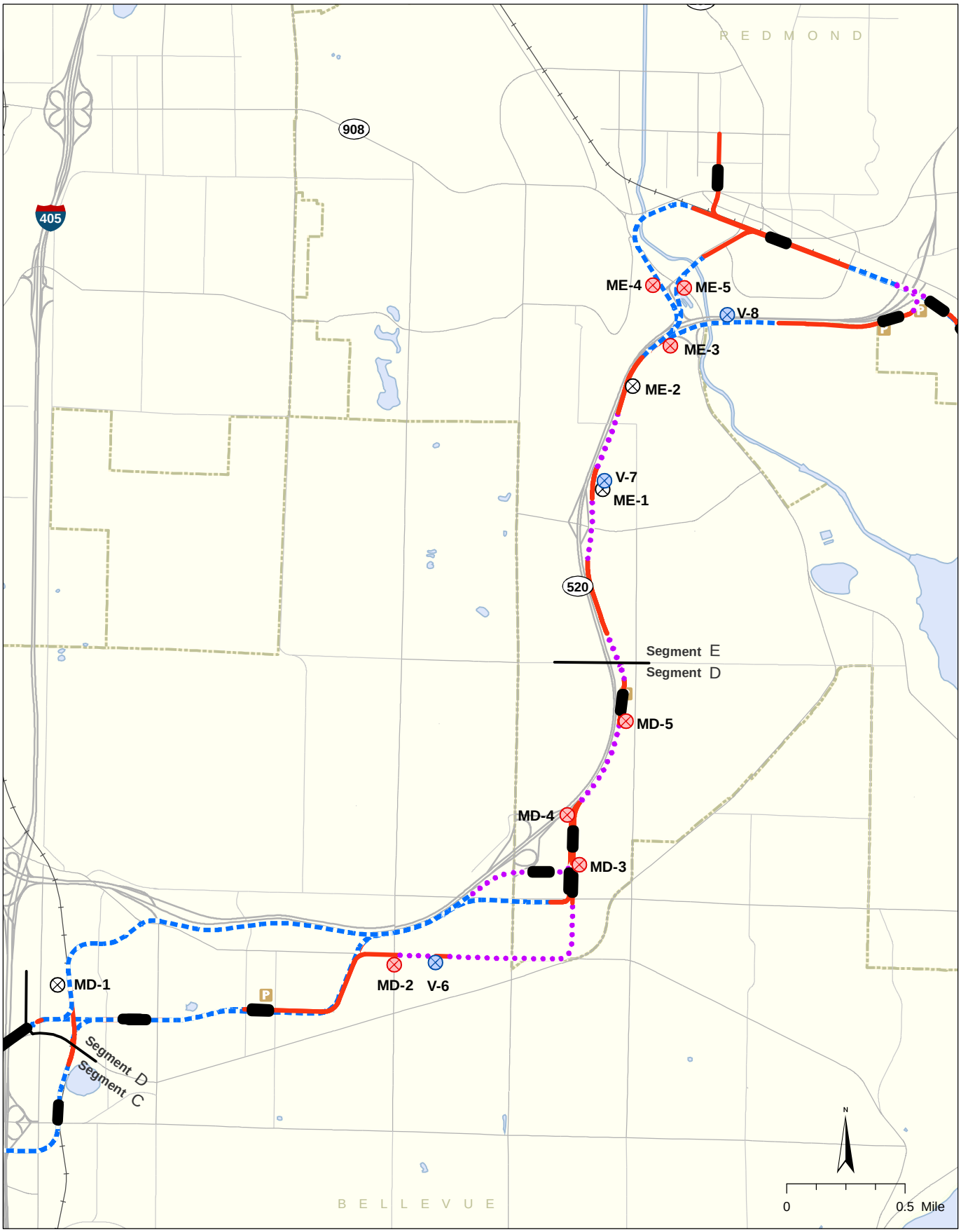
Land use in the southern section of Segment C includes the Surrey Downs residential area and Bellevue High School, which transitions to commercial and office uses around Main Street. Hotels and office parks are also present at the south end of 112th Avenue SE in this segment. The commercial core of Downtown Bellevue is located on Bellevue Way between NE 4th Street and NE 8th Street, and includes several large shopping centers and office towers. There are some mixed-use buildings in Downtown Bellevue with commercial uses on the ground floors and residential units on the upper floors. Other noise sensitive properties in this area include the theater at Meydenbauer Convention



Source: Data from City of Bellevue (2005) and King County (2006).

Long-Term Noise Monitoring Location
Short-Term Noise Monitoring Location
Vibration Monitoring Location
At-Grade Route
Elevated Route
Retained-Cut Route
Tunnel Route
Proposed Station
New and/or Expanded Park-and-Ride Lot

Exhibit 4.7-4 **Noise and Vibration Monitoring Locations Segments A, B, and C**
East Link Project



Source: Data from City of Bellevue (2005) and King County (2006).

Long-Term Noise Monitoring Location
Short-Term Noise Monitoring Location
Vibration Monitoring Location
At-Grade Route
Elevated Route
Retained-Cut Route
Tunnel Route
Proposed Station
New and/or Expanded Park-and-Ride Lot

Exhibit 4.7-5 **Noise and Vibration Monitoring Locations Segments D and E**
East Link Project

TABLE 4.7-5
Existing Conditions Noise Monitoring Summary

Monitoring Location[a]	Site Address	Land Use Type	Type of Measurement	Leq (dBA)	Ldn (dBA)
Segment A					
MA-1	Taejon Park	Park	Short-term	68	69
MA-2	East Portal Park	Park	Short-term	68	69
MA-3	West Mercer Way Park	Park	Short-term	65	65
MA-4	2257 80th Avenue SE	Single-family	Short-term	51	54
MA-5	3700 East Mercer Way	Single-family	Long-term	56	55
Segment B					
MB-1	Enatai Beach Park	Park	Short-term	62	62
MB-2	3457 107th Avenue SE	Single-family	Short-term	64	66
MB-3	3246 109th Avenue SE	Single-family	Short-term	72	72
MB-4	3264 111th Avenue SE	Single-family	Long-term	64	66
MB-5	3218 113th Avenue SE	Single-family	Short-term	70	72
MB-6	3005 113th Avenue SE	Single-family	Short-term	67	69
MB-7	11035 SE 26th Street	Single-family	Long-term	50	53
MB-8	11038 SE 25th Street	Single-family	Short-term	61	63
MB-9	1928 109th Avenue SE	Single-family	Short-term	64	66
MB-10	1850 108th Avenue SE	Single-family	Short-term	63	65
MB-11	1435 Bellevue Way SE	Single-family	Short-term	64	66
MB-12	1030 Bellevue Way SE	Multi-family	Short-term	67	69
MB-13	10256 SE 8th Street	Multi-family	Long-term	60	62
MB-14	1638 SE 17th Street	Single-family	Long-term	58	60
MB-15	1600 109th Avenue SE	Single-family	Short-term	55	55
MB-16	3050 SE 118th Street	Multi-family	Short-term	58	60
MB-17	2500 SE 118th Unit 303	Multi-family	Long-term	62	64
Segment C					
MC-1	420 Bellevue Way	Multi-family	Short-term	66	66
MC-2	321 Bellevue Way	Multi-family	Long-term	60	60
MC-3	300 112th Avenue SE	Hotel	Short-term	75	75
MC-4	221 112th Avenue SE, #221	Multi-family	Short-term	69	71
MC-5	11039 SE 2nd Street	Single-family	Short-term	57	58
MC-6	80 110th Avenue NE	Single-family	Long-term	57	59
MC-7	100 SE 108th Ave SE	Office	Short-term	61	63
MC-8	225 112th Avenue SE	Commercial	Short-term	62	63
MC-9	308 108th Avenue NE	Commercial	Short-term	64	65
MC-10	Bellevue Regional Library	Mixed-use	Short-term	62	63
MC-11	10814 NE 12th Place	Single-family	Short-term	58	59
MC-12	11121 NE 12th Street	Commercial	Short-term	67	68
MC-13	1245 112th Avenue NE	Office	Long-term	57	60
MC-14	Surrey Downs Park	Park	Long-term	62	64
Segment D					
MD-1	1815 116th Avenue	Office	Long-term	58	58
MD-2	Near Highland Park (Trail 50 feet from NE 20th Street)	Park	Short-term	65	65
MD-3	152nd Avenue NE, 550 feet north of NE 26th Street	Commercial	Short-term	64	65
MD-4	Overlake Assisted Living Center	Commercial	Short-term	64	65
MD-5	Near Microsoft Building 44	Mixed-use	Short-term	70	71
Segment E					
ME-1	5409 154th Avenue NE	Single-family	Long-term	60	64
ME-2	15516 61st Court	Single-family	Long-term	65	68
ME-3	15834 NE 67th Place	Single-family	Short-term	58	60
ME-4	7250 Old Redmond Road	Multi-family	Short-term	63	64
ME-5	15821 Leary Way NE	Multi-family	Short-term	62	64

