INTERSTATE 5 COLUMBIA RIVER CROSSING

Noise and Vibration Technical Report

May 2008

Columbia River CROSSING

TO: Readers of the CRC Technical Reports

FROM: CRC Project Team

SUBJECT: Differences between CRC DEIS and Technical Reports

The I-5 Columbia River Crossing (CRC) Draft Environmental Impact Statement (DEIS) presents information summarized from numerous technical documents. Most of these documents are discipline-specific technical reports (e.g., archeology, noise and vibration, navigation, etc.). These reports include a detailed explanation of the data gathering and analytical methods used by each discipline team. The methodologies were reviewed by federal, state and local agencies before analysis began. The technical reports are longer and more detailed than the DEIS and should be referred to for information beyond that which is presented in the DEIS. For example, findings summarized in the DEIS are supported by analysis in the technical reports and their appendices.

The DEIS organizes the range of alternatives differently than the technical reports. Although the information contained in the DEIS was derived from the analyses documented in the technical reports, this information is organized differently in the DEIS than in the reports. The following explains these differences. The following details the significant differences between how alternatives are described, terminology, and how impacts are organized in the DEIS and in most technical reports so that readers of the DEIS can understand where to look for information in the technical reports. Some technical reports do not exhibit all these differences from the DEIS.

Difference #1: Description of Alternatives

The first difference readers of the technical reports are likely to discover is that the full alternatives are packaged differently than in the DEIS. The primary difference is that the DEIS includes all four transit terminus options (Kiggins Bowl, Lincoln, Clark College Minimum Operable Segment (MOS), and Mill Plain MOS) with each build alternative. In contrast, the alternatives in the technical reports assume a single transit terminus:

- Alternatives 2 and 3 both include the Kiggins Bowl terminus
- Alternatives 4 and 5 both include the Lincoln terminus

In the technical reports, the Clark College MOS and Mill Plain MOS are evaluated and discussed from the standpoint of how they would differ from the full-length Kiggins Bowl and Lincoln terminus options.

Difference #2: Terminology

Several elements of the project alternatives are described using different terms in the DEIS than in the technical reports. The following table shows the major differences in terminology.

DEIS terms	Technical report terms
Kiggins Bowl terminus	I-5 alignment
Lincoln terminus	Vancouver alignment
Efficient transit operations	Standard transit operations
Increased transit operations	Enhanced transit operations

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Difference #3: Analysis of Alternatives

The most significant difference between most of the technical reports and the DEIS is how each structures its discussion of impacts of the alternatives. Both the reports and the DEIS introduce long-term effects of the full alternatives first. However, the technical reports then discuss “segment-level options,” “other project elements,” and “system-level choices.” The technical reports used segment-level analyses to focus on specific and consistent geographic regions. This enabled a robust analysis of the choices on Hayden Island, in downtown Vancouver, etc. The system-level analysis allowed for a comparative evaluation of major project components (replacement versus supplemental bridge, light rail versus bus rapid transit, etc). The key findings of these analyses are summarized in the DEIS; they are simply organized in only two general areas: impacts by each full alternative, and impacts of the individual “components” that comprise the alternatives (e.g. transit mode).

Difference #4: Updates

The draft technical reports were largely completed in late 2007. Some data in these reports have been updated since then and are reflected in the DEIS. However, not all changes have been incorporated into the technical reports. The DEIS reflects more recent public and agency input than is included in the technical reports. Some of the options and potential mitigation measures developed after the technical reports were drafted are included in the DEIS, but not in the technical reports. For example, Chapter 5 of the DEIS (Section 4(f) evaluation) includes a range of potential “minimization measures” that are being considered to reduce impacts to historic and public park and recreation resources. These are generally not included in the technical reports. Also, impacts related to the stacked transit/highway bridge (STHB) design for the replacement river crossing are not discussed in the individual technical reports, but are consolidated into a single technical memorandum.

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Interstate 5 Columbia River Crossing

Noise and Vibration Technical Report:

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ACRONYMS

Acronym	Description
ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
APE	Area of Potential Effect
API	Area of Potential Impact
BMP	Best Management Practice
BNSF	Burlington Northern Santa Fe Railroad
BPA	Bonneville Power Administration
BRT	Bus Rapid Transit
CFR	Code of Federal Regulations
CRC	Columbia River Crossing
dB	Decibel
dBA	A-weighted decibel
DEIS	Draft Environmental Impact Statement
DEQ	Oregon Department of Environmental Quality
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
Ft	feet/foot
FONSI	Finding of No Significant Impact
FTA	Federal Transit Administration
GIS	Geographic Information System
GMA	Growth Management Act
HCT	High-Capacity Transit
L_{dn}	24-hour, Time Weighted, A-weighted Sound Levels
LE	Listed Endangered
L_{eq}	Energy Average Sound Levels
L_{max}	Maximum Noise Levels
LOS	Level of Service
LRT	Light Rail Transit
LT	Listed Threatened
Mi	mile
Min	minute
MOA	Memorandum of Agreement
MP	Milepost
Mph	Miles per hour
NEPA	National Environmental Policy Act
NRHP	National Register of Historic Places
OAR	Oregon Administrative Rule
ODOT	Oregon Department of Transportation
OHP	Oregon Highway Plan
ORS	Oregon Revised Statutes
RCW	Revised Code of Washington

Acronym	**Description**
ROD	Record of Decision
ROW	Right-of-way
RTC	Regional Transportation Commission
RTP	Regional Transportation Plan
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SEPA	State Environmental Policy Act
SHPO	State Historic Preservation Office
SNR	Sensitive Noise Receptors
SRA	Sensitive Resource Areas
STIP	State Transportation Improvement Plan
TAZ	Transportation Analysis Zone
TCP	Traditional Cultural Properties
TDM	Transportation Demand Management
TEA-21	Transportation Equity Act for the 21st Century
TIP	Transportation Improvement Program
TPR	Transportation Planning Rule
TSCA	Toxic Substances and Control Act
TSP	Transportation System Management
UGA	Urban Growth Area
UGB	Urban Growth Boundary
UPRR	Union Pacific Railroad
V/C	Volume to Capacity Ratio
VMT	Vehicle Miles Traveled
WSDOT	Washington State Department of Transportation

1. Summary

1.1 Introduction

The purpose of this Noise and Vibration Analysis is to describe existing and future noise and vibration levels, potential noise and vibration impacts and proposed noise and vibration mitigation measures for the Interstate 5 (I-5) Columbia River Crossing (CRC) project. The Federal Highway Administration (FHWA), Federal Transit Administration (FTA), Oregon Department of Transportation (ODOT), and Washington Department of Transportation (WSDOT) have developed guidance for assessing noise and vibration impacts for highways and transit systems. The methods described in this report comply with the guidance documents for these agencies.

The report includes a discussion of the following elements:

- Existing noise and vibration conditions in areas potentially affected by the alternatives
- Regulations and policies governing evaluation and mitigation of impacts
- Methodology used in the analysis
- Impacts of the alternatives (short-term, long-term, and cumulative)
- Potential mitigation measures

1.2 Description of the Alternatives

The alternatives being considered for the CRC project consist of a diverse range of highway, transit, bike, and pedestrian transportation choices. Some of these choices – such as the number of traffic lanes across the river – could affect transportation performance and impacts throughout the bridge influence area or beyond. These are referred to as “system-level choices.” Other choices – such as whether to run high-capacity transit (HCT) on Washington Street or Washington and Broadway Streets – have little impact beyond the area immediately surrounding that proposed change and no measurable effect on regional impacts or performance. These are called “segment-level choices.” This report discusses the impacts from both system- and segment-level choices, as well as “full alternatives.” The full alternatives combine system-level and segment-level choices for highway, transit, pedestrian, and bicycle transportation. They are representative examples of how project elements may be combined. Other combinations of specific elements are possible. Analyzing the full alternatives allows us to understand the combined performance and impacts that would result from multimodal improvements spanning the bridge influence area.

Following are brief descriptions of the alternatives being evaluated in this report, which include:

- System-level choices,
- Segment-level choices, and
- Full alternatives.

1.2.1 System-Level Choices

System-level choices have potentially broad influence on the magnitude and type of benefits and impacts produced by this project. These options may influence physical or operational characteristics throughout the project area and can affect transportation and other elements outside the project corridor as well. The system-level choices include:

- River crossing type (replacement or supplemental)
- High-capacity transit mode (bus rapid transit or light rail transit)
- Tolling (no toll, I-5 only, I-5 and I-205, standard toll, higher toll)

This report compares replacement and supplemental river crossing options. A replacement river crossing would remove the existing highway bridge structures across the Columbia River and replace them with three new parallel structures – one for I-5 northbound traffic, another for I-5 southbound traffic, and a third for HCT, bicycles, and pedestrians. A supplemental river crossing would build a new bridge span downstream of the existing I-5 bridge. The new supplemental bridge would carry southbound I-5 traffic and HCT, while the existing I-5 bridge would carry northbound I-5 traffic, bicycles, and pedestrians. The replacement crossing would include three through-lanes and two auxiliary lanes for I-5 traffic in each direction. The supplemental crossing would include three through-lanes and one auxiliary lane in each direction.

Two types of HCT are being considered – bus rapid transit and light rail transit. Both would operate in an exclusive right-of-way through the project area, and are being evaluated for the same alignments and station locations. The HCT mode – Light Rail Transit (LRT) or Bus Rapid Transit (BRT) – is evaluated as a system-level choice. Alignment options and station locations are discussed as segment-level choices. BRT would use 60-foot or 80-foot long articulated buses in lanes separated from other traffic. LRT would use one- and two-car trains in an extension of the MAX line that currently ends at the Expo Center in Portland.

Under the standard operating scenario, LRT trains would run at approximately 7.5 minute headways during the peak periods. BRT would run at headways between 2.5 and 10 minutes depending on the location in the corridor. BRT would need to run at more frequent headways to match the passenger-carrying capacity of the LRT trains. This report also evaluates performance and impacts for an enhanced operations scenario that would double the number of BRT vehicles or the number of LRT trains during the peak periods.

1.2.2 Segment-Level Choices

1.2.2.1 Transit Alignments

The transit alignment choices are organized into three corridor segments. Within each segment the alignment choices can be selected relatively independently of the choices in the other segments. These alignment variations generally do not affect overall system performance but could have important differences in the impacts and benefits that occur in each segment. The three segments are:

- Segment A1 – Delta Park to South Vancouver
- Segment A2 – South Vancouver to Mill Plain District
- Segment B – Mill Plain District to North Vancouver

In Segment A1 there are two general transit alignment options - offset from, or adjacent to, I-5. An offset HCT guideway would place HCT approximately 450 to 650 feet west of I-5 on Hayden Island. An adjacent HCT guideway across Hayden Island would locate HCT immediately west of I-5. The alignment of I-5, and thus the alignment of an adjacent HCT guideway, on Hayden Island would vary slightly depending upon the river crossing and highway alignment, whereas an offset HCT guideway would retain the same station location regardless of the I-5 bridge alignment.

HCT would touch down in downtown Vancouver at Sixth Street and Washington Street with a replacement river crossing. A supplemental crossing would push the touch down location north to Seventh Street. Once in downtown Vancouver, there are two alignment options for HCT – a two-way guideway on Washington Street or a couplet design that would place southbound HCT on Washington Street and northbound HCT on Broadway. Both options would have stations at Seventh Street, 12th Street, and at the Mill District Transit Center between 15th and 16th Streets.

From downtown Vancouver, HCT could either continue north on local streets or turn east and then north adjacent to I-5. Continuing north on local streets, HCT could either use a two-way guideway on Broadway or a couplet on Main Street and Broadway. At 29th Street, both of these options would merge to a two-way guideway on Main Street and end at the Lincoln Park and Ride located at the current WSDOT maintenance facility. Once out of downtown Vancouver, transit has two options if connecting to an I-5 alignment: head east on 16th Street and then through a new tunnel under I-5, or head east on McLoughlin Street and then through the existing underpass beneath I-5. With either option HCT would connect with the Clark College Park and Ride on the east side of I-5, then head north along I-5 to about SR 500 where it would cross back over I-5 to end at the Kiggins Bowl Park and Ride.

There is also an option, referred to as the minimum operable segments (MOS), which would end the HCT line at either the Mill Plain station or Clark College. The MOS options provide a lower cost, lower performance alternative in the event that the full length HCT lines could not be funded in a single phase of construction and financing.

1.2.2.2 Highway and Bridge Alignments

This analysis divides the highway and bridge options into two corridor segments, including:

- Segment A – Delta Park to Mill Plain District
- Segment B – Mill Plain District to North Vancouver

Segment A has several independent highway and bridge alignment options. Differences in highway alignment in Segment B are caused by transit alignment, and are not treated as independent options.

There are two options for the replacement crossing – it could be located either upstream or downstream of the existing I-5 bridge. At the SR 14 interchange there are two basic configurations being considered. A traditional configuration would use ramps looping around both sides of the mainline to provide direct connection between I-5 and SR 14. A less traditional design could reduce right-of-way requirements by using a "left loop" that would stack both ramps on the west side of the I-5 mainline.

1.2.3 Full Alternatives

Full alternatives represent combinations of system-level and segment-level options. These alternatives have been assembled to represent the range of possibilities and total impacts at the project and regional level. Packaging different configurations of highway, transit, river crossing, tolling and other improvements into full alternatives allows project staff to evaluate comprehensive traffic and transit performance, environmental impacts and costs.

Exhibit 1-1 summarizes how the options discussed above have been packaged into representative full alternatives.

Exhibit 1-1. Full Alternatives

	Packaged Options				
Full Alternative	**River Crossing Type**	**HCT Mode**	**Northern Transit Alignment**	**TDM/TSM Type**	**Tolling Method[a]**
1	Existing	None	N/A	Existing	None
2	Replacement	BRT	I-5	Aggressive	Standard Rate
3	Replacement	LRT	I-5	Aggressive	Two options[b]
4	Supplemental	BRT	Vancouver	Very Aggressive	Higher rate
5	Supplemental	LRT	Vancouver	Very Aggressive	Higher rate

[a] In addition to different tolling rates, this report evaluates options that would toll only the I-5 river crossing and options that would toll both the I-5 and the I-205 crossings.

[b] Alternative 3 is evaluated with two different tolling scenarios, tolling and non-tolling.

Modeling software used to assess alternatives' performance does not distinguish between smaller details, such as most segment-level transit alignments. However, the geographic difference between the Vancouver and I-5 transit alignments is significant enough to warrant including this variable in the model. All alternatives include Transportation Demand Management (TDM) and Transportation System Management (TSM) measures designed to improve efficient use of the transportation network and encourage alternative transportation options to commuters such as carpools, flexible work hours, and telecommuting. Alternatives 4 and 5 assume higher funding levels for some of these measures.

Alternative 1: The National Environmental Policy Act (NEPA) requires the evaluation of a No-Build or "No Action" alternative for comparison with the build alternatives. The No-Build analysis includes the same 2030 population and employment projections and the same reasonably foreseeable projects assumed in the build alternatives. It does not include any of the I-5 CRC related improvements. It provides a baseline for comparing the build alternatives, and for understanding what will happen without construction of the I-5 CRC project.

Alternative 2: This alternative would replace the existing I-5 bridge with three new bridge structures downstream of the existing bridge. These new bridge structures would carry Interstate traffic, BRT, bicycles, and pedestrians. There would be three through-lanes and two auxiliary lanes for I-5 traffic in each direction. Transit would include a BRT system that would operate in an exclusive guideway from Kiggins Bowl in Vancouver to the Expo Center station in Portland. Express bus service and local and feeder bus service would increase to serve the added transit capacity. BRT buses would turn around at the existing Expo Station in Portland, where riders could transfer to the MAX Yellow Line.

Alternative 3: This is similar to Alternative 2 except that LRT would be used instead of BRT. This alternative is analyzed both with a toll collected from vehicles crossing the Columbia River on the new I-5 bridge, and with no toll. LRT would use the same transit alignment and station locations. Transit operations, such as headways, would differ, and LRT would connect with the existing MAX Yellow Line without requiring riders to transfer.

Alternative 4: This alternative would retain the existing I-5 bridge structures for northbound Interstate traffic, bicycles, and pedestrians. A new crossing would carry southbound Interstate traffic and BRT. The existing I-5 bridges would be re-striped to provide two lanes on each structure and allow for an outside safety shoulder for disabled vehicles. A new, wider bicycle and pedestrian facility would be cantilevered from the eastern side of the existing northbound (eastern) bridge. A new downstream supplemental bridge would carry four southbound I-5 lanes (three through-lanes and one auxiliary lane) and BRT. BRT buses would turn around at the existing Expo Station in Portland, where riders could transfer to the MAX Yellow Line. Compared to Alternative 2, enhanced transit service would provide more frequent service. Express bus service and local and feeder bus service would increase to serve the added transit capacity.