[a] Sites shown on Exhibits 4.7-4 and 4.7-5

Center, the Bellevue Regional Library, and McCormick and Ashwood parks. In addition, single-family residential land uses were identified along the northern edge of Downtown Bellevue, north of NE 12th Street. Sensitive land uses east of I-405 include the Overlake Hospital, a broad range of nearby medical offices, a new Group Health medical building and a proposed Children's Hospital ASC. There is also a multifamily residential area at the north end of Lake Bellevue, south of NE 12th Street.

Twelve locations were monitored in Downtown Bellevue: nine short-term and three long-term. Peak-hour noise levels ranged from 57 dBA Leq in quiet areas away from major arterial roads to 75 dBA Leq near the Hilton Hotel between 112th Avenue SE and I-405. Noise levels at residences along Bellevue Way ranged from 66 dBA Ldn for properties near the roadway to 60 dBA Ldn for properties shielded from roadway noise. Along 112th Avenue, noise levels are dominated by local traffic and vehicles on I-405. Measured noise levels in this area ranged from 60 to 70 dBA depending on the proximity to the roadway and shielding from existing structures. Noise levels at single-family residences along NE 12th Street (MC-13) ranged from 59 dBA Ldn for shielded properties to 68 dBA Ldn for residences directly adjacent to major arterial roads. The measured noise level at the Bellevue Regional Library (MC-10) was 58 dBA Leq. Noise levels on NE 12th Street ranged from 57 to 67 dBA Leq with Ldn noise levels of up to 68 dBA.

Segment D

Land use in Segment D is mainly commercial and light industrial, including retail, distribution facilities, and office spaces, which are generally not noise sensitive. The only noise-sensitive land uses are single- and multifamily residences along 116th Avenue NE and on the south side of SR 520. The Overlake area is predominantly office parks and commercial land uses. Major sources of noise in this segment include traffic noise from State Route (SR) 520 and major arterials, such as Bel-Red Road.

Five locations were monitored in Segment D: one long-term site and four short-term sites. The long-term site was at a residential area along 116th Avenue NE, near the 116th Maintenance Facility Alternative (MF1). The Ldn at residences along 116th Avenue NE was measured at 58 dBA. A short-term site was located near Highland Park, were the Leq and estimated Ldn were 65 dBA. The three remaining short-term sites were located near the Overlake area, including one near the former Group Health Campus, one at the Overlake Assisted Living Center, and one near Microsoft. Estimated Ldn at these sites ranged from 65 to 71 dBA, with measured peak hour Leq levels ranging from 64 to 70 dBA Leq.

Segment E

Segment E begins in the commercial area at the NE 40th Street and is adjacent to SR 520 and office parks until NE 51st Street. North of NE 51st Street, land use changes to single-family residential. Most residences in this area are located behind a noise wall along SR 520. Land use remains single-family residential to the West Lake Sammamish Parkway exit, where land use changes to multifamily residential, park, and commercial south of Downtown Redmond. Other sensitive land uses include Marymoor Park. Land use in the downtown area varies but is mainly commercial and retail, with some mixed-use buildings that have residential use on upper floors. Major sources of noise in this segment include traffic noise from SR 520 and major arterials, such as West Lake Sammamish Parkway and SR 202.

Five locations were monitored in Segment E: two long-term and three short-term. For locations along SR 520 with existing noise walls, the Ldn ranged from 60 to 64 dBA with peak-hour levels of 58 to 60 dBA Leq. There is a small group of homes along 156th Avenue NE (ME-2) that do not have a noise wall, where the measured Ldn was 68 dBA. The multifamily units along 156th Place NE, NE Leary Way and West Lake Sammamish Parkway NE are dominated by traffic noise on SR 520 and arterial roads, with an estimated Ldn of 64 dBA.

4.7.2.2 Vibration Measurements

Vibration measurement test sites were selected based on a review of aerial photographs, supplemented by a visual land-use survey. Unlike response to noise, human response to vibration is not dependent on existing vibration levels. Humans respond to a new source of vibration based on the frequency of the events. Therefore, rather than measuring existing vibration levels, vibration measurements focused on characterizing the vibration propagation through the ground at representative locations in the project vicinity. This information was used as input for the analysis model. Eight sites, designated as Sites V-1 through V-8, were selected to represent a range of soil conditions near residences and other sensitive land uses along the rail corridor (Exhibits 4.7-4 and 4.7-5). Measurements were conducted at sites in Seattle, Bellevue, and Redmond in March 2007. The *Noise and Vibration Technical Report* (Appendix H2) provides more detail.

4.7.3 Environmental Impacts

This section summarizes the models used to predict future noise and vibration levels and identifies where levels are predicted to exceed accepted criteria, causing an impact. These sources include light rail operation, changes in traffic due to the project, and construction activities. The projection models for these sources are described below.

4.7.3.1 Project Assumptions for Noise Analysis

Noise from East Link operations was modeled using the methods described in the FTA *Transit Noise and Vibration Assessment Manual* (2006). Input to the model included the following assumptions:

- Light rail train headways and speeds as described in Appendix E, Operating Plan Summary. The speeds are dependent on location, with a maximum operating speed of 55 mph.
- Measured reference noise levels for new state-of-the-art, low-noise Sound Transit light rail vehicles equipped with noise reducing wheel skirts covering the wheel-rail interface The projected Ldn and Lmax assuming a train speed of 50 miles per hour (mph) are shown in the *Noise and Vibration Technical Report* (Appendix H2). For reference, typical noise levels from a light rail pass-by are similar to a medium truck, such as a UPS delivery vehicle and quieter than a diesel bus.
- Elevations of sensitive properties and any shielding or other topographical features that could affect noise transmission
- Plan and profile of all proposed East Link alternatives and design options, including the locations of special track work, such as crossovers, where wheel impacts make a clicking noise and vibration levels can be increased.

The procedure used to evaluate the impacts of the project alternatives is based upon the change in the noise level that would be caused by each alternative and the number of dwelling units potentially affected by project noise. This method is consistent with the FTA *Transit Noise and Vibration Manual*. The FTA noise assessment methodology was also applied to the park-and-ride lots and transit centers.

Traffic noise was evaluated where required by FTA and FHWA. Traffic noise was analyzed using the WSDOT methods provided in the *Traffic Noise Abatement Policy and Procedures* (WSDOT, 2006). Per FHWA policy, traffic noise was evaluated for specific locations, as described in Section 4.7.1.2.

4.7.3.2 Project Assumptions for Vibration Analysis

Projections of ground-borne vibration from East Link operations were based on the following assumptions:

- Vibration source levels were based on measurement data for the Sound Transit new light rail vehicles, as measured by Wilson Ihrig & Associates, Inc. (2007).
- Vibration propagation tests were conducted at representative sites along the corridor near sensitive receptors, as described in Section 4.7.2.3. The results of these tests were combined with the vehicle vibration source-level measurement data to provide projections of vibration levels from vehicles operating on the East Link Project alternatives.
- Light rail train headways and speeds as described in Appendix E, Operating Plan Summary. The speeds are dependent on location, with a maximum operating speed of 55 mph.
- Wheel impacts at turnouts and crossovers typically cause localized vibration increases of 10 VdB.

The approach used for assessing vibration impact uses many of the same inputs as the noise impact assessment, such as speed, frequency of vehicle events, and distance from the receiver to the tracks. The vibration impact assessment combines vehicle characteristics with soil propagation properties to estimate vibration levels at sensitive receptors, as described in detail in previous sections. The FTA impact threshold for residential vibration is 72 VdB and the impact threshold for residential ground-borne noise is 35 dBA, as presented in Table 4.7-2.

4.7.3.3 No Build Alternative

Under the No Build Alternative, there would be no project-related noise or vibration impacts. However, there are areas in the project vicinity where existing and future traffic noise levels would exceed the WSDOT criteria.

4.7.3.4 Impacts During Operations

Light Rail and Traffic Noise Impacts

Project-related light rail and traffic noise impacts before mitigation considerations are presented in the following sections. Table 4.7-6 provides a summary of the noise impacts for the different alternatives and the general locations of these impacts are shown in Exhibits 4.7-6 and 4.7-7. Impacts to wildlife are construction-related and are discussed in Section 4.8, Ecosystems. No operational impacts to parks were identified. All noise impacts identified are discussed in

this section by segment. Additional information about these impacts is located in the *Noise and Vibration Technical Report* (Appendix H2).

All proposed park-and-ride lots are at existing park-and-ride lot locations or in well-established transportation corridors. Traffic accessing the park-and-ride lots, while potentially resulting in slight increases in noise, would not result in noise impacts at any sensitive properties.

Segment A
No noise impacts from either East Link operations or traffic are expected to occur on any adjacent sensitive land uses. Installation of light rail on the I-90 floating bridge would require use of expansion joints at each end of the floating bridge structure that could create noise. The expansion joints are not predicted to cause noise impacts above the FTA criteria because of the 700- to 800-foot distance to noise sensitive properties.

Segment B
Under the Bellevue Way Alternative (B1) there would be 3 severe light rail noise impacts and 80 traffic noise impacts. The light rail noise impacts would be near SE 30th Street and due in part to a nearby crossover track. The traffic noise impacts, which would occur along Bellevue Way, would be due to roadway widening, and most would occur at multifamily structures north of 112th Ave SE. With the 112th SE At-Grade (B2A) or and 112th SE Bypass (B3) alternatives, there would be no light rail noise impacts; however, there are 20 traffic noise impacts projected between the South Bellevue Station and 112th Avenue SE due to road widening. No noise impacts were identified for the 112th SE Elevated Alternative (B2E). Finally, the BNSF Alternative (B7) along the BNSF right-of-way would result in 98 light rail noise impacts, including 39 severe impacts. The severe impacts would be due to a crossover near the Emerald Apartments and the Brookshire Condominiums to the west of the BNSF corridor.

Segment C
The number and severity of noise impacts in Segment C would vary depending on the alternative and connector from Segment B. South of Main Street, the Bellevue Way Tunnel Alternative (C1T) is the only Segment C alternative with traffic noise impacts, resulting from roadway modifications on Bellevue Way that impact 21 multifamily units. East of I-405, C1T and the 106th NE Tunnel Alternative (C2T) would both result in moderate light rail noise impacts at 12 multifamily units on the northern end of Lake Bellevue, before connecting to Segment D. When connecting from 112th SE Elevated (B2E), C2T would have severe light rail noise impacts on 2 single-family residences and 4 multifamily residences. When connecting to the 112th SE Bypass (B3) and BNSF (B7) alternatives, C2T would have moderate light rail noise impacts on 4 hotel rooms along 114th Avenue SE. The 108th NE Tunnel Alternative (C3T) would result in severe light rail noise impacts on 2 single-family residences, 4 multifamily units, and hotel rooms along 112th Avenue SE south of Main Street when connecting to the 112th SE Elevated Alternative (B2E). When connecting to the 112th SE Bypass (B3) and BNSF (B7) alternatives, C3T would have moderate light rail noise impacts on 4 hotel rooms along 114th Avenue SE.

Under the Couplet Alternative (C4A) from the 112th SE At-Grade (B2A) connector, there would be moderate light rail impacts to 12 multifamily units near SE 6th Street. When connecting to the 112th SE Elevated Alternative (B2E), C4A would have severe light rail noise impacts to six multifamily units near SE 1st Place. When connecting to the 112th SE Bypass (B3) and BNSF (B7) alternatives, C4A would have moderate light rail noise impacts on 4 hotel rooms along 114th Avenue SE.

Under the 112th NE Elevated Alternative (C7E), the connector from 112th SE At-Grade (B2A) would cause severe light rail noise impacts at 10 multifamily units and 2 single-family residences near SE 1st Place. With the elevated connection to the 112th SE Elevated Alternative (B2E), the number of impacts would be reduced to 4 multifamily and 2 single-family, although the impacts would still be considered severe under FTA criteria. When connecting to the 112th SE Bypass (B3) and BNSF (B7) alternatives, C7E would have moderate light rail noise impacts on 4 hotel rooms along 114th Avenue SE.

The 110th NE Elevated Alternative (C8E) would have moderate light rail noise impacts at 4 hotel rooms along 114th Avenue SE and 80 multifamily units on 110th Avenue NE, between NE 8th Street and NE 12th Street. The 110th NE Elevated Alternative (C8E) would also have three moderate noise impacts at the single-family residences located north of NE 12th Street.

Segment D
The only light-rail noise impact identified in Segment D would be with the SR 520 Alternative (D5), which would impact 10 multifamily units on the south side of SR 520.

Segment E
In Segment E, light rail noise impacts were identified at 26 multifamily units along the elevated section of the Redmond Way Alternative (E1) near 156th Place

TABLE 4.7-6
Summary of Potential Noise Impacts

Alternative	Connection Alternatives	Moderate Light Rail Impacts[a, c]	Severe Light Rail Impacts[b, c]	Traffic Noise Impacts[c]	Proposed Mitigation	Residual Impacts (after mitigation)
Segment A						
A1, I-90	N/A	None	None	None	None	None
Segment B						
B1, Bellevue Way	N/A	None	3 SF units	41 SF and 359MF units	Sound walls, insulation, relocate crossovers	Exterior only-54 MF and SF units
B2A, 112th SE At-Grade	N/A	None	None	20 SF units	Sound walls, insulation	None
B2E, 112th SE Elevated	N/A	None	None	None	None	None
B3, 112th SE Bypass	N/A	None	None	20 SF units	Sound walls, insulation	None
B7, BNSF	N/A	59 MF units	39 MF units	None	Sound walls	None
Segment C						
C1T, Bellevue Way Tunnel	B1, Bellevue Way	12 MF units	None	21 MF units	Sound walls, insulation	Exterior only-21 MF units
C2T, 106th NE Tunnel	B2A, 112th SE At-Grade	12 MF units	None	None	Sound walls	None
	B2E, 112th SE Elevated	12 MF units	18 Hotel rooms 2 SF units 4 MF units	None		
	B3 or B7, 112th SE Bypass or BNSF	12 MF units 4 Hotel rooms	None	None		
C3T, 108th NE Tunnel	B2A, 112th SE At-Grade	None	None	None	None	None
	B2E, 112th SE Elevated	None	18 Hotel rooms 2 SF units 4 MF units	None	Sound walls	None
	B3 or B7, 112th SE Bypass or BNSF	4 Hotel rooms	None	None	None	None
C4A, Couplet	B2A, 112th SE At-Grade	12 MF units	None	None	Sound walls, insulation	Exterior only-12 MF units
	B2E, 112th SE Elevated	None	6 MF units	None	Sound walls	Exterior only-6 MF units
	B3 or B7, 112th SE Bypass or BNSF	4 Hotel rooms	None	None	None	None
C7E, 112th SE Elevated	B2A, 112th SE At-Grade	None	10 MF units 2 SF units	None	Sound walls	None
	B2E, 112th SE Elevated	None	4 MF units 2 SF units	None	Sound walls	None
	B3 or B7, 112th SE Bypass or BNSF	4 Hotel rooms	None	None	None	None

TABLE 4.7-6
Summary of Potential Noise Impacts

Alternative	Connection Alternatives	Moderate Light Rail Impacts[a, c]	Severe Light Rail Impacts[b, c]	Traffic Noise Impacts[c]	Proposed Mitigation	Residual Impacts (after mitigation)
C8E, 110th NE Elevated	B3 or B7, 112th SE Bypass or BNSF	80 MF units 3 SF units 4 Hotel rooms	None	None	Sound walls, insulation	Exterior only-80 MF units
Segment D						
D2A, NE 16th At-Grade D2E, NE 16th Elevated D3, NE 20th	All Segment C alternatives	None	None	None	None	None
D5, SR 520	All Segment C alternatives	10 MF units	None	None	Sound walls	None
Segment E						
E1, Redmond Way	N/A	26 MF units	None	None	Sound walls, insulation	None
E2, Marymoor E4, Leary Way	N/A	None	None	None	None	None

[a] **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 noise level, the predicted 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.