Alternative 5: This is similar to Alternative 4 except that LRT would be used instead of BRT. LRT would have the same alignment options, and similar station locations and requirements. LRT service would be more frequent (approximately 3.5 minute headways during the peak period) compared to 7.5 minutes with Alternative 3. LRT would connect with the existing MAX Yellow Line without requiring riders to transfer.

1.3 Long-Term Effects

The long-term effects identified in this report include noise impacts from traffic on project roadways and noise and vibration impacts from the operation of the proposed high-capacity transit (HCT). The long-term noise and vibration effects from traffic and the HCT are summarized in the following sections.

1.3.1 Long-Term Traffic Noise Effects

Currently, there are an estimated 234 traffic noise impacts to noise sensitive land uses in the project area and that number would rise to 268 under the future No-Build Alternative. Under the No-Build Alternative, routine maintenance of the existing noise walls in Vancouver would occur but no new noise walls would be constructed. Background traffic growth would cause a general increase in traffic noise levels throughout the project area, and in many locations is a major source of traffic noise. For example, the traffic noise impact at the Smith Apartments at the intersection of Washington Street and West Fifth Street is due primarily to local traffic, not traffic on I-5.

The full build alternatives, which would include noise walls, would reduce noise levels substantially throughout the project corridor compared to today's and the projected No-Build Alternative noise levels. Several noise-sensitive land uses currently without noise wall mitigation are exposed to high traffic noise levels. Many of these land uses would receive long-term noise reduction benefits with the proposed mitigation. With the recommended mitigation measures, there would be an estimated 76 residual traffic noise impacts to noise sensitive land uses. This represents an overall reduction in traffic noise impacts by 169 from the No-Build Alternative. The residual impacts are due in part to traffic noise from local arterials and connectors, such as Washington Street, W Sixth Street, Main Street, McLoughlin Boulevard, E Mill Plain among others. There are up to 12 residual residential impacts along I-5 at the overpass for East 29th and East 33rd Streets.

1.3.2 Long-Term HCT Noise and Vibration Effects

Transit modes include light rail transit (LRT) and bus rapid transit (BRT). In general, the LRT alternatives would have much lower noise impacts to the community than the BRT alternatives. For example, the use of LRT with the replacement crossing would result in approximately 37 noise impacts, whereas the same full alternative with BRT would result in 79 noise impacts, including 26 that are considered severe impacts under the Federal Transit Authority (FTA). Noise walls and residential sound insulation would mitigate all noise impacts caused by the LRT and BRT, however, long-term outdoor noise levels would be 2 to 3 L_{dn} higher with the BRT.

The operation of LRT has the potential for long-term vibration effects, however these would be mitigated with the measures recommended in the project design. No long-term vibration effects are expected with any of the full LRT build alternatives.

1.4 Temporary Effects

Construction phases for the CRC project would include: preparation for construction of new structures, construction of new structures and roadway paving, demolition of existing structures and miscellaneous activities, including striping, lighting, and signs. Maximum noise levels specifically during pile driving activities could be 99 to 105 dBA at 50 feet. During the preparation, construction and demolition phases, maximum noise levels could reach the lower to mid 90 dBA at the nearest residences (50 to 100 feet).

Maximum noise levels would be in the lower 80 dBA range for the miscellaneous activities such as striping and installing signs.

These temporary effects would end when project construction is completed.

1.5 Mitigation

1.5.1 Mitigation for Long-Term Traffic Noise Effects

Mitigation in the form of noise walls are recommended to the extent reasonable and feasible in all areas where noise impacts are projected. Noise wall mitigation measures would be required for all build alternatives. The noise walls that are currently along I-5 between Fourth Plain and SR 500 would be replaced with new noise walls.

Two noise walls, one on the west side and one on the east side, are proposed on the bridge structure to mitigate all noise impacts predicted to occur to the residences on or near the Columbia River.

A noise wall is recommended between Mill Plain and Fourth Plain that would mitigate traffic noise impacts predicted at the 35 residences and would further benefit 20 additional homes in the area.

A noise wall is recommended from Fourth Plain to just north of the SR 500 interchange that would mitigate noise impacts at 76 of the 82 residences and would further benefit 22 additional homes in the area. Because the remaining six residences would be near required openings in the wall, they would receive some noise reduction benefit but it would not be feasible to achieve the required noise reduction to fully mitigate the noise impact at these homes.

A noise wall is also recommended along the east side of I-5 near the Fort Vancouver area that would mitigate all traffic noise impacts predicted at the 24 residential land uses. In addition, the noise wall would provide a noise reduction benefit for 21 additional residential uses in the Fort Vancouver area.

A final noise wall is recommended along the east side of I-5 from E. Fourth Plain to about 500 feet past E. 37th Street. The wall would mitigate all but four of the 35 residential traffic noise impacts predicted in this area. The areas of the Vancouver Barracks Post Cemetery expected to have noise impacts would also be mitigated with this wall. In addition, the noise wall would provide a noise reduction benefit of 3 dBA or more for 21 additional homes in the area.

1.5.2 Mitigation for Long-Term LRT or BRT Noise and Vibration Effects

Although noise insulation of private residences is generally not allowed under FHWA guidelines for traffic noise impacts, it is allowed under FTA guidelines for transit-related impacts. Therefore, for long-term LRT or BRT noise effects, residential sound insulation was considered. Sound insulation of residences is recommended as part of the mitigation measures for either transit options, LRT or BRT. Residential sound insulation could be in the form of adding an extra layer of glazing to the windows, sealing any holes in exterior surfaces that act as sound leaks, or by providing forced ventilation and air-conditioning so that windows do not need to be opened. The extent of these building insulation measures would be determined during the final design phase of the project.

Potential vibration impacts associated with the operation of LRT would be mitigated with ballast mats, resilient fasteners, or tire degraded aggregate (TDA). The selected vibration mitigation method would depend on the track type and level of vibration impact.

Because LRT wheel squeal is likely to occur at the proposed 90-degree curves at Main Street and McLoughlin or Main Street and 16th, it is recommended that provision for trackside lubricators be made during project design so that they can be installed if needed after project completion.

1.5.3 Mitigation for Short-Term Construction Noise and Vibration Effects

The following is a list of recommended noise mitigation measures that should be contained in the contract specifications:

- Require all engine-powered equipment to have mufflers installed according to the manufacturer's specifications.
- Require all equipment to comply with pertinent EPA equipment noise standards.
- Limit jackhammers, concrete breakers, saws, and other forms of demolition to daytime hours of 8:00 a.m. to 5:00 p.m. on weekdays with more stringent restrictions on weekends.
- Minimize noise by regular inspection and replacement of defective mufflers and parts that do not meet the manufacturer’s specifications.
- Install temporary or portable acoustic barriers around stationary construction noise sources and along the sides of the temporary bridge structures where feasible.
- Locate stationary construction equipment as far from nearby noise-sensitive properties as possible.
- Shut off idling equipment.
- Reschedule construction operations to avoid periods of noise annoyance identified in complaints.
- Notify nearby residents whenever extremely noisy work would be occurring.
- Substitute broadband or smart alarms for back-up beepers to reduce the potential for impacts during evening and nighttime hours.

2. Methods

2.1 Introduction

The Federal Highway Administration (FHWA), Federal Transit Administration (FTA), Oregon Department of Transportation (ODOT), and Washington Department of Transportation (WSDOT) have developed guidance for assessing noise and vibration impacts for highways and transit systems. In addition, City, State and County regulations and ordinances that were also considered for applicability to this project. The methods described in this report comply with the guidance documents for these agencies, and include:

- FHWA *Procedures for Abatement of Highway Traffic Noise and Construction Noise*, 23 CFR 772, US Code of Federal Regulations, 1982
- FTA *Transit Noise and Vibration Impact Assessment, Final Report* May, 2006
- ODOT *Traffic Noise Manual*, Updated January 2007
- WSDOT *Traffic Noise Analysis and Abatement Policy and Procedures*, March 2006
- City of Portland Municipal Code Title 18, *Noise Control*. August, 1997
- Vancouver Municipal Code (VMC) Title 20, *Noise Impact Overlay District*

2.2 Analysis Requirements

This section provides the details on the methods of a noise and vibration study. Included is an introduction to acoustics, project study area, impact criteria and analysis methods. Understanding the adverse effects of traffic, high-capacity transit (HCT) and construction noise is an integral part of this EIS.

Federal, state, and local governments provide guidance on acceptable noise levels to ensure the public’s health and well being, both now and in the future. Traffic and construction noise analyses are required by law for federally funded projects that (1) involve construction of a new highway, (2) substantially change the horizontal or vertical alignment, or (3) increase the number of through traffic lanes on an existing highway. Oregon and Washington State policies also require the review and consideration of noise abatement on projects that substantially alter the ground contours surrounding a state highway.

In addition to the highway component of the CRC project, there is an HCT component. The HCT could include either light rail transit (LRT) or a bus rapid transit (BRT) system between North Vancouver and the Portland Expo Center. Potential noise and vibration related to the HCT component are analyzed using the criteria from the FTA.

The following sections provide information related to the study area, impact criteria and analysis methods for this project. In addition, a detailed introduction to acoustics and vibration is included.

2.3 Introduction to Acoustics and Vibration

Highway-related projects that are concerned only with traffic are generally analyzed for potential noise impacts but not vibration. However, because this project includes an HCT component, the FTA requires that both noise and vibration from the HCT component be analyzed. Section 2.3.1 provides a detailed introduction to acoustics and section 2.3.2 provides the same for vibration.

2.3.1 Sound

Sound is any change in air pressure that the human ear can detect, from barely perceptible sounds to sound levels that can cause hearing damage. These changes in air pressure are translated to sound in the human ear. The greater the change in air pressure, the louder the sound. For example, a quiet whisper in a library creates a relatively small change in room air pressure, whereas air pressure changes are much greater in the front row of a rock concert.

In addition to the loudness, frequency is a term also used to describe sound. The frequency of sound is determined by the number of recurring changes in air pressure per second. A sound that contains a relatively high number of pressure changes per second is generally referred to as a high frequency noise (for example, an ambulance siren). A sound that has a low number of pressure changes per second is referred to as low frequency (for example, a bass drum).

A person’s response to noise is subjective and can vary greatly from person to person. Some key factors that can influence an individual’s response include the loudness, frequency, the amount of background noise present, and the nature of the activity taking place that the noise affects. For example, children playing outside during the day, while there is background traffic noise, are generally less obtrusive than if the children were making the same amount of noise during the nighttime sleeping hours. When sounds are unpleasant, unwanted, or disturbingly loud, they are normally considered “noise”.

2.3.1.1 Decibel Scale

Sound is measured both in terms of loudness and frequency. The unit used to measure the loudness of noise is called a decibel (dB). A range from 0 to 120 dB is the typical range of hearing. A decibel is defined as 10*log (P/P_{ref}), where P is the root-mean-square (rms) sound pressure in Pascal (Newtons per square meter) and P_{ref} is the reference rms sound pressure of 2×10^{-5} Pascal. The audible sound pressure variations range from the threshold of hearing—a very small 2×10^{-5} Pascal—to 100 Pa, a level so loud it is referred to as the threshold of pain. Because the ratio between these numbers is more than a million to one, using Pascal to describe sound levels can be awkward. The decibel or dB measurement is a logarithmic conversion of sound pressure level variations from Pascal to a unit of measure with a more convenient numbering system. This conversion not only allows for a more convenient scale, but is also a more accurate representation of how the human ear reacts to variations in air pressure. While the loudness of sound is an easy concept for most people, a sound's frequency is just as important in understanding how we hear sounds.

Frequency is measured in terms of the number of changes in air pressure that occur per second. The unit we use to measure the frequency of noise is called hertz (Hz). While the human ear can detect a wide range of frequencies from 20 Hz to 20,000 Hz, it is most sensitive to sounds at the middle frequencies (500 to 4,000 Hz). The human ear is progressively less sensitive to sound at frequencies above and below this middle range. For example, a noise level of 60 dB at 250 Hz would be considerably less noticeable to a person than 60 dB at 1,000 Hz.

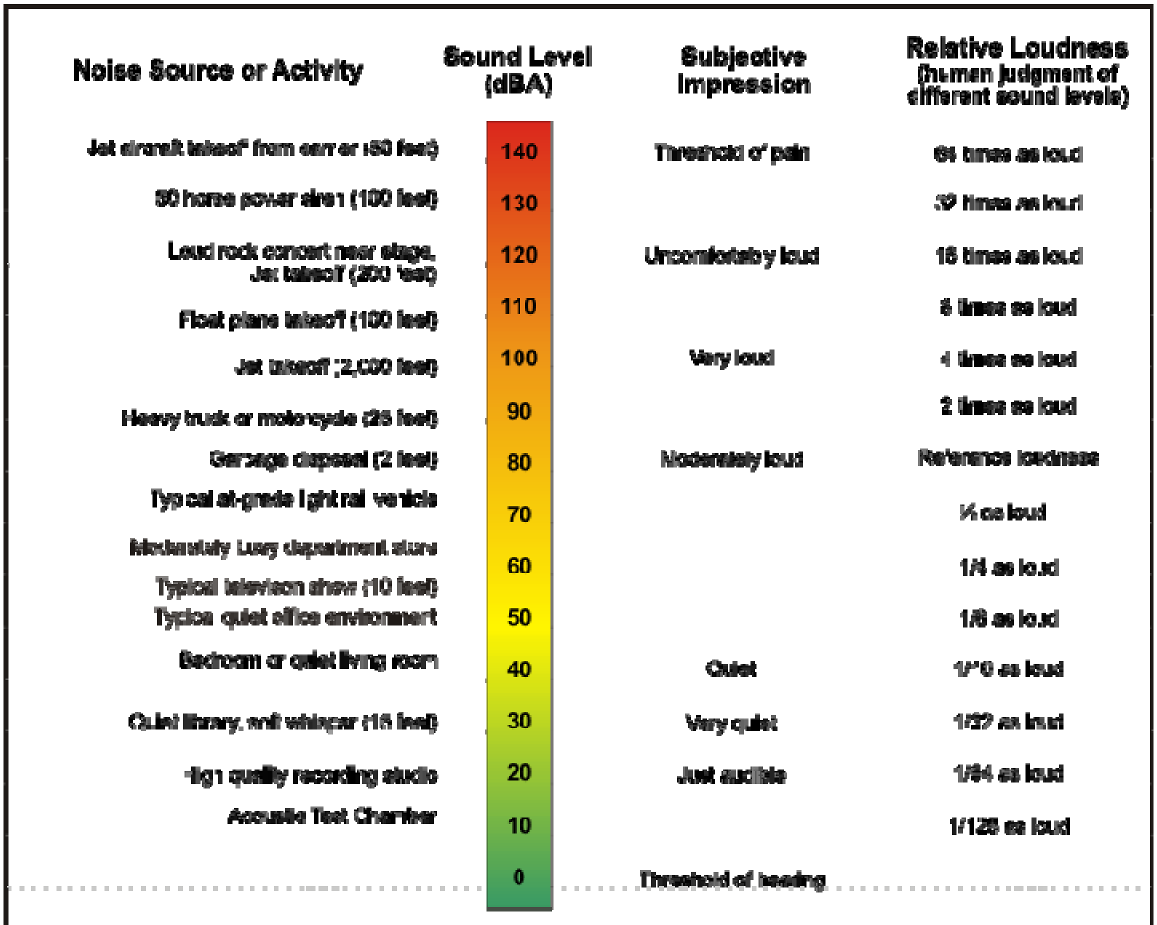
Discussing sounds in terms of both loudness and frequency can be tedious and confusing. To simplify matters, an adjustment is made to the dB measurement scale that, in addition to loudness, accounts for the human ear's sensitivity to different frequencies. The adjusted dB scale, referred to as the A-weighted decibel scale, provides an accurate "single number" measure of what the human ear can actually hear. When the A-weighted scale is used, decibel levels are designated as dBA. The dBA unit of measurement is used in this report as required by the FHWA and FTA for traffic and HCT studies.

2.3.1.2 Typical Noise Levels

Normal human conversation ranges between 44 and 65 dBA when people are about 3 to 6 feet apart. Very slight changes in noise levels, up or down, are generally not detectable by the human ear. The smallest change in noise level that a human ear can perceive is about 3 dBA, while increases of 5 dBA or more are clearly noticeable. For most people, a 10 dBA increase in noise levels is judged as a doubling of sound level, while a 10 dBA decrease in noise levels is perceived to be half as loud. For example, a person talking at 70 dBA is perceived as twice as loud as the same person talking at 60 dBA.