[b] **Severe Impact:** Project-generated noise in the severe impact range can be expected to cause a substantial 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.

[c] SF = single family; MF = multifamily

NE. No other noise impacts were identified in Segment E.

Maintenance Facilities

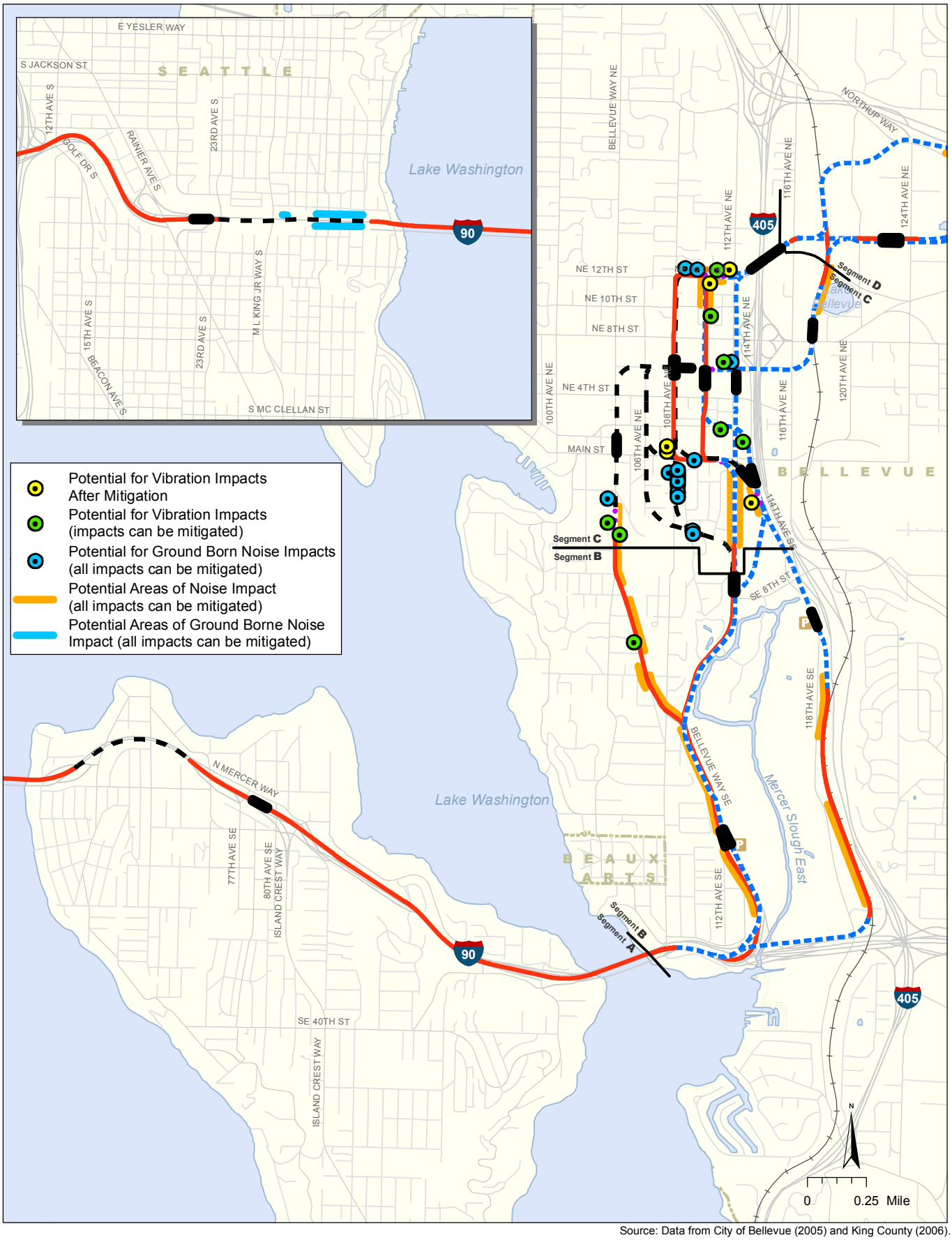
All maintenance facility alternatives are located in currently established commercial and light industrial areas. Maintenance facility alternatives are not projected to result in any exceedance of the Washington State Administrative Code for noise.

Wheel Squeal

Wheel squeal is caused by the oscillation of the wheel against the rail on curved sections of train track. Curves with a radius of less than 300 feet have the ability to produce maximum noise levels of 83 to 85 dBA at 50 feet. Locations where this could occur include the tight radius curves in Segment C in Downtown Bellevue under the Couplet (C4A), 112th NE Elevated (C7E), and 110th NE Elevated (C8E) alternatives. In Segment D, the NE 16th At-Grade (D2A), NE 16th Elevated (D2E), and NE 20th (D3) alternatives have potential for wheel squeal on 136th Place NE and along 152nd Avenue NE. There is also the potential for wheel squeal in Segment E under the Marymoor Alternative (E2) along 161st Avenue NE and near Redmond Way at SR 520. All wheel squeal noise could be mitigated and there would be no residual impacts.