In most neighborhoods, nighttime noise levels are noticeably lower than daytime noise levels. In a quiet rural area at night, noise levels from crickets or winds rustling leaves on the trees can range between 32 and 35 dBA. As residents start their day and local traffic increases, the same rural area can have noise levels ranging from 50 to 60 dBA. While noise levels in urban neighborhoods are louder than rural areas, they share the same pattern of lower noise levels at night than during the day. Quiet urban nighttime noise levels range from 40 to 50 dBA. Noise levels during the day in a noisy urban area are frequently as high as 70 to 80 dBA. Exhibit 2-1 is a graph of noise levels for typical noise sources and also provides a normal human response to the noise level.

Exhibit 2-1. Typical Sound Levels



Sources: Beranek (1988) and U.S. EPA (1971).

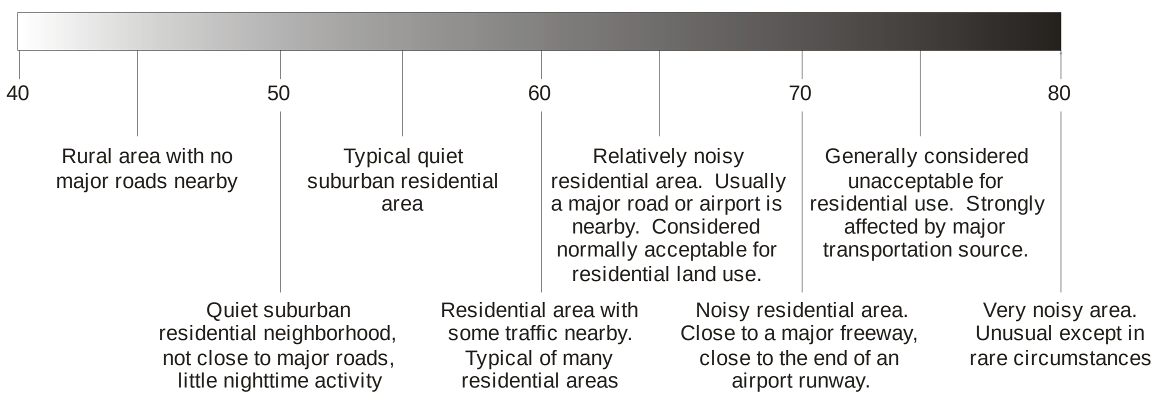
2.3.1.3 Measuring Sound

Noise levels from most sources tend to vary with time. For example, noise levels increase when a car approaches, then reach a maximum peak as it passes, and decrease as the car moves farther away. In this example, noise levels within a 1-minute timeframe may range from 45 dBA as the vehicle approaches, increase to 65 dBA as it passes by, and return to 45 dBA as it moves away. To account for the variance in loudness over time, a common noise measurement is the equivalent sound pressure level (Leq). The Leq is defined as the energy average noise level, in dBA, for a specific time period (for example, 1 minute). Returning to the example of the passing car, let's assume the energy average noise level was 60 dBA during the entire period of time the car could be heard as it passed by. In this example, the noise level would be stated as 60 dBA Leq. The hourly L_{eq} is the preferred noise descriptor for traffic noise and for HCT noise at schools, libraries, and other institutional uses.

Another noise level descriptor is the Day-Night Equivalent Sound Level, L_{dn}, 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 noise event during the nighttime hours is equivalent to ten events during the daytime hours. This strongly weights L_{dn} toward nighttime noise to reflect most people being more easily annoyed by noise during the nighttime hours when background noise is lower and most people are sleeping.

Most urban and suburban neighborhoods will have L_{dn}'s in the range of 50 to 70 dBA. An L_{dn} 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. A 70 dBA-L_{dn} exterior noise level would usually be considered unacceptable for residential land use without special measures taken to enhance outdoor-indoor sound insulation. Substantial improvements in building sound insulation (on the order of 5 to 10 dBA) can often be achieved by adding an extra layer of glazing to the windows, by sealing any holes in exterior surfaces that act as sound leaks, and by providing forced ventilation and air-conditioning so that windows do not need to be opened. Residential neighborhoods that are not near major sound sources will usually be in the range of L_{dn} 55 to 60 dBA. If there is a freeway or moderately busy arterial nearby, or any nighttime noise sources, L_{dn} is usually in the range of 60 to 65 dBA. Exhibit 2-2 defines typical community noise levels in terms of L_{dn}.

Exhibit 2-2. Typical Community Noise Levels in L_{dn}



Source: FTA, April 1995

Several other sound level descriptors are commonly used, and are used for construction noise in this analysis. The maximum level of an event (such as the car pass-by described early) is called the L_{max}. The sound level descriptor Lxx is defined as the sound level exceeded xx percent of the time. Washington State uses the Lxx values to determine compliance with noise regulations and for construction noise. The versions of this descriptor used by Washington State and their corresponding definitions are listed below:

- $L_{2.5}$ - The sound level is exceeded 2.5 percent of the time. This is a measure of the loudest sound levels during the measurement period. Example: During a 1-hour measurement, an $L_{2.5}$ of 95 dBA means the sound level was at or above 95 dBA for 1.5 minutes.

- $L_{8.3}$ - The sound level is exceeded 8.3 percent of the time. This is a measure of the louder sound levels during the measurement period. Example: During a 1-hour measurement, an $L_{8.3}$ of 85 dBA means the sound level was at or above 85 dBA for 5 minutes.
- L_{25} - The sound level is exceeded 25 percent of the time. This is a measure of the nominal background level. Example: During a 1-hour measurement, an L_{25} of 50 dBA means the sound level was at or above 50 dBA for 15 minutes.

2.3.1.4 Sound Propagation

Several factors determine how sound levels decrease or attenuate over a distance. There are two general rules of thumb that apply to noise sources that can be categorized as either a point source (for example, a church bell) or a line source (such as constant flowing traffic on a busy highway).

A single point noise source will attenuate at a rate of 6 dB each time the distance from the source doubles. Thus, a point source that produces a noise level of 60 dB at a distance of 50 feet would attenuate to 54 dB at 100 feet and to 48 dB at 200 feet. A line source such as a highway, however, generally reduces at a rate of approximately 3 dB each time the distance doubles. Using the same example above, a line source measured at 60 dB at 50 feet would attenuate to 57 at 100 feet and to 54 at 200 feet.

The general rules of thumb for attenuation of point and line sources are influenced by the physical surroundings between the source and the receiver. For example, interactions of sound waves with the ground often result in slightly higher attenuation (called ground absorption effects) than the reduction factors given in the preceding paragraph. Other factors that affect the attenuation of sound with distance include existing structures; topography; foliage; ground cover; and atmospheric conditions such as wind, temperature, and relative humidity. The potential effects these factors have on sound propagation are described below.

- Existing structures can substantially affect noise levels. Buildings or walls can reduce noise levels by physically blocking the path between the source and the receiver. Measurements have shown that a single-story house has the potential, through shielding, to reduce noise levels by as much as 10 dB or greater. The actual noise reduction will depend greatly on the geometry of the noise source, receiver, and location of the structure. In cases where the source and the receiver are located on the same side of a structure, noise levels may be higher than expected due to the combination of sound transmitted directly from the source and sound reflected off the structure. Increases in noise caused by reflection are normally 3 dB or less, which is the minimum change in noise levels that can be noticed by the human ear.
- Topography includes existing hills, berms, and other ground surface features between the noise source and receiver location. As with structures, topography can potentially reduce or increase sound, depending on the location or geometry of the surrounding terrain. Hills and berms that block the path between the noise source and receiver will reduce noise levels at the receiver location. In some

locations, however, the topography can cause an overall increase in sound levels by either reflecting or channeling the noise towards a sensitive receiver location.

- Dense foliage can slightly reduce noise levels. As a general rule of thumb, if the foliage is sufficiently dense that you cannot see over it or through it then it may be providing some additional noise level reduction from the source to the receiver. For example, the Federal Highway Administration (FHWA) has stated that up to a 5 dBA reduction in traffic noise may result for locations that have at least 100 feet of dense evergreen foliage between the roadway and the receiver.
- The presence (or absence) of ground cover between the receiver and the noise source can also affect noise transmission. For example, sound travels across reflective surfaces, such as water or pavement, with minimal attenuation. On the other hand, sound will be more attenuated or absorbed as it travels across ground cover such as field grass, lawn, or even loose soil.
- Atmospheric conditions that can affect the transmission of noise include wind, temperature, humidity, and precipitation. Wind blowing in the direction from the source to the receiver can increase sound levels; conversely, wind can reduce noise levels when blowing in a direction from the receiver to the source. Noise levels can increase during a temperature inversion as the layer of warmer air atop the trapped layer of cooler air causes a deflection of skyward-bound sound waves back to the receivers at ground level. Other atmospheric conditions such as humidity and precipitation are rarely severe enough to noticeably affect the amount of noise attenuation. Because weather conditions change frequently, atmospheric conditions are not considered in transportation noise studies.

2.3.2 Vibration

Vibration consists of oscillatory waves that propagate from the source through the ground to adjacent buildings, and is typically referred to as ground-borne vibration. Two types of vibration will be reviewed and analyzed in this report, vibration from the operation of a possible light rail system, and vibration related to the construction of the project.

2.3.2.1 Transit Vibration

On steel-wheel/steel-rail train systems, ground-borne 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. The primary concern is that the vibration and radiated noise can be intrusive and annoying to building occupants. The building vibration caused by ground-borne vibration may be perceived as motion of building surfaces, rattling of windows, items on shelves, or pictures hanging on walls. Ground-borne vibration can also be perceived as a low-frequency rumbling noise, which is referred to as ground-borne noise. Factors that influence the amplitudes of ground-borne 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 that the vibration propagates through. Use of continuously welded rail eliminates wheel impacts at rail joints and results in significantly lower vibration levels than with jointed. All of TriMet light rail lines use continuously welded rail (CWR) and track maintenance on the rail (rail grinding) is performed on a regular basis.

Ground-borne vibration is different from airborne noise in that it is not a wide-spread environmental problem, and is generally limited to localized areas near rail systems, construction sites, and some industrial operations. Road traffic rarely creates perceptible ground-borne 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 ground-borne 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.

2.3.2.2 Construction Vibration

Vibration from construction projects is caused by general equipment operations, and is usually highest during pile driving, soil compacting, jack-hammering and construction related demolition activities. As with the light rail, the vibration is sometimes noticeable outdoors but it is almost exclusively an indoor problem. Although it is conceivable for ground-borne vibration from construction projects to cause building damage, the vibration from construction activities is almost never of sufficient amplitude to cause even minor cosmetic damage to buildings. The primary concern is that the vibration can be intrusive and annoying to building occupants.

2.3.2.3 Measuring Vibration

Vibration is an oscillatory motion that can be described in terms of the displacement, velocity, or acceleration of the oscillations. Ground-borne vibration for transit projects is usually characterized in terms of the vibration velocity because, over the frequency range relevant to ground-borne 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:

$$Lv = 20 \times \log (V/Vref);$$

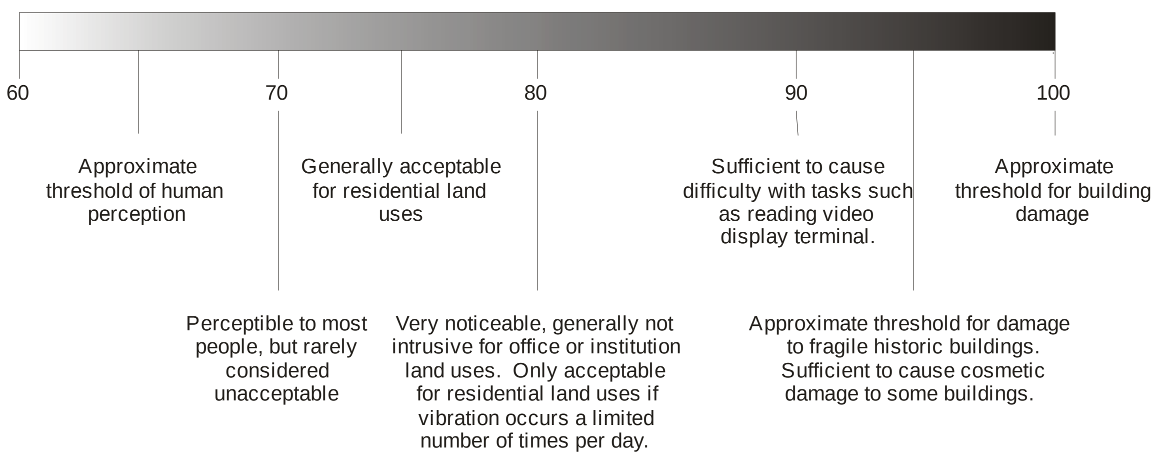
where V is the velocity amplitude in inches/second, Vref is 10^{-6} inches/second, Lv is the velocity level in decibels. The abbreviation VdB is used here for vibration decibels to minimize confusion with sound decibels.

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 ground-borne vibration.

The U.S. Department of Transportation (USDOT) has guidelines for vibration levels from construction related activities, and recommends that the maximum peak-particle-velocity levels (PPV) remain below 0.05 inches per second at the nearest structures. The PPV represents the maximum instantaneous peak in the velocity of an object's vibratory motion about the equilibrium position. It is used to define the thresholds of potential building damage from vibration since it is thought to be more directly correlated to peak stresses in building components than RMS vibration. The relationship between PPV and RMS depends on the shape and duration of a specific waveform. The RMS amplitude is always less than the PPV and in ground-borne vibration; PPV amplitude is usually 2 to 5 times greater than RMS amplitude.

Exhibit 2-3 gives a general idea of human and building response to different levels of vibration in VdB. 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 significant unless the RMS vibration velocity level exceeds 70 VdB. This is a typical level 50 ft 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.

Exhibit 2-3. Typical Levels of Ground-Borne Vibration (VdB)



Source: FTA, April 1995

2.4 Study Area

Noise and vibration impacts normally occur within approximately 500 feet or less of highways or roads and 350 feet or less from transit lines. Because of the varying alternatives, locations of the potential HCT alternatives, and noise and vibration sensitivity of many areas, the noise and vibration analysis will be performed for all noise sensitive land uses that could have impacts or noticeable increases in noise or vibration. In general, the analysis covers the areas within 500 to 600 feet from the nearest highway or transit right-of-way (ROW).

2.5 Effects Guidelines

Relevant rules and regulations concerning recognized environmental conditions consist of, but are not limited to, the federal and state laws discussed below. This report does not include detailed descriptions; however, brief descriptions are provided to gain an understanding of the relevance that each law and regulation has to the project.

2.5.1 Federal Highway Administration Noise Criteria

The criteria for highway noise impacts are taken from the FHWA *Procedures for Abatement of Highway Traffic Noise and Construction Noise*, 23 CFR 772, US Code of Federal Regulations, 1982. Projects that include construction of new highways or reconstruction of existing highways by significantly changing either the horizontal or vertical alignment or by increasing the number of through traffic lanes require analysis and consideration of abatement. A significant change in the horizontal or vertical alignment occurs when the change is likely to result in increased noise levels to developed lands. The traffic noise abatement criteria are listed in Exhibit 2-4. A noise impact occurs if predicted noise levels approach the levels listed in Exhibit 2-4 or substantially exceed existing noise levels. Each state defines quantitative levels considered to approach or substantially exceed existing noise levels.

Exhibit 2-4. FHWA Traffic Noise Abatement Criteria

Land Use Category		Hourly L_{eq} (dBA)
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 (exterior)
Type B:	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, (exterior) motels, hotels, schools, churches, libraries and hospitals	67 (exterior)
Type C:	Developed lands, properties or activities not included in the above categories	72 (exterior)
Type D:	Undeveloped land	—
Type E:	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums	52 (interior)

2.5.2 Federal Transit Administration Noise Criteria

The criteria for transit impacts are taken from the FTA *Transit Noise and Vibration Impact Assessment*, *Final Report* May, 2006. The FTA noise criteria would apply to the bus rapid transit and light rail transit elements of the project. The criteria in the FTA Guidance Manual are founded on well-documented research on community reaction to noise and are based on change in noise exposure using a sliding scale. The amount that the transit project is allowed to change the overall noise environment is reduced with increasing levels of existing noise. The FTA Noise Impact Criteria groups 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. This includes residences, hospitals, and hotels where nighttime sensitivity is assumed to be of utmost importance.

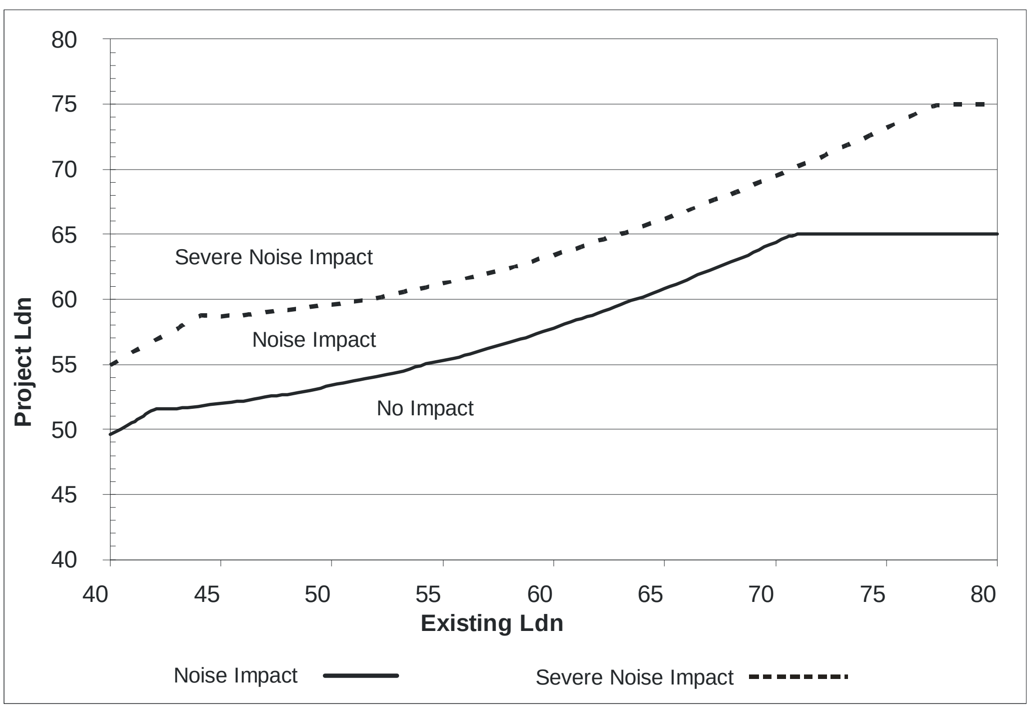
Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches, office buildings and other commercial and industrial land use.

The L_{dn} is used to characterize noise exposure for residential areas (Category 2) and maximum 1-hour L_{eq} during the period that the facility is in use is used for other noise sensitive land uses such as school buildings (Categories 1 and 3).

There are two levels of impact included in the FTA criteria, as shown in Exhibit 2-5. These two levels of impact are summarized below:

- **Severe:** Severe noise impacts are considered "significant" as this term is used in the National Environmental Policy Act (NEPA) and implementing regulations. Noise mitigation will normally be specified for severe impact areas unless there is no practical method of mitigating the noise.
- **Impact:** In this range, often called a moderate impact, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These other factors can include the predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing outdoor-indoor sound insulation, and the cost effectiveness of mitigating noise to more acceptable levels.

Exhibit 2-5. FTA Transit Noise Impact Criteria



Source: *FTA Manual for Transit Noise and Vibration Impact Assessment*, FTA May 2006.

Exhibit 2-6 summarizes the noise impact criteria for fixed guideway transit operations. The future noise exposure would be the combination of the existing noise and additional noise exposure caused by the transit project. Exhibit 2-7 gives the information from

Exhibit 2-6 in a slightly different form, in terms of the allowable increase in cumulative noise exposure (noise from existing sources plus project noise) as a function of existing noise exposure. As the existing noise exposure increases, the amount of the allowable increase in the overall noise exposure caused by the project decreases.

Exhibit 2-6. FTA Noise Impact Criteria

Existing Noise Exposure Leq or L_{dn}[1]	Project Noise Exposure Impact Thresholds, L_{dn} or L_{eq}[1] (all noise levels in dBA)			
	Category 1 or 2 Sites		Category 3 Sites	
	Impact	Severe Impact	Impact	Severe Impact
<43	Amb.+10	Amb.+15	Amb.+15	Amb.+20
43-44	52	58	57	63
45	52	58	57	63
46-47	53	59	58	64
48	53	59	58	64
49-50	54	59	59	64
51	54	60	59	65
52-53	55	60	60	65
54	55	61	60	66
55	56	61	61	66
56	56	62	61	67
57-58	57	62	62	67
59-60	58	63	63	68
61-62	59	64	64	69
63	60	65	65	70
64	61	65	66	70
65	61	66	66	71
66	62	67	67	72
67	63	67	68	72
68	63	68	68	73
69	64	69	69	74
70	65	69	70	74
71	66	70	71	75
72-73	66	71	71	76
74	66	72	71	77
75	66	73	71	78
76-77	66	74	71	79
>77	66	75	71	80

Notes:

[1] Ldn is used for land uses where nighttime sensitivity is a factor; Daytime Leq is used for land use involving only daytime activities.

Category Definitions:
Category 1: Buildings or parks where quiet is an essential element of their purpose.
Category 2: Residences and buildings where people normally sleep. This includes residences, hospitals, and hotels where nighttime sensitivity is assumed to be of utmost importance.
Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches.

Source: *FTA Manual for Transit Noise and Vibration Impact Assessment*, FTA May 2006.

Exhibit 2-7. FTA Impact Criteria by Allowable Cumulative Increase

Existing Ambient Noise Level Leq or Ldn[1]	Allowable Cumulative Noise Level Increases, L_{eq} or L_{dn}[1] (all noise levels in dBA)			
	Category 1 and 2 Sites		Category 3 Sites	
	Impact	Severe Impact	Impact	Severe Impact
45	8	14	12	19
46	7	13	12	18
47	7	12	11	17
48	6	12	10	16
49	6	11	10	16
50	5	10	9	15
51	5	10	8	14
52	4	9	8	14
53	4	8	7	13
54	3	8	7	12
55	3	7	6	12
56	3	7	6	11
57	3	6	6	10
58	2	6	5	10
59	2	5	5	9
60	2	5	5	9
61	1.9	5	4	9
62	1.7	4	4	8
63	1.6	4	4	8
64	1.5	4	4	8
65	1.4	4	3	7
66	1.3	4	3	7
67	1.2	3	3	7
68	1.1	3	3	6
69	1.1	3	3	6
70	1.0	3	3	6
71	1.0	3	3	6
72	0.8	3	2	6
73	0.6	2	1.8	5
74	0.5	2	1.5	5
75	0.4	2	1.2	5

Notes:

[1] Ldn is used for land uses where nighttime sensitivity is a factor; Daytime Leq is used for land use involving only daytime activities.

Category Definitions:
Category 1: Buildings or parks where quiet is an essential element of their purpose.
Category 2: Residences and buildings where people normally sleep. This includes residences, hospitals, and hotels where nighttime sensitivity is assumed to be of utmost importance.
Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches.

Source: *FTA Manual for Transit Noise and Vibration Impact Assessment*, FTA May 2006.

2.5.3 Federal Transit Administration Vibration Criteria

The FTA has developed impact criteria for acceptable levels of ground-borne noise and vibration (*FTA Manual for Transit Noise and Vibration Impact Assessment*, FTA May 2006). The FTA vibration criteria would apply to the bus rapid transit and light rail transit components of the project. Experience with ground-borne vibration from rail systems and other common vibration sources suggests that:

- Ground-borne vibration from transit trains should be characterized in terms of the RMS vibration velocity amplitude. A 1-second RMS time constant is assumed. This contrasts to vibration from blasting and other construction procedures that have the potential to cause building damage. When looking at potential for building damage, ground-borne 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 urban transit systems with 10 to 20 trains per hour throughout the day, limits for acceptable levels of residential ground-borne vibration are usually between 70 and 75 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 most commuter rail systems having fewer daily operations than the typical urban transit line, the criteria in the FTA Manual include an 8 VdB higher impact threshold if there are fewer than 70 trains per day.
- Ground-borne 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.

Exhibit 2-8 summarizes the FTA impact criteria for ground-borne vibration and ground-borne noise. These criteria are based on published standards, criteria, and design goals including ANSI S3.29 and the noise and vibration guidelines of the American Public Transit Association (APTA) (*APTA Guidelines for Design of Rapid Transit Facilities, 2007.*

Some buildings, such as concert halls, TV and recording studios, and theaters, can be very sensitive to vibration and noise but do not fit into any of the three categories. Because of the sensitivity of these buildings, they usually warrant special attention during the environmental assessment of a transit project. Exhibit 2-9 gives criteria for acceptable levels of ground-borne vibration and noise for various types of special buildings.

Exhibit 2-8. FTA Ground-Borne Vibration Impact Criteria

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 u-inch/sec)		Ground-Borne Noise Impact Levels (dB re 20 micro-Pa)	
	Frequent[1] Events	Infrequent[2] Events	Frequent[1] Events	Infrequent[2] Events
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB[3]	65 VdB[3]	--NA--[4]	--NA--[4]
Category 2: Residences and buildings where people normally sleep.	72 VdB	80 VdB	35 VdB	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	83 VdB	40 dBA	48 dBA

Notes:

[1] Frequent Events" is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.

[2] Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.

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

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

Source: *FTA Manual for Transit Noise and Vibration Impact Assessment*, FTA May 2006.

Exhibit 2-9. FTA Ground-Borne Vibration Impact Criteria for Special Buildings

Type of Building or Room	Ground-Borne Vibration Impact Levels (VdB re 1 u-inch/sec)		Ground-Borne Noise Impact Levels (dB re 20 micro-Pa)	
	Frequent[1] Events	Infrequent Events[2]	Frequent Events[1]	Infrequent Events[2]
Concert Halls	65 VdB	65 VdB	25 dBA	25 dBA
TV Studios	65 VdB	65 VdB	25 dBA	25 dBA
Recording Studios	65 VdB	65 VdB	25 dBA	25 dBA
Auditoriums	72 VdB	80 VdB	30 dBA	38 dBA
Theaters	72 VdB	80 VdB	35 dBA	43 dBA

Notes:

[1] Frequent Events" is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.

[2] Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.

If the building will rarely be occupied when the trains are operating, there is no need to consider impact. As an example, consider locating a commuter rail line next to a concert hall. If no commuter trains will operate after 7 p.m., it should be rare that the trains interfere with the use of the hall.

Source: *FTA Manual for Transit Noise and Vibration Impact Assessment*, FTA May 2006.

2.5.4 State Noise Criteria

The following sections discuss applicable state noise regulations. Washington and Oregon do not have specific regulations that limit ground or structural vibrations.

2.5.4.1 Oregon Noise Impact Criteria

The Oregon Department of Transportation (ODOT) is responsible for implementing the FHWA regulations in Oregon. Under ODOT policy, a traffic noise impact occurs if predicted noise levels are within 2 A-weighted decibels (dBA) of the FHWA criteria; a

10-dBA increase in noise is considered substantial. These criteria are applied to the peak noise impact hour. Exhibit 2-10 shows the noise impact criteria used for highway projects in Oregon.

Exhibit 2-10. ODOT Noise Impact Criteria

Description of Activity	Impact Criteria (in dBA)
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.	55 (exterior)
Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.	65 (exterior)
Developed lands, properties, or activities not included in the previous two categories.	70 (exterior)
Undeveloped lands.	--
Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.	50 (interior)
Source: ODOT. June 1996. Noise Manual.	

The Oregon Department of Environmental Quality (DEQ) has established noise control regulations of allowable noise levels for individual vehicles and for industrial and commercial uses. Maximum allowable noise levels for in-use vehicles are determined by vehicle type, operating conditions, and model year. The regulations also set noise standards for new and existing industrial and commercial noise sources. Park-and-ride lots and maintenance facilities are two examples where the DEQ standards might apply to project alternatives. The noise regulations for new and existing industrial and commercial noise sources limit allowable statistical sound levels (Lxx), discrete frequency sounds, and impulsive sounds. Lxx is a statistical noise level descriptor, where “xx” is a percentage of the measurement time, usually 1 hour. The statistical noise descriptors used in the Oregon regulations and summarized in Exhibit 2-11 are L1, L10, and L50; these are defined as follows:

- L1: The sound level exceeded 1 percent of the time. This is a measure of the loudest sound levels during the measurement period. Example: During a 1-hour measurement, an L1 of 90 dBA means the sound level was 90 dBA or louder for 0.6 minutes, or 36 seconds.
- L10: The sound level exceeded 10 percent of the time. This is a measure of the louder sound levels during the measurement period. Example: During a 1-hour measurement, an L10 of 85 dBA means the sound level was 85 dBA or louder for 6 minutes.
- L50: The sound level exceeded 50 percent of the time. Example: During a 1-hour measurement, an L50 of 50 dBA means the sound level was 50 dBA or louder for 30 minutes.

Exhibit 2-11. DEQ Industrial and Commercial Noise Source Standards

Statistical Descriptor	Existing Noise Source (dBA)		New Noise Source (dBA)		New Source in Quiet Area (dBA)	
	7 am-10 pm	10 pm-7 am	7 am-10 pm	10 pm-7 am	7 am-10 pm	10 pm-7 am
L1	75	60	75	60	60	55
L10	60	55	60	55	55	50
L50	55	50	55	50	50	45

Source: OAR 340-35-035, Tables 7 and 8.

2.5.4.2 Washington Noise Impact Criteria

The Washington Department of Transportation (WSDOT) is responsible for administering the FHWA regulations in Washington. Under WSDOT policy, a traffic noise impact occurs if predicted noise levels are within 1 dBA of the FHWA criteria. An increase of 10 dBA or more is considered substantial. Exhibit 2-12 shows the noise impact criteria used for highway projects in Washington.

Exhibit 2-12. WSDOT Noise Impact Criteria

Land Use Category	Description of Activity	Abatement Criteria (in dBA)
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.	56 (exterior)
B	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.	66 (exterior)
C	Developed lands, properties, or activities not included in the previous two categories.	71 (exterior)
D	Undeveloped lands.	--
F	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.	51 (interior)

Source: WSDOT. November 1997. “Noise Abatement Policy and Procedures.”

The Washington Administrative Code (WAC) limits motor vehicle noise and industrial and commercial noise sources in a manner similar to Oregon. Vehicle limits apply to all vehicles operating in Washington (WAC 173-62).

Industrial and commercial environmental noise regulations in Washington define three classes of property use and maximum noise levels allowed between uses (WAC 173.60). The regulations do not apply to highway or transit noise, but would apply to associated stationary noise sources such as highway construction noise at night for residential properties, park-and-ride lots and maintenance facilities. Exhibit 2-13 summarizes these environmental noise regulations. Between the hours of 10:00 p.m. and 7:00 a.m., the maximum allowable levels shown in Exhibit 2-13 are reduced by 10 dBA. The levels shown in Exhibit 2-13 may be exceeded for the time periods shown in Exhibit 2-14. Data in the two tables can be combined to express the limits in terms of statistical noise levels.

Exhibit 2-13. Washington State Noise Regulations

Noise Source (Property type)	Receiving Property Maximum Allowable Sound Level (dBA)		
	Residential	Commercial	Industrial
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

Source: WAC 173.60.

Exhibit 2-14. Noise Regulation Adjustments

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

Source: WAC 173.60.

2.5.5 Local Noise Criteria

The City of Portland and the City of Vancouver each have zoning and planning regulations that require new noise-sensitive uses constructed in certain noise-impacted areas to use noise-reducing construction techniques.

The City of Portland has restrictive noise regulations that apply to industrial and commercial noise sources. The full regulations are given in the City of Portland Municipal Code Title 18, *Noise Control*. In addition, the City regulates construction noise, and virtually all major construction projects require a noise variance. Multnomah County, Clackamas County, and the City of Portland do not have vibration regulations.

The City of Vancouver has incorporated the state regulations shown in Exhibits 2-13 and 2-14 into the Vancouver Municipal Code (VMC) Title 20, *Noise Impact Overlay District*), with the exception that the residential-to-residential maximum allowable sound level is omitted. In addition, the VMC includes prohibitions against off-site vibration impacts that are discernible without instruments at the property line and construction activity between 8 p.m. and 7 a.m. The regulations do not apply to public streets and sidewalks, rail maintenance yards, or essential public facilities such as the interstate highway system or intercity passenger rail. The VMC would apply to rail transit stops and stations and to park-and-ride lots.

2.6 Data Collection Methods

Noise and vibration monitoring was performed as part of the noise and vibration analysis. The noise data is crucial and is used to validate the traffic noise model that determines the location of noise impacts. Vibration data is used to predict the level of vibration and ground borne noise from operation of the light rail vehicles. Rubber tired vehicles, such as buses, rarely have vibration issues, and if they do is usually due to poorly maintained pavement and pot holes.

The methods and equipment used to collect the noise and vibration data is described in the following sections. Actual noise and vibration data is summarized in Chapter 4.

2.6.1 Noise Data Collection Methods

Noise monitoring was performed at 68 locations between the southern end of Hayden Island, at the boat house docks, to SR 500 in Vancouver. Of the 68 monitoring sites, eight were long-term (24 to 48 hours) and the other 60 were short-term (15 minutes) monitoring sites. The long-term sites are required for analysis of the HCT alternatives, and therefore are primarily located along potential HCT routes. The short-term sites are used for primarily for traffic noise, but are also used to support the HCT analysis.