Vibration and Ground-Borne Noise Impacts

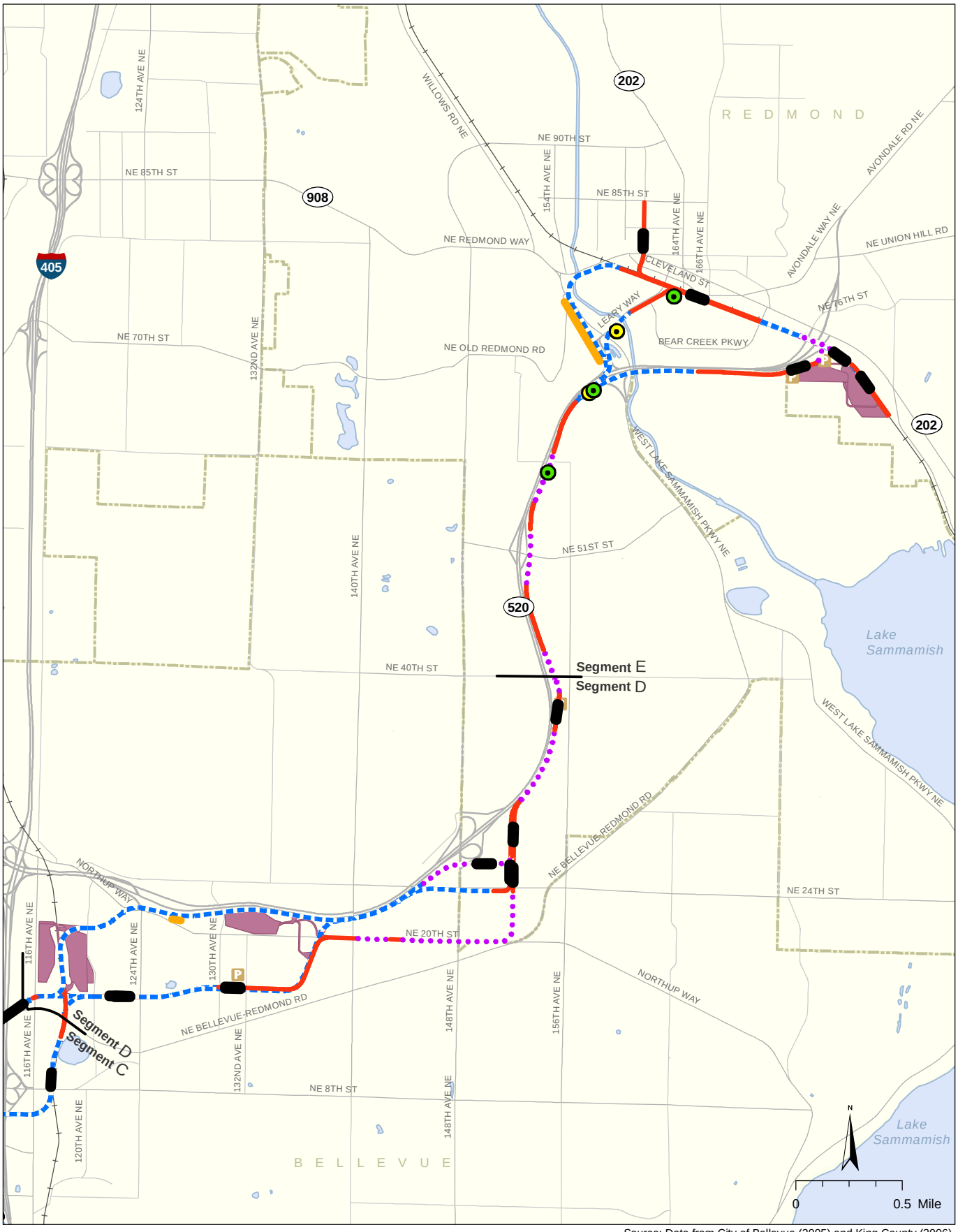
Table 4.7-7 provides a summary of the vibration and ground-borne noise impacts for the different alternatives; the general locations of these impacts are shown in Exhibits 4.7-6 and 4.7-7. Ground-borne noise is only assessed for tunnel sections or for buildings that have sensitive interior spaces that are well insulated from exterior noise. At other locations, because of the masking effects of airborne noise, the ground-borne noise is not a factor. In the table, the columns for the number of vibration and ground-borne noise impacts refer to the number and type of buildings where vibration or ground-borne noise impact is projected to occur. The number of units for residential units is provided, although it is likely that not all units would be affected. For multifamily buildings, the actual number of units impacted in each building would be determined after further testing during preliminary engineering and design.



Source: Data from City of Bellevue (2005) and King County (2006).

At-Grade Route
Elevated Route
Retained-Cut Route
Tunnel Route
Proposed Station
P New and/or Expanded Park-and-Ride Lot

Exhibit 4.7-6
Noise and Vibration Segments A, B, and C
East Link Project



Source: Data from City of Bellevue (2005) and King County (2006).

- Potential for Vibration Impacts After Mitigation
- Potential for Vibration Impacts (impacts can be mitigated)
- Potential Areas of Noise Impact (all impacts can be mitigated)
- At-Grade Route
- Elevated Route
- Retained-Cut Route
- Tunnel Route
- Proposed Station
- Maintenance Facility and Access Track
- New and/or Expanded Park-and-Ride Lot

Exhibit 4.7-7
Noise and Vibration Segments D and E
East Link Project

All impacts identified in the sections below are related to the proximity of the proposed tracks to individual buildings and to the speed of the light rail vehicle. In most cases, the impacts are limited to buildings within 50 feet of the proposed tracks.

Potential vibration and ground-borne noise levels and impacts reported in this section are described prior to mitigation considerations. Although most impacts can be mitigated, the residual impacts remaining after mitigation are provided in Table 4.7-7. Detailed information and exhibits for each impact are located in the *Noise and Vibration Technical Report* (Appendix H2).

Segment A
Ground-borne noise impacts would occur at 25 single-family residences above the I-90 Mount Baker Tunnel. These impacts occur because high-frequency vibration travels easily through the ground in this area. No vibration impacts would occur.

Segment B
In Segment B, the only vibration impact would be to a single-family residence under with Bellevue Way Alternative (B1). This impact would occur due to the proximity of the residences to the track and because high-frequency vibration travels easily through the ground in this area.

Segment C
The vibration impacts in Segment C would be due to the proximity of the proposed alternative and the speed of the light rail vehicles. The greatest number of impacts would occur with the Couplet (C4A) or the 110th NE Elevated (C8E) alternatives, and would be to mixed-use buildings which have ground floor commercial uses with multi-family residences above. The distance to sensitive uses in these buildings, may eliminate these impacts. In addition to the residential land uses in this corridor, vibration and ground-borne noise impacts were also assessed for the special sensitive receptors in this segment, including the Bellevue Arts Museum, the theater in Meydenbauer Center, the Overlake Hospital MRI Unit, the Overlake Hospital Optical Surgery Unit, as well as the MRI unit at the new Group Health Medical Center. The only location of these that would be impacted under any of the alternatives is the theater in Meydenbauer Center, which has the potential for both vibration and ground-borne noise impacts from the Bellevue Way Tunnel (C1T) and the 106th NE Tunnel (C2T) alternatives. Details regarding the ground-borne noise and vibration levels at these sensitive sites are included in Tables 9, 10, 11, 49, and 50 of the *Noise and Vibration Technical Report* (Appendix H2).

Segment D
No vibration impacts are projected for Segment D, including at the proposed Children's Hospital Bellevue ASC medical facility.

Segment E
Vibration impacts would occur to three single-family residences with the Redmond Way Alternative (E1) and the Marymoor Alternative (E2). The Leary Way Alternative (E4) would have vibration impacts on one single-family residence, one multifamily building, and one hotel. These vibration impacts would be due to the proximity of the residences and because high-frequency vibration travels easily through the ground in this area.

Maintenance Facilities
Maintenance facility alternatives are not expected to result in any vibration impacts.

4.7.3.5 Impacts During Construction

This section provides a summary of potential construction noise and vibration impacts. More detailed information is provided in the *Noise and Vibration Technical Report* (Appendix H2).

Noise

Noise related to construction would result from the operation of heavy equipment needed to construct the project. State and local ordinances regulate construction noise, and the contractor would be required to adhere to these regulations. The primary construction noise ordinance is found in the Washington State Administrative Code. The Washington State construction noise ordinance has been adopted in some form by most cities and counties around the state, including the cities of Seattle, Bellevue and Redmond. No specific construction noise ordinance was identified for Mercer Island, and therefore the Washington State construction ordinance would also be the governing criteria for construction activities on the island. Specific information on the Washington State Administrative Code, which outlines the construction specific regulations for most locations, is provided below, followed by the noise analysis. Construction outside normal weekday hours (i.e., 7 a.m. to 10 p.m.) may require a noise variance from the city or county where the work is being performed.

The following sections describe allowable noise exceedances for general construction equipment, haul trucks, and alarms.

General Equipment: For construction activities, the limits in Table 4.7-3 may be exceeded between 7 a.m. and 10 p.m. on weekdays, and 9 a.m. and 10 p.m. on weekends, as shown in Table 4.7-8.