All noise measurements were taken in accordance with the American National Standards Institute (ANSI) procedures for community noise measurements. The measurement locations were at least 5 feet from any solid structure to prevent acoustical reflections and at a height of 5 feet off the ground as required by ANSI Standards. The equipment used for noise monitoring included Bruel & Kjaer Type 2238 and Bruel & Kjaer Type 2250 Sound Level Meters. All meters were calibrated prior to, and after the measurement period using a Bruel & Kjaer Type 4231 Sound Level Calibrator. Complete system calibration is performed on an annual basis by Bruel & Kjaer Instruments. System calibration is traceable to the National Institute of Standards and Testing (NIST). All measurement systems meet or exceed the requirements for an ANSI Type 1 noise measurement system.

2.6.2 Noise Measurement Locations and Levels

On the Portland side, there were two long-term sites on the floating home docks, just west of I-5. Other long-term sites include locations on Broadway, Main Street, East McLoughlin Boulevard, and three along K Street for the I-5 HCT alternatives.

There are 6 short-term sites in the downtown Vancouver area and 32 additional short-term sites north of downtown, on the west side of I-5. There were six noise monitoring sites on the Fort Vancouver properties, and 18 additional short-tem sites north of Fort Vancouver on the east side of I-5.

Exhibit 2-15 provides a summary of the measured noise levels and Exhibits 2-16, 2-17, and 2-18 show the locations on aerial photos. Peak-hour L_{eq} is listed for all monitoring locations, however the L_{dn} is only provided for FTA Category 2 land uses along the HCT alignment alternatives. Graphs of the long-term data are in Appendix A.

Exhibit 2-15. Noise Monitoring Summary

Area	Rec#[1]	Location	Analysis Type[2]	Type[3]	Leq[4]	L_{dn}[5]
Portland	PD-2	1545 N. Jantzen, M. Tworgerer Floating home	Both	Long-term	67	69
	PD-5	1545 N. Jantzen, M. Frost Floating home	Both	Long-term	63	63
Downtown Vancouver	DT-2	5th and Washington - near I-5/SR 14 ramps	N/A	Short	66	
	DT-3	6th and Washington - Smith Tower	Both	Short	69	
	DT-4	East 7th along the side of the hotel	Traffic	Short	68	
	DT-5	316 E 7th - Normandy Apartments	Traffic	Short	75	
	DT-6	401 E 13th St. - Shilo Inn Hotel	Traffic	Short	63	
	DT-7	500 E 13th - Fort Apartments	Traffic	Short	63	
West side of I-5, north of East 15th	VW-1	514 E 15th St.	Traffic	Short	65	
	VW-3	1601 E G St	Both	Short	65	64
	VW-4	615 E 17th St	Both	Short	65	64
	VW-6	701 E McLoughlin	Both	Short	67	66
	VW-7	704 E McLaughlin	Both	Short	66	65
	VW-8	1908 Reserve St	Traffic	Short	72	
	VW-9	1914 E H St	Traffic	Short	59	
	VW-10	1931 E H St	Traffic	Short	58	
	VW-12	2205 E H St.	Traffic	Short	57	
	VW-13	810 E I St	Traffic	Short	63	
	VW-14	2400 E H St	Traffic	Short	58	
	VW-15	904 E 26th St	Traffic	Short	65	
	VW-16	804 E 26th St	Traffic	Short	61	
	VW-17	900 E 27th	Traffic	Short	60	
	VW-18	815 E 27th St	Traffic	Short	59	
	VW-19	2714 E H St	Traffic	Short	57	
	VW-20	901 E 29th St	Traffic	Short	65	
	VW-21	814 E 30th St	Traffic	Short	59	
	VW-22	903 E 31st St	Traffic	Short	69	
	VW-23	615 E 31st St	Traffic	Short	53	
	VW-24	3114 E H St	Traffic	Short	53	
	VW-25	3200 E I St	Traffic	Short	59	
	VW-26	904 E 33rd St	Traffic	Short	67	
	VW-27	3306 E I St	Traffic	Short	58	
	VW-28	901 E 34th St	Traffic	Short	60	
	VW-29	3413 E H St	Traffic	Short	58	
	VW-30	811 E 36th St	Traffic	Short	57	
	VW-31	3615 E H St	Traffic	Short	53	
	VW-32	701 E I St	Traffic	Short	63	
	VW-33	3801 E H St	Traffic	Short	57	
	VW-35	3915 E I St	Traffic	Short	66	
	VW-36	Discovery Middle School: East parking area	Traffic	Short	74	
	VW-39	415 E McLaughlin	HCT	Long-term	63	62
	VW-43	2217 E Broadway	HCT	Long-term	64	64
	VW-48	3001 Main St	HCT	Long-term	69	69

Area	Rec#[1]	Location	Analysis Type[2]	Type[3]	Leq[4]	L_{dn}[5]
	VW-54	Covington Court Apartments	HCT	Long-term	71	71
Fort Vancouver Area	FV-2	Historic Tree - park area	Traffic	Short	67	
	FV-4	Park area near parking and buildings	Traffic	Short	66	
	FV-6	FHWA grass area near entrance	Traffic	Short	69	
	FV-12	Ft Vancouver Hospital - along the side	Traffic	Short	67	
	FV-14	Near intersection of McClellan and Barnes	Traffic	Short	69	
	FV-16	Officers ROW	Traffic	Short	70	
East side of I-5, north of Mill Plain	VE-1	Clark College Play field	Both	Short	61	61
	VE-2	VA Medical	Both	Short	58	57
	VE-3	VA Cemetery - near I-5	Both	Short	69	71
	VE-4	2600 K St	Both	Long-term	72	75
	VE-5	2615 K St	Both	Short	63	65
	VE-6	1111 E 28th St	Both	Short	57	57
	VE-7	2816 E K St	Both	Short	69	71
	VE-8	2914 E K St	Both	Long-term	69	72
	VE-9	1109 E 30th	Both	Short	57	57
	VE-10	3014 E K St	Both	Short	65	66
	VE-11	1104 E 32nd St	Both	Short	59	59
	VE-12	3200 E K St	Both	Short	65	66
	VE-13	United Pentecostal Church	Both	Short	64	65
	VE-14	3335 E K St	Both	Short	54	53
	VE-15	3503 E K St	Both	Short	61	61
	VE-16	3611 E K St	Both	Long-term	69	70
	VE-17	3608 L St	Both	Short	61	64
	VE-18	3708 L St	Both	Short	65	66

Notes
1. Noise modeling number
2. Measurements for traffic, HCT or both
3. Long-term (24+ hours) or short-term (15-20 minutes) measurement period
4. Peak traffic hour Leq noise levels
5. 24-hour Ldn noise level

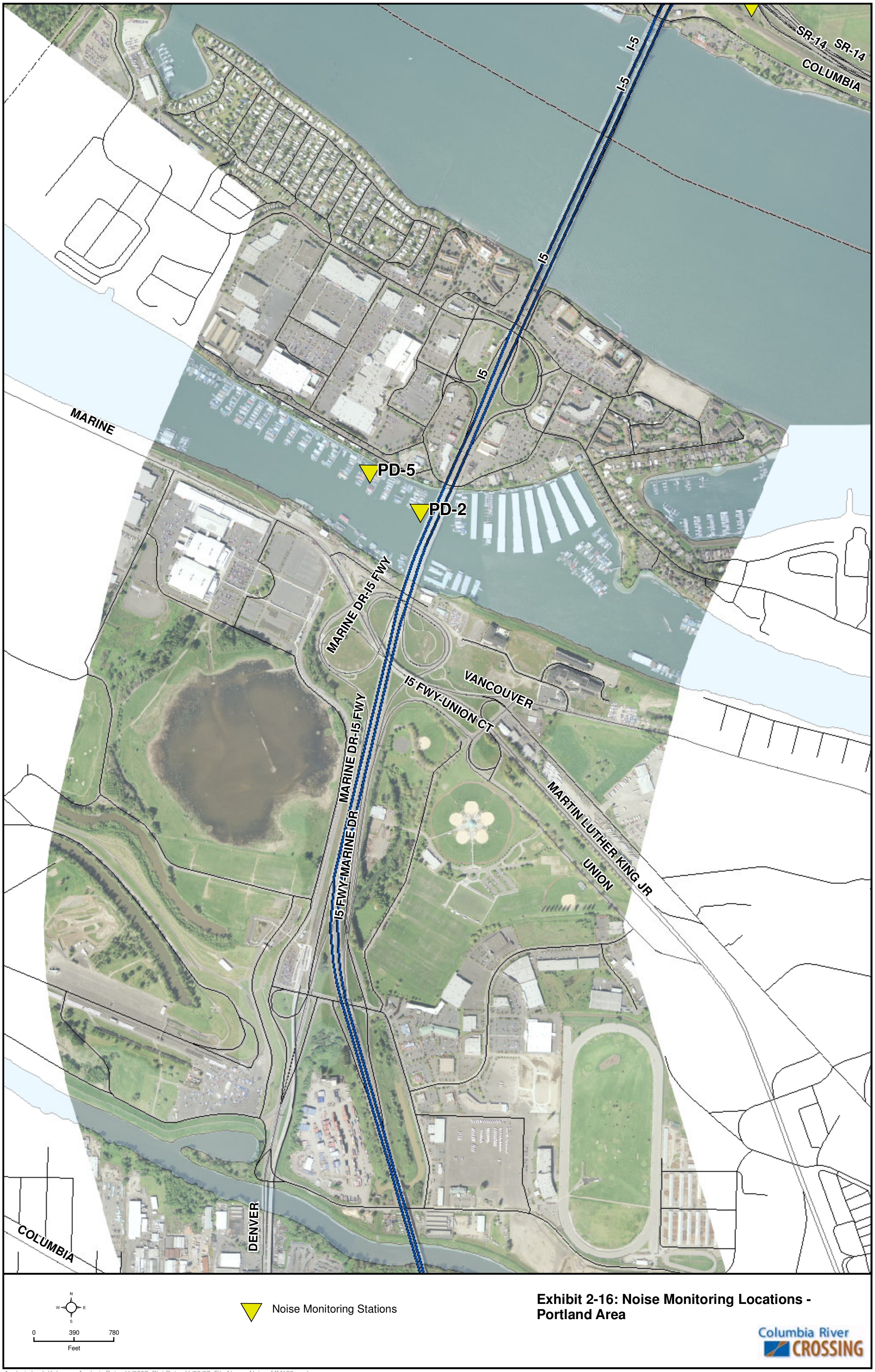


Exhibit 2-16: Noise Monitoring Locations - Portland Area

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/2907; Plot Date: 11/29/07; File Name: Noise_MM133.mxd

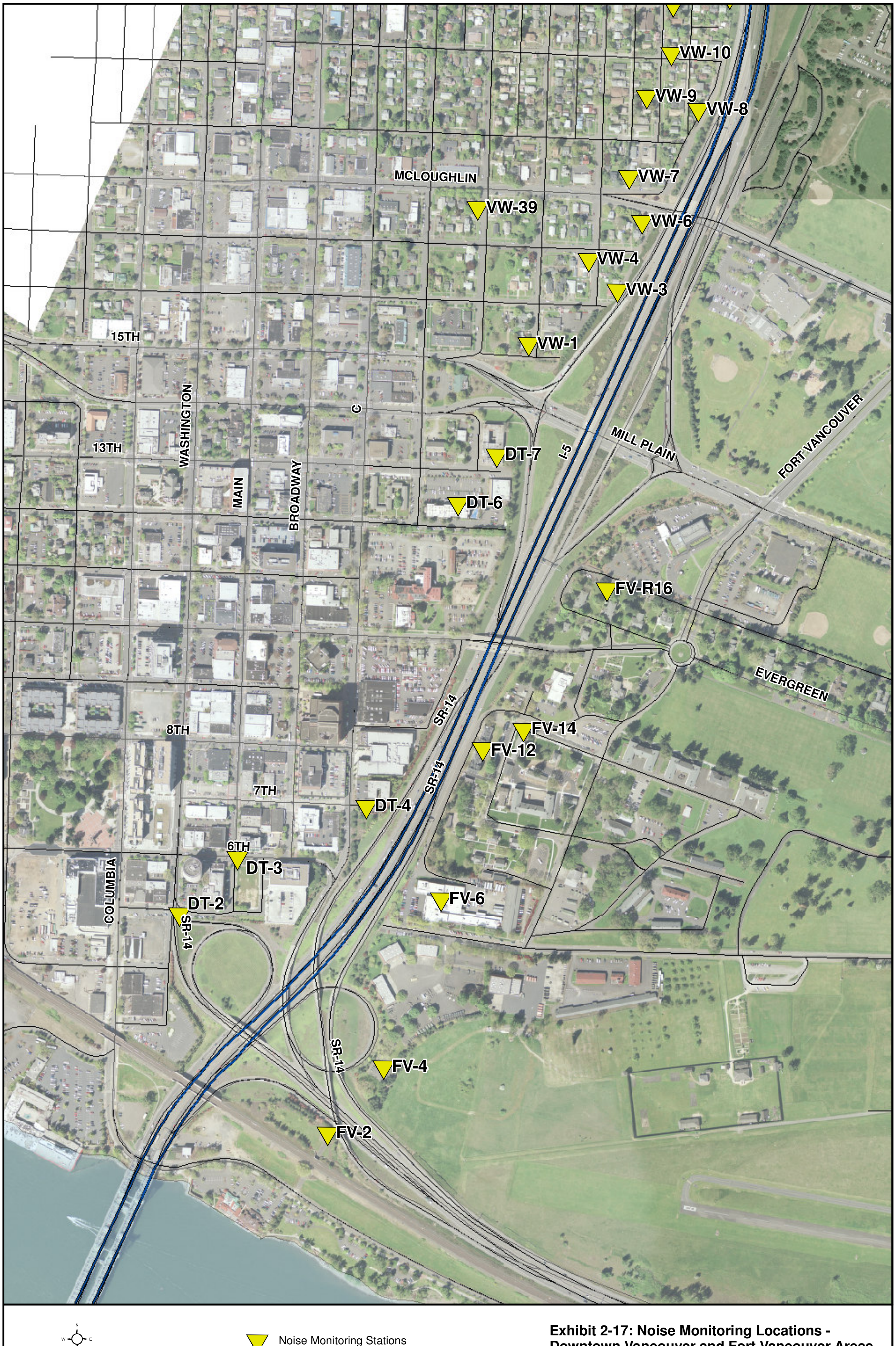
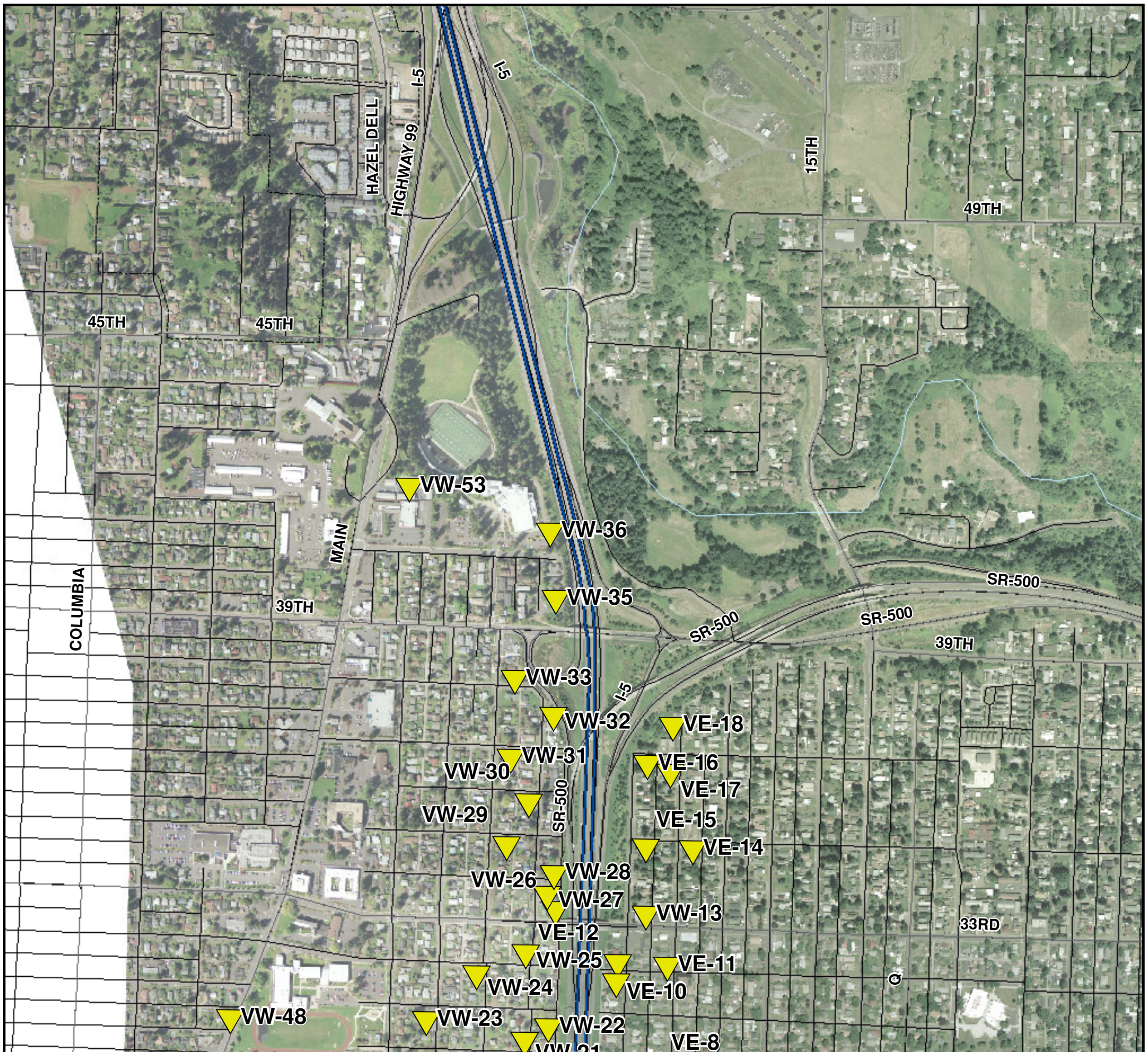


Exhibit 2-17: Noise Monitoring Locations - Downtown Vancouver and Fort Vancouver Areas

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/2907; Plot Date: 11/29/07; File Name: Noise_MM133.mxd



N
W E
S
0 325 650
Feet

Noise Monitoring Stations

Exhibit 2-18: Noise Monitoring Locations - North Vancouver

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/2907; Plot Date: 11/29/07; File Name: Noise_MM133.mxd

Noise levels in the project corridor ranged from 53 to 75 dBA Leq, with 24-hour L_{dn} noise levels ranging from 57 to 75 dBA. In the Portland area, noise levels at the residential floating home docks ranged from 63 to 67 dBA, with the louder noise levels at docks nearest to I-5. Noise levels in downtown Vancouver Washington ranged from 63 to 75 dBA Leq, with the 75 dBA level near the SR 14 and I-5 ramps.