TABLE 4.7-7
Summary of Potential Vibration Impacts

Alternative	Connection Alternatives	Before Mitigation		After Mitigation	
		Number of Vibration Impacts [a]	Number of Ground-Borne Noise Impacts [a, b]	Number of Vibration Impacts [a]	Number of Ground-Borne Noise Impacts [a, b]
Segment A					
A1, I-90	N/A	None	25 SF	None	None
Segment B					
B1, Bellevue Way	N/A	1 SF	None	None	None
B2A, 112th SE At-Grade	N/A	None	None	None	None
B2E, 112th SE Elevated	N/A	None	None	None	None
B3, 112th SE Bypass	N/A	None	None	None	None
B7, BNSF	N/A	None	None	None	None
Segment C					
C1T, Bellevue Way Tunnel [c]	B1, Bellevue Way	1 SF 1 hotel 1 theater	1 theater	None	None
C2T, 106th NE Tunnel	B2A, 112th SE At-Grade	1 theater	1 theater	None	None
	B2E, 112th SE Elevated	1 theater	1 theater 1 SF	None	None
	B3, 112th SE Bypass B7, BNSF	1 theater	1 theater	1 hotel	None
C3T, 108th NE Tunnel	B2A, 112th SE At-Grade	None	15 SF	None	None
	B2E, 112th SE Elevated	None	15 SF	None	None
	B3, 112th SE Bypass B7, BNSF	1 hotel	4 SF	1 hotel	None
C4A, Couplet	B2A, 112th SE At-Grade B2E, 112th SE Elevated	5 MF (729 units total) 1 SF	None	2 MF (176 units total)	None
	B3, 112th SE Bypass B7, BNSF	5 MF (729 units total) 1 SF 1 hotel	N/A	2 MF (176 units total) 1 hotel	None
C7E, 112th NE Elevated	B2A, 112th SE At-Grade B2E, 112th SE Elevated	None	N/A	None	None
	B3, 112th SE Bypass B7, BNSF	1 hotel	N/A	1 hotel	None
C8E, 110th NE Elevated	B3, 112th SE Bypass B7, BNSF	3 MF (418 units total) 2 SF 2 hotels	N/A	1 MF (38 units) 1 hotel	None
Segment D					
All alternatives	N/A	None	None	None	None
Segment E					
E1, Redmond Way	N/A	3 SF	None	1 SF	None
E2, Marymoor	N/A	3 SF	None	1 SF	None
E4, Leary Way	N/A	1 SF 1 MF 1 hotel	None	None	None

[a] SF = single family, MF = multifamily

[b] Ground-borne noise is only assessed for tunnel locations.

Haul Trucks: Noise from haul trucks is exempt when operating on public roadways. Maximum permissible sound levels for haul trucks at the construction site are limited to 86 dBA for speeds of 35 mph or less and 90 dBA for speeds over 35 mph.

Alarms: Sounds created by back-up alarms are exempt when operated for less than 30 minutes per incident.

Several construction phases would be required to complete the East Link Project. This analysis assumes the worst-case noise levels based on three major construction phases, further defined in Table 4.7-8:

- Demolition, Site Preparation, and Utility Relocation
- Construction of Structures, Track Installation, and Paving
- Miscellaneous Activities

The actual noise levels experienced during construction would generally be lower than those presented in this section. The noise levels discussed here and presented in Table 4.7-8 are for periods of maximum construction activity and are considered worst-case for the major phases of construction, measured at a distance of 50 feet from the construction site. Residential and commercial land uses are most sensitive to construction noise.

In Segment A, most construction activities would occur in the I-90 corridor, which is some distance from commercial and residential uses. Noise from construction would be 75 to 78 dBA Lmax due to the distance between the construction and noise-sensitive properties.

In Segments B through E, construction of elevated guideways, at-grade trackways, tunnels, stations, and tunnel portals would result in increased levels of truck traffic near construction staging areas. Haul truck and delivery truck volumes and times of travel would vary depending on the specific site activities occurring at any one time. The highest levels shown in Table 4.7-8 would be experienced during the heaviest construction periods. Noise levels would be 5 to 15 dBA lower than the highest levels during minor construction work, such as finishing work and system installation.

Construction of bridges and elevated structures may require pile driving, which can produce maximum short-term noise levels of 99 to 105 dBA at 50 feet from the work site. Actual levels can vary and would depend on the distance and topographical conditions between the pile-driving location and the receiver location. There is a potential for pile driving in Segments B, C, D, and E for elevated profiles and may also occur in areas of retained cuts in Segments C and D. Pile driving would be required to meet the impact criteria of the Washington State Administrative Code.

Under the Segment B alternatives there are single- and multifamily residences and several businesses that could be affected by construction noise. Under the Bellevue Way (B1), the 112th SE At-Grade (B2A), the 112th SE Elevated (B2E) and the 112th SE Bypass (B3) alternatives, noise levels at adjacent properties would have short periods of time with maximum noise levels exceeding 80 dBA Lmax. Construction noise would occur during utilities relocation, installation of retaining walls (where required), re-paving Bellevue Way, and construction of the elevated guideways for

TABLE 4.7-8
Maximum Noise Levels for Typical Construction Phases at 50 Feet from the Work Site

Scenario[a]	Equipment[b]	Lm[c]	Leq[d]
Demolition, Site Preparation, and Utility Relocation	Air compressors, backhoe, concrete pumps, crane, excavator, forklifts, haul trucks, loader, pumps, power plants, service trucks, tractor trailers, utility trucks, vibratory equipment	94	87
Construction of Structures, Track Installation and Paving	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	88
Miscellaneous Activities	Air compressors, backhoe, crane, forklifts, haul trucks, loader, pumps, service trucks, tractor trailers, utility trucks, welders	91	83

Note: Combined worst-case noise levels for all equipment at a distance of 50 feet from work site.

[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.

[d] Leq (dBA) is an energy average noise emission for construction equipment operating under the given scenario.

the B2E and B3 alternatives. Noise levels would be greatest for properties adjacent to Bellevue Way, but would be less for those located along 112th Avenue SE, where residences and business parks are set back farther from the project corridor in many places. During construction of elevated structures for B2E and B3, noise from pile driving could produce Lmax noise levels of 98 to 105 dBA at 50 feet from the work site. For the BNSF Alternative (B7), noise levels at the multi-family apartments and condominiums adjacent to the alternative in the BNSF corridor could reach 80 dBA Lmax for short periods. Because this alternative is not on a major roadway, it is less likely that any nighttime work would be required near the noise-sensitive units. Construction of Alternative B7 would also increase noise at some commercial structures; however existing traffic noise from I-405 would remain a substantial noise source at commercial structures along this alternative.

In Segment C, the longest period of high-intensity construction activities would occur at cut and cover tunneling sites and tunnel staging areas. Typical daytime noise levels from the staging areas are projected to be 73 to 84 dBA, depending on the level and type of activity at the time. Noise levels near the tunnel portals and staging area on Bellevue Way for the Bellevue Way Tunnel Alternative (C1T) could exceed 80 dBA Lmax during heavy construction periods. Noise levels near the tunnel portal and staging areas in Surrey Downs Park or along Main Street for the 106th NE Tunnel (C2T), the 108th Tunnel (C3T), and the Couplet (C4A) alternatives are predicted to range from 73 to 84 DBA Lmax at 50 feet from the work site. Similar levels are projected along NE 12th Street and McCormick Park for C3T, C4A, and the 110th Elevated Alternative (C8E). For construction of elevated structures along 112th Avenue NE for the 112th Elevated Alternative (C7E) and along 110th Avenue NE for the 110th Elevated Alternative (C8E), maximum noise levels would range from 80 to 85 dBA at 50 feet from the project construction area. Construction of the light rail along NE 12th St would result in an increase in noise levels at the Overlake Hospital. The hospital parking area would provide some shielding from patient rooms. Construction noise could also be an issue at the Group Health Hospital under alternatives on NE 8th Street.

Construction of the at-grade and elevated profiles through Segment D would result in short-term high noise levels at commercial and retail structures located along the corridor. Construction of the light rail along NE 12th Street would result in an increase in noise levels at the proposed Children's Hospital, if it is built before East Link. Levels would reach those given in Table 4.7-8 when the activities are near these properties and would decrease as the activities move away. Commercial and retail land uses along the proposed corridors would experience maximum noise levels between 80 to 85 dBA at 50 feet from the project construction area during heavy construction periods. Construction of Segment D and E alternatives along the south and east shoulder of SR 520 may result in relocating sound walls in some areas. During this period, noise from construction and traffic would increase for the residential area north of NE 51st Place to a maximum of 85 dBA, with typical hourly average noise levels ranging between 70 and 80 dBA.