Noise levels in the Fort Vancouver area ranged from 66 to 70 dBA L_{eq}. North of the Fort, within the Clark College and VA Medical Center Campus, measured peak-hour L_{eq} noise levels ranged from 58 to 61, with 24-hour L_{dn} noise levels of 57 to 61 dBA.

The residential areas in North Vancouver have noise levels ranging from 53 to 74 dBA L_{eq}. The highest noise levels were recorded at locations near openings in noise walls or in areas with no noise walls, where noise levels typically ranged from 67 to 75 dBA L_{eq}. Second and third line receivers with shielding from I-5 have noise levels that ranged from 53 to 62 dBA L_{eq}.

2.6.2.1 Noise Model Validation

Existing traffic noise levels were also modeled, as previously described, to test the agreement of calculated and measured noise levels. Traffic volumes and speeds as observed during the noise monitoring were used as input to the model. Speed measurements were made using a Stalker II Radar Gun, with typical speeds ranging from 55 to 62 MPH. Traffic counts used for validation are given in Exhibit 2-19.

Exhibit 2-19. Traffic Counts for I-5

Northbound I-5						Hourly Equivalent Counts[1]		
#	Start Time	End Time	Cars[2]	MT[3]	HT[4]	Cars[2]	MT[3]	HT[4]
1	1:30	1:45	1028	25	66	4112	100	264
2	2:16	2:31	1210	31	57	4840	124	228
3	2:51	3:06	1278	16	61	5112	64	244
4	3:13	3:28	1311	30	52	5244	120	208
5	3:38	3:53	1322	16	59	5288	64	236
Southbound I-5						**Hourly Equivalent Counts[1]**		
#	**Start Time**	**End Time**	**Cars[2]**	**MT[3]**	**HT[4]**	**Cars[2]**	**MT[3]**	**HT[4]**
1	1:51	2:06	853	22	80	3412	88	320
2	2:16	2:31	847	28	73	3388	112	292
3	2:51	3:06	824	33	61	3296	132	244
4	3:13	3:28	879	19	83	3516	76	332
5	3:38	3:53	957	24	63	3828	96	252

Notes:
1. Traffic counts normalized to a 1-hour count
2. Cars = normal passenger vehicles, van, and small trucks
3. MT= Medium trucks; includes vehicles with two axels and more than for tires, such as delivery vans for UPS, DHL or FedEx
4. HT= Heavy trucks and buses; includes trucks with more than 2 axels, such as dump trucks and long haul tractor trailers

After careful review of the noise monitoring field notes, it was determined that 45 of the 68 noise monitoring locations had noise levels that were dominated by either I-5 traffic or nearby main arterials and qualified as acceptable noise model validation sites. Exhibit 2-20 provides the results of the noise model validation.

Exhibit 2-20. Noise Model Validation Results

Receiver #	Modeled[1]	Measured[2]	Modeled – Measured[3]
PD-5	63.9	63.0	0.1
PD-2	68.7	67.0	-2.3
DT-2	65.1	66.0	1.2
DT-4	68.2	68.1	-0.6
DT-5	72.8	75.1	0.4
DT-6	64.6	63.4	-1.9
VW-1	64.7	65.3	-2.6
VW-3	65.1	64.7	1.4
VW-6	65.5	67.4	1.1
VW-7	63.6	66.2	-1.4
VW-10	59.7	58.3	-1.9
VW-12	58.1	57.0	2.4
VW-13	61.3	62.7	0.8
VW-14	55.8	57.7	1.6
VW-15	67.4	65.0	1.2
VW-16	62.1	61.3	-0.4
VW-17	61.8	60.2	2.3
VW-18	60.2	59.0	-1.9
VW-19	57.0	57.4	0.7
VW-21	61.0	58.7	-1.5
VW-22	66.8	68.7	0.1
VW-25	60.1	59.4	2.1
VW-26	65.9	67.4	1.7
VW-29	58.2	58.1	-0.5
VW-32	64.9	62.8	-2.2
VW-35	67.9	66.2	2.0
VW-36	73.1	73.6	2.2
FV-4	63.8	66.0	0.5
FV-12	69.3	67.3	-1.3
FV-14	71.4	69.2	0.1
VE-1	61.3	60.8	1.4
VE-2	56.5	57.8	0.9
VE-3	69.4	69.3	-2.3
VE-4	73.4	72.0	-1.9
VE-6	57.7	56.8	-0.8
VE-8	66.7	69.0	-2.2
VE-9	55.3	57.2	0.1
VE-10	64.0	64.8	-2.3
VE-11	57.0	59.2	1.2

Receiver #	Modeled[1]	Measured[2]	Modeled – Measured[3]
VE-12	64.3	64.7	-0.4
VE-13	62.8	64.1	-1.3
VE-14	56.3	54.3	2.0
VE-15	60.8	61.2	-0.4
VE-17	62.4	61.4	1.0
VE-18	65.1	65.3	-0.2

Notes:
1. Modeled noise levels from TNM in dBA-L_{eq}
2. Measured noise levels in dBA-L_{eq}
3. Difference, modeled minus measured in dBA-L_{eq}

The modeled and measured noise results for virtually all receivers agree within 2 dBA. An agreement of +/- 2 dBA or less is considered acceptable for modeled and measured noise level deviations. For the nine locations that did not meet the +/- 2 dBA, only one was off by 0.6 dBA while the rest were all within 0.4 dBA of the +/- 2 dBA level, and the slight differences were due to building shielding, local area traffic, aircraft over-flights, and other miscellaneous noise reducing or shielding sources.

2.6.3 Light Rail Noise Levels

Noise impact from light rail operations is a function of the speed and length of the light rail vehicle trains, the type of track, the number of trains in the daytime and nighttime hours, and the distance that the tracks are from sensitive receptors. In areas where the trains would operate in a right of way shared with vehicular traffic, noise from warning horns and bells used to warn the public of approaching trains are only used if there is a potential for an accident or if pedestrians or vehicles are too close to the tracks. For this assessment, it is assumed that audible warning signals would not be used before every street/rail at-grade crossing. This methodology is consistent with the current operation of the Portland Light Rail alignments.

Steel wheels rolling on steel rails are usually the major source of noise from light rail vehicles, although the motor ventilation system will sometimes be a noticeable noise source at specific frequencies. Because the noise from light rail vehicles originates near the ground, substantial noise mitigation can be achieved with relatively low sound walls near the tracks. For example, on elevated structures, where sound walls can be located within a few feet of the transit vehicles, walls that are 3.5 to 4 ft high are very effective at controlling wayside noise.

The following approach was used to develop the projections of impact and the recommended mitigation measures for light rail vehicle operations:

1. Existing noise levels in the community were measured. The results of the noise survey are summarized in Section 2.6.2.

2. A model of the noise levels that would be generated by Portland Light Rail system was developed and used for this project. The model is based on equations provided in the Federal Transit Administration (FTA) manual *Transit Noise and*

Vibration Impact Assessment, *May 2006*. The reference noise levels for the projections, summarized in Exhibit 2-21, are based on measured noise levels generated by the newer light rail vehicles used on the Portland TriMet system. These vehicles have panels covering the wheel openings, commonly referred to as wheel skirts, which reduce the noise levels compared to normal light rail vehicles.

Exhibit 2-21. Light Rail Vehicle Noise Reference Levels

Reference sound level:	78 dBA
Conditions	
Speed: 50 mph	
Length: two vehicles	
Distance from Track Centerline: 50 ft	
Track Type: Tie and Ballast	

3. The sensitive receptors along each alternative were grouped into clusters of one to fifteen buildings that are close together and would be approximately the same distance from the tracks, and would therefore experience the same noise exposure. The conditions surrounding the clusters, such as train speed and track type, are also the same for all receptors within a given cluster.

4. Noise exposure projections were developed for each receptor cluster. The projections incorporate train speed, expected number and length of trains during the day (7 a.m. to 10 p.m.) and nighttime (10 p.m. to 7 a.m.) hours, and distance of the receptors to the tracks. The schedules used for noise projections assume:

    a. Replacement: Peak hour (7:00 am to 7:00 pm) headways of 7.5 minutes, off-peak headways of 15 minutes (7:00 pm to 2:00 am)

    b. Supplemental: Peak hour (7:00 am to 7:00 pm) headways of 6 minutes, off-peak headways of 15 minutes (7:00 pm to 2:00 am)

5. The projections also include adjustments based on the track type as summarized in Exhibit 2-22.

6. Graphical representations of projected L_{dn} and L_{max} vs. distance assuming a train speed of 50 mph are shown in Exhibit 2-23.

Exhibit 2-22. Track Type Adjustments for Noise Level Projections

Track Type	Adjustment in dB
At-grade Ballast and Tie Track, Ballast Exposed	0
Elevated Structure	+3
Embedded Track	+3
Retained Cut	-6
At-Grade Station	0
Cross Over	+10
Source: FTA Transit Noise and Vibration Manual	

Exhibit 2-23. Predicted LRT Noise Levels

The noise projections in Exhibit 2-23 were compared to the impact thresholds of the FTA criteria shown in Exhibit 2-5. As shown in Exhibit 2-5, the horizontal scale is the Existing L_{dn}, which was estimated for each cluster from the noise survey results, and the vertical scale is the L_{dn} caused by the project. Exhibit 2-5 shows that if the existing L_{dn} is 65 dBA, there is:

1. No impact as long as the project L_{dn} is less than 62 dBA.
2. Moderate impact if the project L_{dn} will be between 62 and 67 dBA. FTA requires that mitigation be evaluated for all areas where moderate impacts are projected, although factors such as cost effectiveness can be incorporated into the decision about whether to specify mitigation for a particular area.
3. Severe impact if the project L_{dn} exceeds 66 dBA. FTA considers severe impact to be a “significant adverse effect” in the context of the NEPA. Noise impacts in the severe range represent the most compelling need for mitigation.

Noise mitigation options were evaluated for all locations where the projected levels of noise exposure exceed either of the FTA noise impact thresholds. The noise mitigation measures for the various alternatives are discussed in Section 8.

2.6.4 Bus Rapid Transit Noise Levels

Noise impact from bus rapid transit (BRT) operations is a function of the type of bus, speed and the number of buses in the daytime and nighttime hours, and the distance between the BRT way and sensitive receptors. Noise from BRT systems comes from tire roadway contact and engine noise. For hybrid electric buses, noise would be generated by the engine only during times the engine was active.

The following approach was used to develop the projections of impact and the recommended mitigation measures:

1. Existing noise levels in the community were measured and are summarized in Section 2.6.2.

2. A model was developed of the noise levels that would be generated by diesel and hybrid buses

Exhibit 2-24. BRT Vehicle Noise Reference Levels

	Diesel Bus	Hybrid Bus
Reference sound level:	84 dBA	78 dBA
Speed:	50 mph	50 mph
Distance from Track Centerline:	50 ft	50 ft

3. Sensitive receptors along each alternative were grouped into clusters that are close together and would have approximately the same noise levels

4. Noise exposure projections were developed for each receptor cluster. The projections incorporate the number and speed BRT during the daytime (7 a.m. to 10 p.m.) and nighttime (10 p.m. to 7 a.m.) hours. The BRT schedules used for the noise projections assumes:

    a. Full Replacement: Peak hour headways of 2.6 minutes, off-peak headways of 3.5 minutes

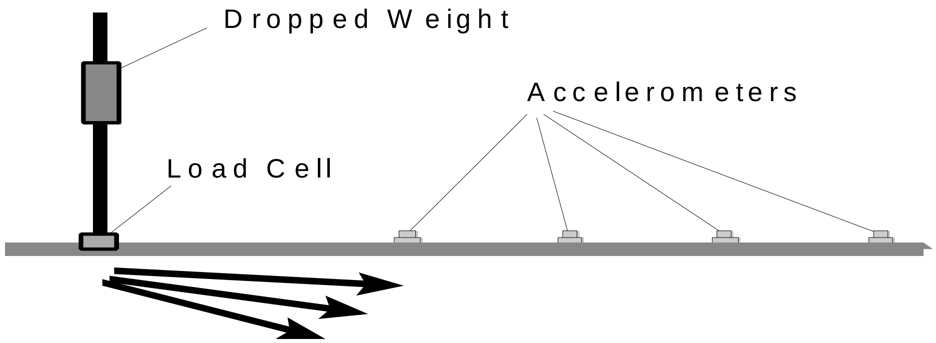
    b. Supplemental Bridge: Peak hour headways of 1.5 minutes, off-peak headways of 2.5 minutes

2.6.5 Vibration Data Collection

An important factor in projecting levels of vibration related to transit operations is the rate at which the vibration reduces as it propagates away from the source. The relationship between a vibration source, and the level of ground vibration at a specific distance from the source, is known as the transfer mobility. To properly determine the transfer mobility, vibration propagation measurements must be conducted. The test consists of dropping a heavy weight on the ground and measuring the vibration levels at several different distances from the location of the dropped weight. A load cell is used to measure the force input to the ground and vibration transducers called accelerometers are used to measure the vibration pulses at various distances from the dropped weight.

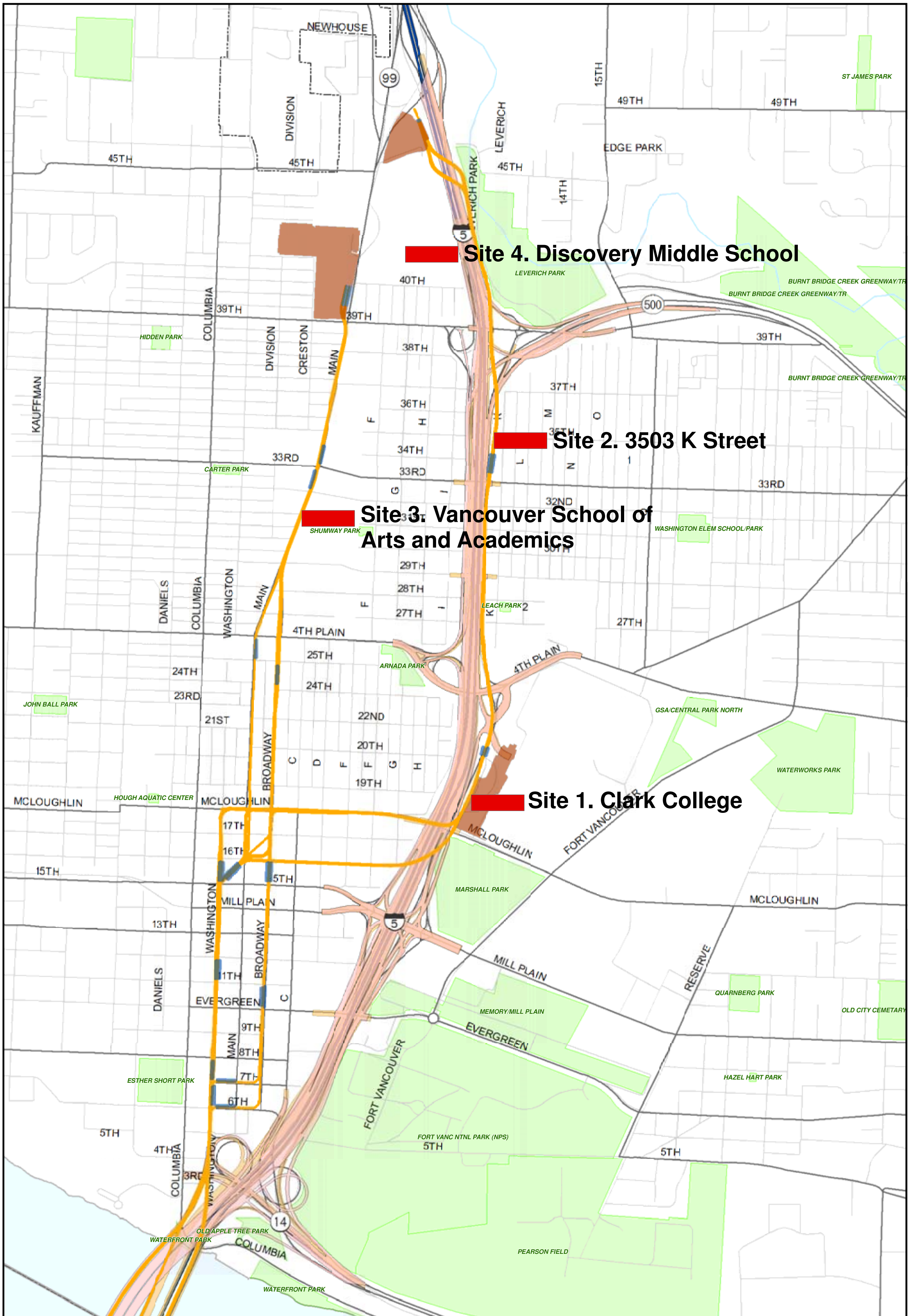
Exhibit 2-25 is a schematic of the test procedure. The vibration levels produced by the test are rather low, and rarely even noticed by nearby residences, but are sufficient to provide the information necessary for the analysis.

Exhibit 2-25. Vibration Propagation Testing Methods



2.6.5.1 Vibration Measurement Locations

Vibration propagation testing was performed at four locations in Vancouver near the proposed HCT alignment alternatives. Site 1 was near Clark College, site 2 was on K Street, site 3 was on Main Street on the school track field, and site 4 was along the edge of the Discovery Middle School's soccer field. The four measurement sites are shown on Exhibit 2-26. Details on the results of the vibration testing are given in Appendix B.



Vibration Propagation Test Sites
Downstream Replacement
Supplemental Alternative
Park and Ride
Transit Stop
Transit Lines

Exhibit 2-26: Vibration Propagation Test Sites

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/29/0707; Plot Date: 11/29/07; File Name: Ex2_26_MM133.mxd

The vibration propagation experiments were conducted at the edge of Clark College by the I-5 highway. Three accelerometers and three geophones were placed 25 ft, 50 ft, 75 ft, 100 ft, 150 ft, and 200 ft from the center of the impact line. The accelerometers (or sensors) were placed along a vector that is perpendicular to the line of impact. One sensor was placed on the asphalt while the other five sensors were placed on the field. The weights were dropped across eleven different locations each 15 ft apart. The measurements were conducted the morning of July 11th, 2007.

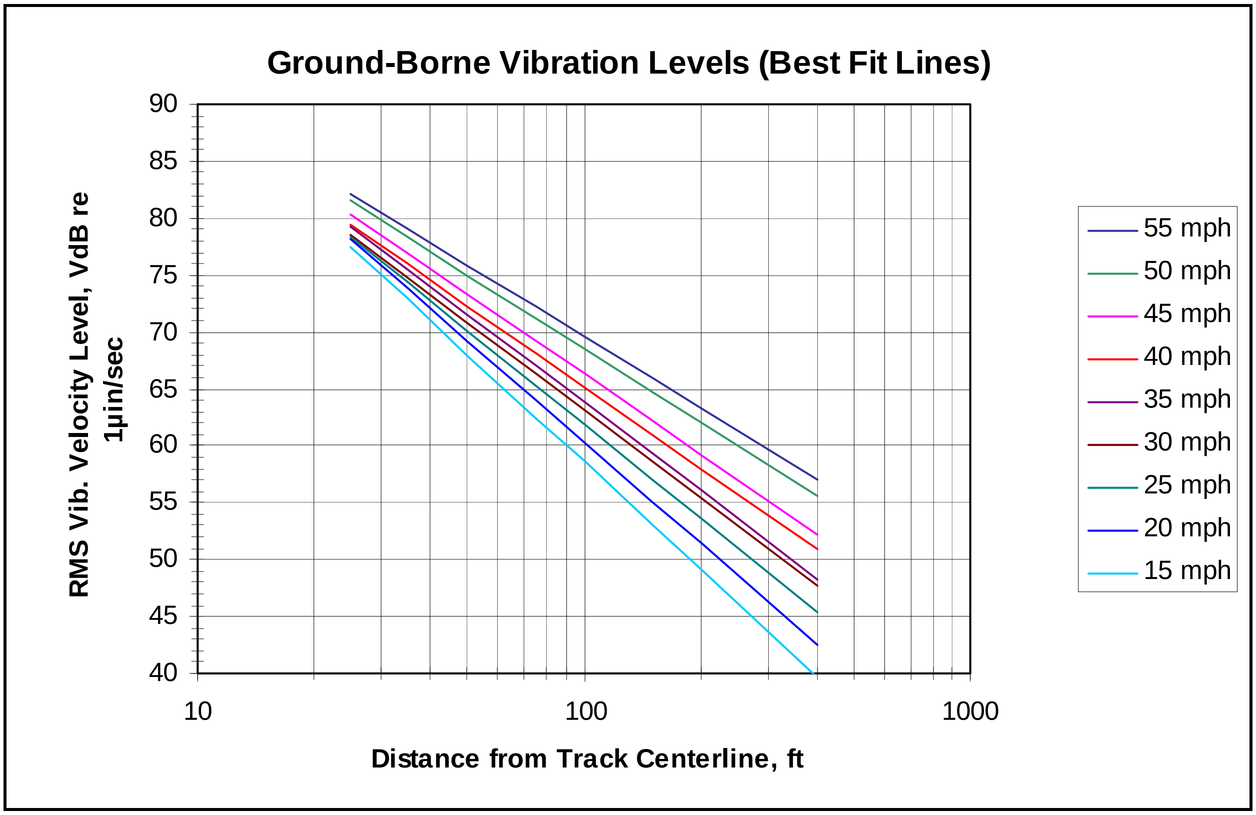
The vibration measurements were taken at the intersection of K Street and E 35th Street. Four accelerometers and two geophones were placed at 25 ft, 50 ft, 75 ft, 100 ft, 150 ft, and 200 ft from the center of the impact line down E 35th Street. The impacts were taken along K Street at eleven different locations each 15 ft apart. One accelerometer was placed on asphalt while the other five sensors were placed along a trail of dirt alongside E 35th Street. The impacts were all conducted on asphalt. The measurement was conducted in the morning of July 10th, 2007.

Vibration measurements were taken along the Vancouver School of Arts and Academics track and field area. As with other sites, four accelerometers and two geophones were placed in a line 25 ft, 50 ft, 75 ft, 100 ft, 150 ft, and 200 ft from the center of the line of impact. One accelerometer and one geophone were mounted to the black tar-like surface between the track and the field. The other sensors were placed in the field. The impacts were conducted on the track again at 11 different locations each spaced 15 ft apart from each other. These measurements were conducted in the afternoon of July 10th, 2007.

Measurements were taken along the edge of the Discovery Middle School’s soccer field. Four accelerometers and two geophones were placed in a linear array at 20 ft, 50 ft, 75 ft, 100 ft, 150 ft, and 200 ft distances from the center of the line of impact. The sensors were placed such that they led into the soccer field while the impacts were conducted along the sidelines. Again, impacts were taken at eleven impact locations each 15 ft apart. Both sensors and impacts were placed in the field during the measurement. These experiments were conducted in the afternoon of July 11th, 2007.

Exhibit 2-27 provides a summary of the result of the vibration testing and predicted propagation curves for the Portland Light Rail Vehicles. Complete details are given in Appendix G.

Exhibit 2-27. Vibration Propagation Test Results



2.7 Analysis Methods

This chapter summarizes the analysis methods for the traffic noise, HCT noise and light rail noise and vibration.

2.7.1 Traffic Noise Criteria

In Oregon, a noise impact occurs if the noise levels during the design-year peak noise hour meet or exceed the noise impact criteria listed in Exhibit 2-10 (based on land use), or if noise levels increase by 10 dBA or more over existing noise levels during the peak noise hour. In Washington, a noise impact occurs if design year noise levels during the peak noise hour exceed the noise impact criteria listed in Exhibit 2-11 (based on land use), or if noise levels increase by 10 dBA or more over existing noise levels during the peak noise hour.

2.7.2 Transit Noise Impact Criteria

The FTA criteria include two levels of impacts, as shown in Exhibit 2-5. These criteria differentiate between impacts and severe impacts as follows:

Impacts: This level is sometimes referred to as moderate impact. In this range, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These other factors can include the predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing building sound insulation, and the cost-effectiveness of mitigating noise to more acceptable levels.

Severe impacts: Severe noise impacts are considered "significant," as this term is used in the National Environmental Policy Act (NEPA) and implementing regulations. Noise mitigation will normally be specified for severe impact areas unless there is no practical method of mitigating the noise.

Transit impacts are evaluated using existing noise levels, plus the noise levels projected for the maximum transit activity scenario. As existing noise levels increase, the allowable incremental increase in the overall noise levels decreases (Exhibit 2-5).

2.7.3 Transit Vibration Impact Criteria

Transit vibration impacts occur if predicted vibration levels for the transit project alone exceed the levels in Exhibits 2-8 and 2-9 (depending on land use). Because vibration events are typically discrete, and the maximum vibration levels cause annoyance, background levels are not added to project levels. In addition to the levels shown in Exhibits 2-8 and 2-9, vibration impacts can occur at lower levels if a specific use is highly vibration-sensitive. This could occur with specialized equipment, such as an MRI machine in a medical office or specialized laboratory equipment.

2.7.4 Long-Term Operational Impacts Approach

2.7.4.1 Traffic Noise

Long-term operational impacts were evaluated through a three-dimensional modeling analysis using the FHWA Traffic Noise Model (TNM), Version 2.5. The predicted noise levels for each alternative were compared to the ODOT or WSDOT absolute noise impact criteria and the 10-dBA relative increase over existing criterion. Noise levels were predicted at discrete locations. Traffic noise levels are affected by vehicle classification mix and vehicle speed. Roadways in the project area are potentially expected to experience congested conditions over substantial periods of the day. Because lower traffic speeds associated with congestion conditions equate to lower noise levels, the peak traffic hours are generally not the same as peak noise impact hours. All long-term operation impacts are assessed using the peak noise impact hour which approximates the worst-case traffic noise hour.

2.7.4.2 Transit Noise

The transit noise analysis for the project alternatives follows the FTA's Detailed Noise Analysis methodology. This methodology provides a comprehensive assessment of project noise impacts commensurate with the level of design detail available. For bus transit/highway transit projects, the FTA guidance recommends following the FHWA methodology and, therefore, TNM was used for this analysis. Bus transit centers or other bus transit/highway transit stationary sources were analyzed following the FTA's Detailed Assessment methodology. The methodology is described in Section 2.6.3

2.7.4.3 Transit Vibration

The transit vibration analysis for this analysis follows the FTA's General Vibration Assessment methodology. This methodology provides a comprehensive assessment of project vibration and ground-borne noise impacts. The project vibration propagation levels are given in Section 2.6.5.

2.7.4.4 Short-Term Construction Impacts Approach

Potential noise and vibration construction impacts were addressed qualitatively. A general comparison of the relative potential impact of the alternatives were based on factors such as expected construction duration, general types of construction activity, extent of construction area, and potential for traffic rerouting.

2.7.4.5 Mitigation Measures Approach

The criteria used by FHWA and FTA to evaluate whether mitigation measures will be included in a project are discussed in the following sections. A discussion of potential changes to mitigation effectiveness between preliminary engineering and final project design, and the potential to affect the design or inclusion of mitigation, are also included.

The mitigation analysis for traffic noise impacts follows ODOT and WSDOT policy and procedures. A range of potential mitigation measures are discussed. Where appropriate, preliminary noise barrier placements are analyzed. The effectiveness and cost-effectiveness of noise barriers are evaluated following ODOT and WSDOT guidance.

Fixed guideway and stationary transit noise source mitigation is discussed generally. Noise barrier methods, as well as building insulation methods, are also discussed. Preliminary noise barrier locations are identified.

For both highway and transit sources, a discussion of sensitive receivers or areas not qualifying for mitigation are included. An explanation of the reasons these areas are not recommended for mitigation is provided.

Vibration mitigation measures are discussed generally. The focus of the discussion is on the general types of mitigation that are appropriate at impacted locations and typical reductions for various mitigation measures. Typical construction noise mitigation measures and mitigation required by local permitting and variance processes are discussed.

2.7.5 Summary of Applicable Regulations and Data Needs

Exhibit 2-28 provides a tabulated summary of the noise and vibration sources and the appropriate criteria used in this analysis.

Exhibit 2-28. Summary of Applicable Regulations and Information Sources

Regulation	Citation	Trigger(s)	Information Sources Used
Procedures for Abatement of Highway Traffic Noise and Construction Noise	23 CFR 772, ODOT Noise Manual, and WSDOT Noise Abatement Policy and Procedures	Noise levels from a roadway with significantly modified horizontal or vertical alignment or the addition of through travel lanes require analysis and consideration of abatement.	Traffic volumes for each affected roadway link with vehicle classification splits. Preliminary design drawings for each alternative including existing and future ground elevations for nearby noise receivers and areas between alternative alignment and receivers. Locations of traffic control devices. Measured existing noise levels. Future posted speeds for links. Direct measurement of noise levels and concurrent traffic counts are needed to calibrate the prediction model.
Procedures for Abatement of Highway Traffic Noise and Construction Noise	23 CFR 772	Evaluate and discuss construction noise and vibration impacts.	Information on expected construction duration and staging, typical types and numbers of construction equipment, information on traffic rerouting during construction.
Transit Noise and Vibration Impact Assessment, Final Report	FTA guidance for evaluation of noise and vibration impacts	Noise and vibration analysis is required for projects with capital assistance from the FTA with the potential for noise and vibration impacts.	For fixed guide way projects: hourly operational schedules, station locations, speed profiles, plan and profile of guideways, ground elevations for nearby receivers and areas between alignments and receivers, locations and types of supporting facilities. For bus transit/highway transit projects the data shown for highway noise analysis is needed, plus the location of transit stations, the hourly number of vehicles using the facility (day and night), and speeds on internal roadways. Direct measurement of 24-hour noise levels, existing vibration levels, and ground vibration transmission characteristics are needed.

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3. Coordination

The noise and vibration discipline team worked directly with federal, state, and local agencies and community groups. The team coordinated with FHWA, FTA, WSDOT, ODOT, David Evans & Associates, and Parametrix. The team also attended several meetings with land use planners associated with the project for additional information on neighborhoods which was used to select the noise monitoring and modeling locations.

Noise analysts coordinated with Mia Waters and Karin Landsberg, of WSDOT's Air Quality, Acoustics, and Energy Program for information related to the methods required for a noise study in the state of Washington. The team also contacted and has worked with David Goodwin, ODOT's Senior Acoustical Specialist. The project team and the public identified noise-sensitive land uses and to determined an acceptable method of analyzing the many noise sensitive receivers within the project corridor to ensure that any required noise mitigation would be considered.

The project team provided the following information:

- Project design drawings – details on the project alignment and profiles.
- Relocations – information about any potential displacement of public facilities, residents, or commercial uses.
- Land use – details on existing project area land use, including noise sensitive receivers such as residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, auditoriums, and offices. The project team also conducted research to identify where any substantial change in land use might be expected.
- Transportation – details on traffic data, including volumes, speeds and vehicle types for all major roadways within the project corridor.
- Recreation and Section 4(f)/Section 6(f) resources – coordination with project team about potential noise effects on parks and historic properties and met with personnel from Fort Vancouver several times and took a tour of the property.
- Schools along the corridor – outdoor uses at their properties.
- Wildlife impacts – worked closely with the project team on issues related to noise from pile driving, general construction noise and operational noise that may impact local wildlife.

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4. Affected Environment

4.1 Introduction

This section provides a description of land uses and a summary of the existing condition noise levels. Existing peak noise hour predictions were performed using existing (2006) traffic volumes and the posted speed limits. The noise levels projections were performed using the FHWA Traffic Noise Model – TNM - version 2.5.