In Segment E, construction of the elevated structures or the at-grade profiles would elevate noise levels at the multifamily units along West Lake Sammamish Parkway NE and 156th Place NE for the Redmond Way Alternative (E1) and along Leary Way NE for E4. Construction of the Marymoor Alternative (E2) would also result in temporary noise increases in Marymoor Park. Pile driving for the Sammamish River crossing for all alternatives and along Leary Way NE for E4 could result in peak levels exceeding 100 dBA. In Downtown Redmond, construction noise would be prevalent along the BNSF corridor under all Segment E alternatives. Construction would also increase noise levels along 161st Avenue NE with the Marymoor Alternative (E2) unless this alternative terminates at the Redmond Town Center Station.

Construction of the potential maintenance facility alternatives located in Segment D (MF1, MF2, and MF3) could have some impact on adjacent properties, but the maintenance facility alternative sites are located in primarily industrial and commercial areas, which are generally not sensitive to train operation and maintenance noise levels. The SE Redmond Maintenance Facility (MF5) would be in an area of primarily commercial use and high existing noise levels, reducing the potential for construction noise impacts.

Vibration

Construction vibration, similar to noise, is highly dependent on the specific equipment and methods employed. Construction vibrations cause a variety of potential effects, ranging from influence on vibration-sensitive equipment and low rumbling or ground-borne noise at lower levels, perceptible human vibrations at moderate levels, and potential slight damage to buildings at the highest levels. Generally, construction vibrations are assessed at locations where prolonged annoyance or damage would be expected.

In most cases, the main concern for construction vibration is potential damage to structures. Most

construction processes do not generate high enough vibration levels to approach damage criteria. The thresholds for building damage are 1 to 2 orders of magnitude higher than criteria for annoyance. Because construction is a short-term, temporary impact, annoyance is usually not an important issue. The only time annoyance is usually addressed for construction vibration is for longer-term impacts, such as those related to the tunneling in Segment C. However, the thresholds for annoyance from construction vibration are substantially lower than those for damage to structures.

The major sources of construction vibration include impact pile driving, augered piling, vibratory rollers, and tunnel boring machines, including associated muck trains. The only project activity with potential to cause building damage is impact pile driving at locations within 25 feet of structures. For a discussion of vibration descriptors and damage criteria, refer to the *Noise and Vibration Technical Report*, Sections 2.2 and 4.5 (Appendix H2).

However, there are many alternatives to impact pile driving, including sonic pile driving, augered piling, and push piling. Specific locations of piling would not be available until preliminary engineering but would likely include locations of elevated structures or retained cuts approaching tunnels. As specific locations of piles are developed, more analysis would be conducted to assess specific impacts. To prevent damage, care would be taken not to pile drive too close to buildings.

In order to assess the potential for annoyance from construction vibration, vibration levels for impact pile driving, vibratory rolling, tunneling and muck trains were predicted for the ground floors inside buildings using conservative assumptions. These assumptions include no coupling attenuation (i.e., reduction in vibration levels due to the foundation of the building) for single-family residences, a 10-decibel building coupling attenuation for large masonry buildings, no floor-to-floor attenuation, and no amplification due to the resonances of the floors. The criteria used to assess construction vibration and ground-borne noise are the same as those used to assess transit operation impacts.

Table 4.7-9 shows the distances at which ground-borne vibration annoyance would occur for both single-family residences and large masonry buildings for each piece of construction equipment. It is important to note that these are temporary impacts, and the annoyance from these activities would be very limited in duration. For most activities, including tunneling, the duration would be only a few days for each activity. The only activity with a longer duration would be the muck trains near the portals of the tunnels, which could be running between 1 month and 18 months, depending on the tunnel alternative chosen and the speed of tunneling. Sound Transit's experience in monitoring vibration during tunneling on Central Link has found no vibration impacts associated with annoyance to residences throughout the length of the tunnel.

TABLE 4.7-9
Distances from Sources to Vibration and Ground-Borne Noise Impact

Construction Equipment	Distance to Ground-Borne Vibration Impact (feet)	Distance to Ground-Borne Noise Impact (feet) [a]
Tunnel-Boring Machine in Soil (large masonry buildings)	6	7
Tunnel-Boring Machine in Soil (single-family residences)	13	14
Muck Trains (large masonry buildings)	8	24
Muck Trains (single-family residences)	16	51
Vibratory Roller (large masonry buildings)	18	None
Vibratory Roller (single-family residences)	36	None
Impact Pile Driving (large masonry buildings)	70	None
Impact Pile Driving (single-family residences)	150	None

[a] Ground-borne noise is only assessed for tunnel locations.

For more information on construction vibration, refer to the *Noise and Vibration Technical Report* (Appendix H2).

4.7.4 Station Platform Noise Levels

Because of the unique setting of several stations in close proximity to major freeways, Sound Transit modeled potential noise levels at proposed station platforms where light rail patrons may be exposed to noise from heavy freeway traffic volumes. These stations included the Rainier, Mercer Island and Ashwood/Hospital stations, which are all located within or above a major freeway. The proposed East Link operations plan would result in a maximum of 15 minutes between train arrivals at any of these stations, and therefore 15 minutes would typically be

the longest exposure to noise for patrons waiting for train arrival.

There are no federal standards for noise exposure on transit passengers at station platforms due to traffic noise. Sound Transit has a general design criteria goal of a 15 minute Leq of 72 dBA for noise from exterior sources at station platforms. The National Institute for Occupations Safety and Health (NIOSHA) standard for workplace noise exposure is 85 dBA for up to 8 hours, or 100 dBA for 15 minutes (NIOSHA, 1998). The U.S. Environmental Protection Agency (EPA) states that communication at close proximity (2 to 4 feet) can be understood with ambient noise levels of 72 to 78dBA (EPA, 1974). For contextual comparison, Sound Transit measured noise levels at two existing flyer bus stops located adjacent to heavy freeway traffic. Existing noise levels at the Rainer I-90 flyer stop were measured at 76 dBA Leq, while the typical existing noise level at the SR 520 flyer stop at Montlake was 81 dBA Leq. Based on these standards and existing bus flyer stop noise levels, Sound Transit will use a 78 dBA 15-minute Leq platform noise level goal for designing stations within or above freeways, where reasonable and feasible.

Station patrons at the Rainier and Mercer Island stations may experience noise levels ranging as high as 86 dBA to 88 dBA during daytime hours. The higher noise levels are due to the highway's retained cut and traffic noise being reflected around the station platform off the adjacent retaining walls. Sound Transit would consider including noise-reducing walls between the tracks and I-90 traffic lanes. Modeling of noise walls in this location shows that they would reduce noise levels by approximately 10 dBA on the platform, bringing the station platform noise for both stations to within Sound Transit's station platform design goal of 78 dBA..

Sound Transit also modeled noise levels at the Ashwood/Hospital station (for C3T, C4A and C8E Alternatives) located directly above I-405 on NE 12th Street. Patrons at the platform may experience traffic noise levels from 75 to 78 dBA from I-405 by the year 2030 and noise reducing measures would not be necessary at this station.

4.7.5 Potential Mitigation Measures

4.7.5.1 Noise Mitigation During Operation

Sound Transit noise policy is committed to minimizing noise levels at the source, which is the vehicle wheel rail interface. This includes using only state-of-the-art, low-noise vehicles equipped with noise-reducing wheel skirts covering the wheel-rail interface. In addition, Sound Transit has committed to a maintenance program that includes periodic rail grinding or replacement, wheel truing or replacement, vehicle maintenance, and operator training, which help to maintain low noise levels along transit corridors. For noise impacts that still exist after these source noise treatments, noise mitigation measures would be considered and reviewed using Sound Transit's Noise Mitigation Policy. The FTA Manual also defines when mitigation is needed and bases this on the severity of the impact, with severe impacts requiring the most consideration. The locations requiring mitigation in Table 4.7-6 would be refined during preliminary engineering and final design.

Transit Noise Mitigation

The potential mitigation options available for noise from transit operations are primarily noise barriers and building sound insulation. Sound walls, the first choice for mitigation, are proposed where feasible and reasonable, as determined by Sound Transit based on specific site conditions. Sound walls would be located on the ground for at-grade profiles and on the guideway structure for elevated profiles. Sound walls are preferred because they stop the noise from reaching the property and protect the outdoor use at the property. For locations where sound walls would not be effective, reasonable or feasible, sound insulation of the building would be considered. Use of sound insulation, however, does not reduce exterior noise levels at the property.

Traffic Noise Mitigation

Traffic noise impacts would be mitigated by noise walls, where determined to be reasonable and feasible. For locations with residual traffic noise impacts caused by the project, sound insulation may also be considered by Sound Transit. Use of FHWA or WSDOT funds for sound insulation of residences for traffic noise abatement is allowed only in specific situations. Federal regulation 23 CFR 772.13(c)(6), and WSDOT and FHWA policies and procedures limits sound insulation for traffic noise abatement to public use or nonprofit institutional structures and only in situations where a barrier is ineffective, unreasonable, and/or infeasible and interior noise levels are above the impact criteria. Sound insulation of residences is allowed only when noise impacts are severe (i.e., above 80 dBA exterior or above 60 dBA interior) and no other type of abatement is possible. In contrast, Sound Transit considers residential sound insulation for any noise impacts related to light rail projects if a barrier is ineffective, unreasonable, and/or infeasible.

Traffic and Transit Noise Mitigation by Alternative

The mitigation proposed follows Sound Transit policy. Table 4.7-6 provides a summary of potential project light rail and traffic noise mitigation for each alternative.

In Segment A, no noise impacts above the FTA criteria were identified and no mitigation is required. To reduce noise levels on the Rainier Station and Mercer Island Station platforms, Sound Transit would consider including noise walls between the tracks and I-90 traffic lanes. In Segment B, a combination of sound walls and sound insulation would be used to mitigate impacts under all alternatives, except for the BNSF Alternative (B7), where all impacts could be mitigated with sound walls. There are several locations along Bellevue Way with the Bellevue Way Alternative (B1) where noise walls would block access, and therefore sound insulation may be considered.

In Segment C, the elevated portions could be mitigated with sound walls, while the areas with at-grade profiles could require sound insulation. In Segment D, it is expected that the noise impacts south of SR 520 could be mitigated with a sound wall. In Segment E, there would be impacts to the multifamily units on 156th Place NE that could be mitigated with a sound wall or potentially with sound insulation.

Wheel Squeal

Several transit agencies, including Tri-Met in Portland, Oregon, have performed research into methods of reducing wheel squeal noise, and non-oil based lubricants have been found to be very effective at reducing or eliminating this type of noise. The lubricants can be applied by personnel working trackside or by an automated applicator. For locations where wheel squeal is an issue, some approved form of trackside or vehicle mounted system would be used to reduce wheel squeal noise.

4.7.5.2 Vibration Mitigation During Operation

Vibration and ground-borne noise impacts that exceed FTA criteria warrant mitigation when determined to be reasonable and feasible. There are a number of mitigation options available for vibration caused by transit operations. In almost all cases, vibration mitigation is possible with either ballast mats or resilient rail fasteners. A ballast mat consists of a pad made of rubber or rubber-like material placed on an asphalt or concrete base with the normal ballast, ties, and rail on top. The reduction in ground-borne vibration provided by a ballast mat is strongly dependent on the vibration frequency content and the design and support of the mat. Resilient fasteners can be used to provide vibration isolation between rails and concrete slabs for direct fixation track on elevated structures or in tunnels. These fasteners include a soft, resilient element between the rail and concrete to provide greater vibration isolation than standard rail fasteners.

Other options for mitigating vibration impacts include the following:

- Tire Derived Aggregate (TDA), which consists of shredded tires wrapped with filter fabric that is added to the base below the track ties.
- Special trackwork to eliminate the gap between tracks at crossovers that causes noise and vibration at these locations.

The locations requiring mitigation in Table 4.7-7 would be refined during preliminary engineering and final design. At some locations, however, light rail trackways or guideways would be within 20 feet of buildings and vibration mitigation would not be effective. Exhibits 4.7-6 and 4.7-7 identify these locations as residual impacts. At these locations, project design modification and additional information on affected buildings could eliminate these impacts. For instance, the type of building foundation may reduce vibration effects and therefore, these residual impacts may be eliminated. In addition, each building would need to be examined in detail to determine where the vibration-sensitive uses are located. For example, the side of a building nearest the proposed alternative may be a vibration sensitive use. Buildings that are mixed use may not have sensitive uses on lower floors where impacts would occur, and the vibration would not be noticeable by the time it reached higher floors with sensitive uses, such as sleeping quarters. Outdoor to indoor vibration testing, which tests how the vibration changes from the soil outside to a sensitive space inside a building, would also help to refine the vibration projections at these locations.

At the theater at Meydenbauer Center, a highly sensitive location, impacts would be mitigated using ballast mats or resilient rail fasteners. However, more extensive mitigation may be required to adequately reduce the vibration levels to below the FTA impact criteria.

4.7.5.3 Construction Noise Mitigation Measures

Sound Transit would, as practical, limit construction activities that produce the highest noise levels to daytime hours, or when disturbance to sensitive receivers would be minimized. Contractors would be required to meet the criteria of the noise ordinance for the city within which they are working. For operation

of construction equipment that could exceed allowable noise limits during nighttime hours (between 10:00 p.m. and 7:00 a.m.), on Sundays or legal holidays, Sound Transit or its contractor would seek the appropriate noise variance from the local jurisdiction. Sound Transit would control nighttime construction noise levels by applying noise level limits and noise control measures where necessary. The contractor would have the flexibility of either prohibiting certain noise generating activities during nighttime hours or providing additional noise control measures to meet these noise limits. Noise control mitigation for nighttime or daytime may include the following measures, as necessary, to meet required noise limits:

- Construction site noise barrier wall by noise sensitive receivers
- During nighttime work use smart back-up alarms, which automatically adjust the alarm level based on the background level, or switch off back-up alarms and replace with spotters.
- Low-noise emission equipment
- Noise deadening measures for truck loading and operations
- Monitoring and maintenance of equipment to meet noise limits
- Lined or covered storage bins, conveyors, and chutes with sound-deadening material
- Acoustic enclosures, shields or shrouds for equipment and facilities
- High-grade engine exhaust silencers and engine-casing sound insulation
- Prohibition of aboveground jack-hammering and impact pile driving during nighttime hours
- Minimization of the use of generators to power equipment
- Limited use of public address systems
- Grading of surface irregularities on construction sites
- Use of moveable noise barriers at the source of the construction activity
- Limitation or avoidance of certain noisy activities during nighttime hours

To mitigate noise related to pile driving, the use of an augur to install the piles instead of a pile driver would greatly reduce the noise levels. If pile driving is necessary, the only mitigation would be to limit the time of day the activity can occur. Pile driving is not expected at most construction locations.

No segment-specific construction mitigation would be necessary for Segment A or Segment B. In Segment C, near the tunnel staging areas of Surrey Downs and McCormick Park, construction of temporary noise barriers adjacent to the construction staging area could be used to reduce noise levels at nearby residential land use. Construction of Segment D and E alternatives along SR 520 near NE 51st Street could require moving existing noise walls and if practical these would be replaced early in project construction.

4.7.5.4 Construction Vibration Mitigation Measures

Building damage from construction vibration would only be anticipated from impact pile driving at very close distances to buildings. If piling is more than 25 to 50 feet from buildings, or if alternative methods, such as push piling or augur piling, can be used damage from construction vibration should not be an issue. Other sources of construction vibration do not generate high enough vibration levels for damage to occur. In any locations of concern, pre-construction surveys would be conducted to document the existing condition of buildings, in case there was an issue during or after construction.

Measures to minimize short-term temporary annoyance from ground-borne vibration and ground-borne noise from construction activities such as piling or vibratory rolling are limited to use of alternative methods, such as push piling or auger piling, or to limiting the hours and duration of these types of activities. Vibration monitoring would be considered for pile driving, vibratory sheet installation, and other construction activities that have the potential to cause high levels of vibration.