4.2 Area of Potential Impact

For transit projects the FTA sets the area of potential impact at 350 feet. ODOT does not specify a distance, but requires that any noise sensitive land use that may have an increase or reduction in noise be considered in the analysis. For traffic noise studies in Washington State, the analysis is required to consider all sensitive land uses within 500 feet of the project right-of-way.

4.3 Land Use

The noise impact criterion levels for noise studies depends on the existing land use or planned and permitted future land use. For example, if an area is zoned for commercial land use, but there are residential units in the area, the noise study evaluates the residences as residential land use. While land use zoning maps are used to determine the general boundaries of various land uses, the project corridor was reviewed thoroughly to determine the actual land uses to ensure the appropriate noise impact criterion levels were established for each of the individual properties.

This section provides a summary of the land uses based on FHWA and FTA criteria.

4.3.1 Portland Land Use

Land use in Portland (Segment A1 Delta Park to South Downtown) includes residential and commercial. Most of the land uses near the highway or HCT alignments are commercial and retail. There is a large group of floating homes located along the southern edge of Hayden Island, on both sides of I-5. Other residential land uses near the project area include the Red Lion Jantzen Beach Hotel, the Oxford Suites, and the Courtyard by Marriott. There is also a large group of single and multi family residential units east of I-5 along N. Hayden Drive and N. Tomahawk Drive, and a large manufactured home park and the Jantzen Beach RV Park located west of I-5.

4.3.2 Downtown Vancouver Land Use

Land use in Downtown Vancouver (A2. Delta Park to South Downtown Segment) includes residential, hotels, parks and commercial. On the east side of I-5, along SR 14 is the Waterfront Park, Old Apple Tree Park and a new foot bridge from Fort Vancouver to the Waterfront Park. On the east side of I-5 along the waterfront is a restaurant and the Red Lion at the Quay hotel. The portion of the hotel nearest to I-5 is a restaurant and bar, and all the rooms are located in the western side of the building, with most rooms well shielded from I-5 noise.

The core of downtown Vancouver has both commercial and residential land uses. There are condominiums and apartments along Washington and Columbia Streets, and the Smith Tower at the intersection of Washington Street and West Sixth Street. There are also hotels and apartments along the western side of I-5 between East Sixth Street and E. 15th Street.

4.3.3 North Vancouver Land Use

Land use in northern Vancouver is primarily residential along both sides of I-5. Single family homes occupy most of the areas on the west side of I-5 from East 15th Street north to SR 500 and on the east side from E. Fourth Plain Boulevard north to SR 500. There are several single family residential houses that were converted to commercial and office type use along Broadway Street and McLoughlin Boulevard.

Land use along the HCT routes along Main Street include residential, school, hotels, and commercial and retail use. Most residential land uses are located between 27th and 35th Streets. Exhibits 4-1, 4-2 and 4-3 provide aerial views with sensitive land uses identified.

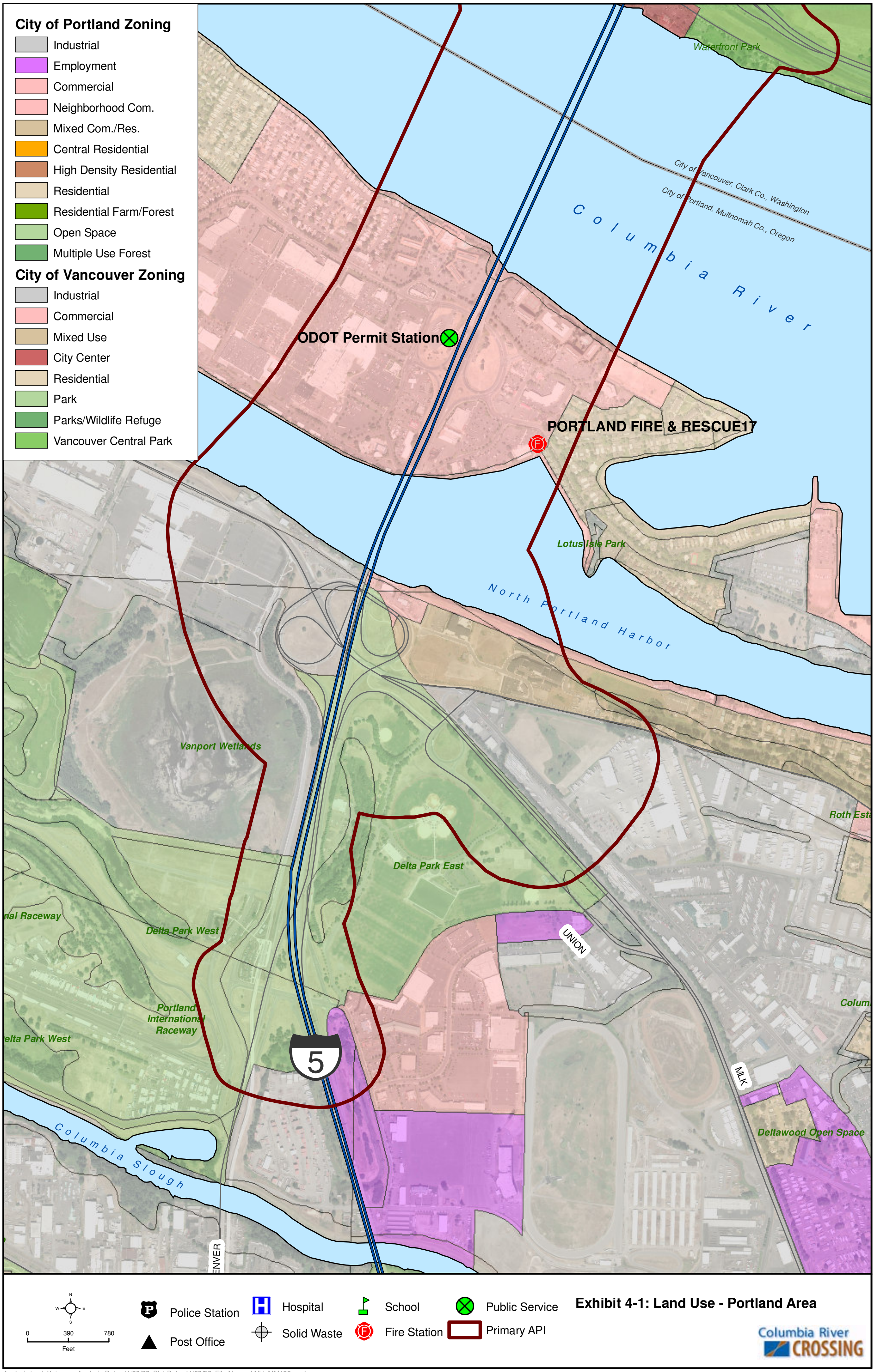

Exhibit 4-1: Land Use - Portland Area

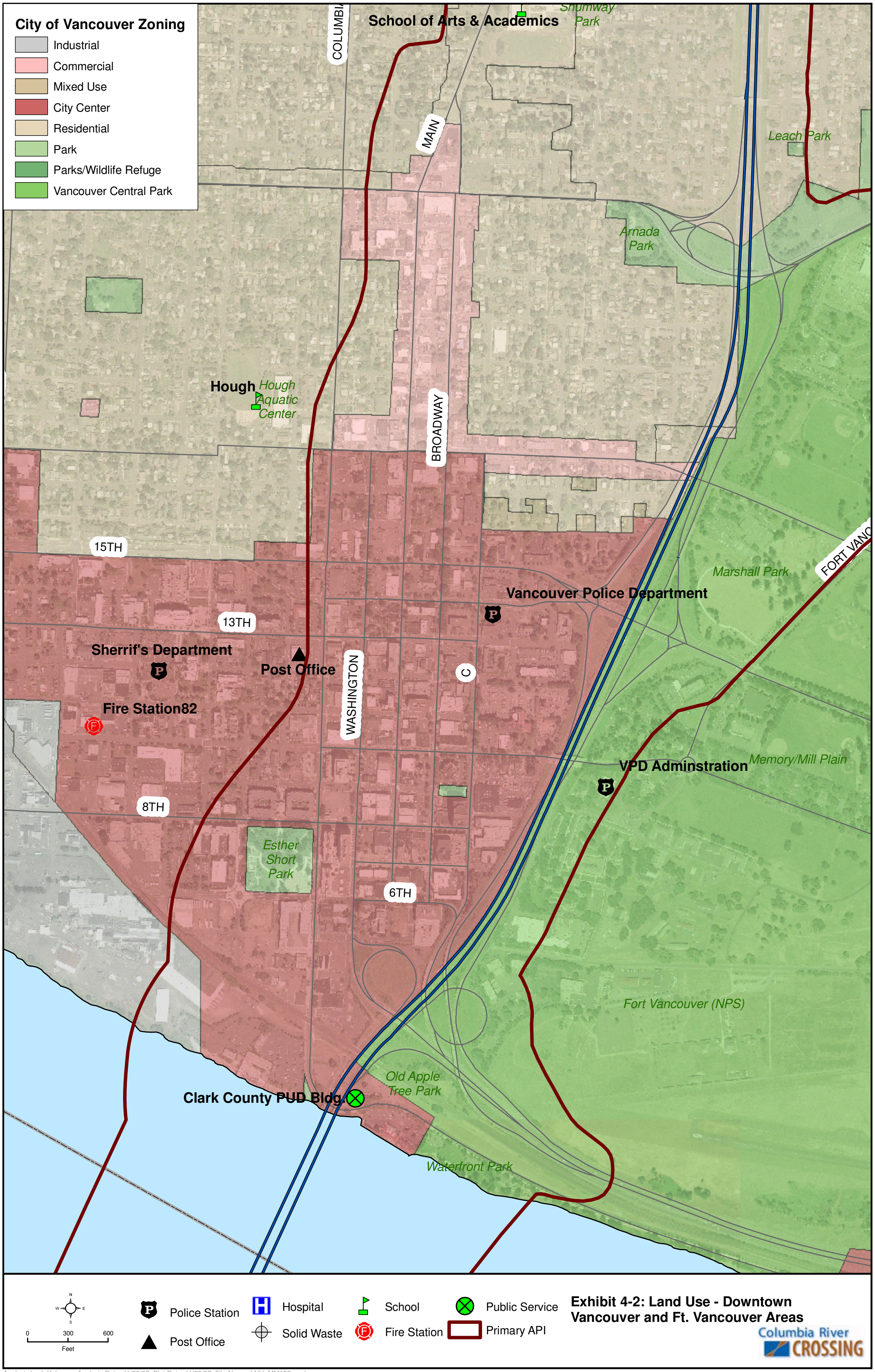

Exhibit 4-2: Land Use - Downtown Vancouver and Ft. Vancouver Areas

Analysis by J. Koloszar; Analysis Date: 11/29/07; Plot Date: 11/29/07; File Name: LNU_MM133.mxd

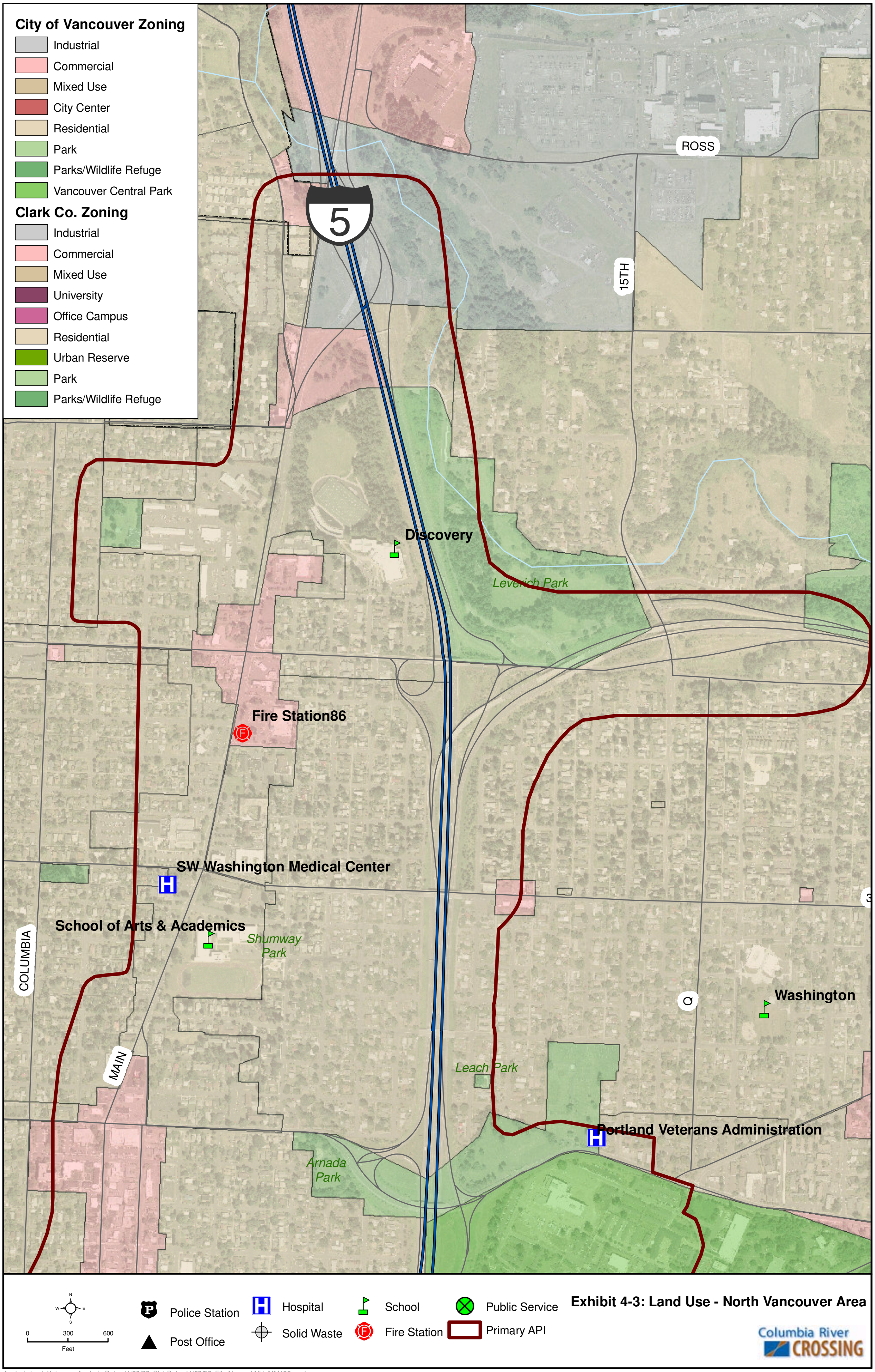

Exhibit 4-3: Land Use - North Vancouver Area

Analysis by J. Koloszar; Analysis Date: 11/29/07; Plot Date: 11/29/07; File Name: LNU_MM133.mxd

4.4 Noise Modeling Locations

Noise levels were modeled at 123 locations along the project corridors. The 123 locations represent approximately 830 noise sensitive uses in the project corridor. The noise modeling locations are shown on Exhibits 4-4, 4-5, and 4-6.

The traffic noise analysis was performed for 101 modeling locations along the project corridor. An additional 22 modeling locations were used exclusively for the HCT analysis. Each modeling location is selected to represent several structures in the same area that are expected to have the same noise level. In addition to single and multi-family residences in the corridor, noise sensitive parks, hotels, schools, churches, hospitals, a cemetery and several commercial land uses were also evaluated.

There are several hotels in the study area and those rooms that are projected to have interior noise levels influenced by traffic on I-5 are included in this analysis. There are two hospitals of concern within the project corridor. The VA Medical center is located just south of Fourth Plain Boulevard and approximately 500 feet east of I-5. The Southwest Washington Medical Center is located on Main at 34th Street. The analysis included the Veterans Cemetery just north of Fourth Plain Boulevard and east of I-5.

4.5 Residential Equivalents

WSDOT uses residential equivalency factors for parks and other non-residential noise sensitive areas. The factor is based on the maximum number of people expected to use a facility during the period of time the facility is available for use. The residential equivalency factor for parks, schools and the cemetery were calculated based on information from the appropriate authority and site inspections. Details on the calculations are given in Appendix E.

4.6 Regional Traffic Noise Conditions

Traffic noise modeling was performed for 101 modeling locations. The modeling locations are shown on Exhibits 4-4, 4-5, and 4-6. Overall, noise levels in the project study area are dominated by traffic on I-5 and currently range from 47 to 74 dBA L_{eq}. Currently there are an estimated 212 noise sensitive land uses that meet or exceed the applicable traffic noise criteria. This number includes single and multi-family residences along with several hotels and the residential equivalents for the parks, schools and cemetery. Of the impacts identified along the entire project corridor, 92 are located on the Portland side, and 120 are located in Vancouver.

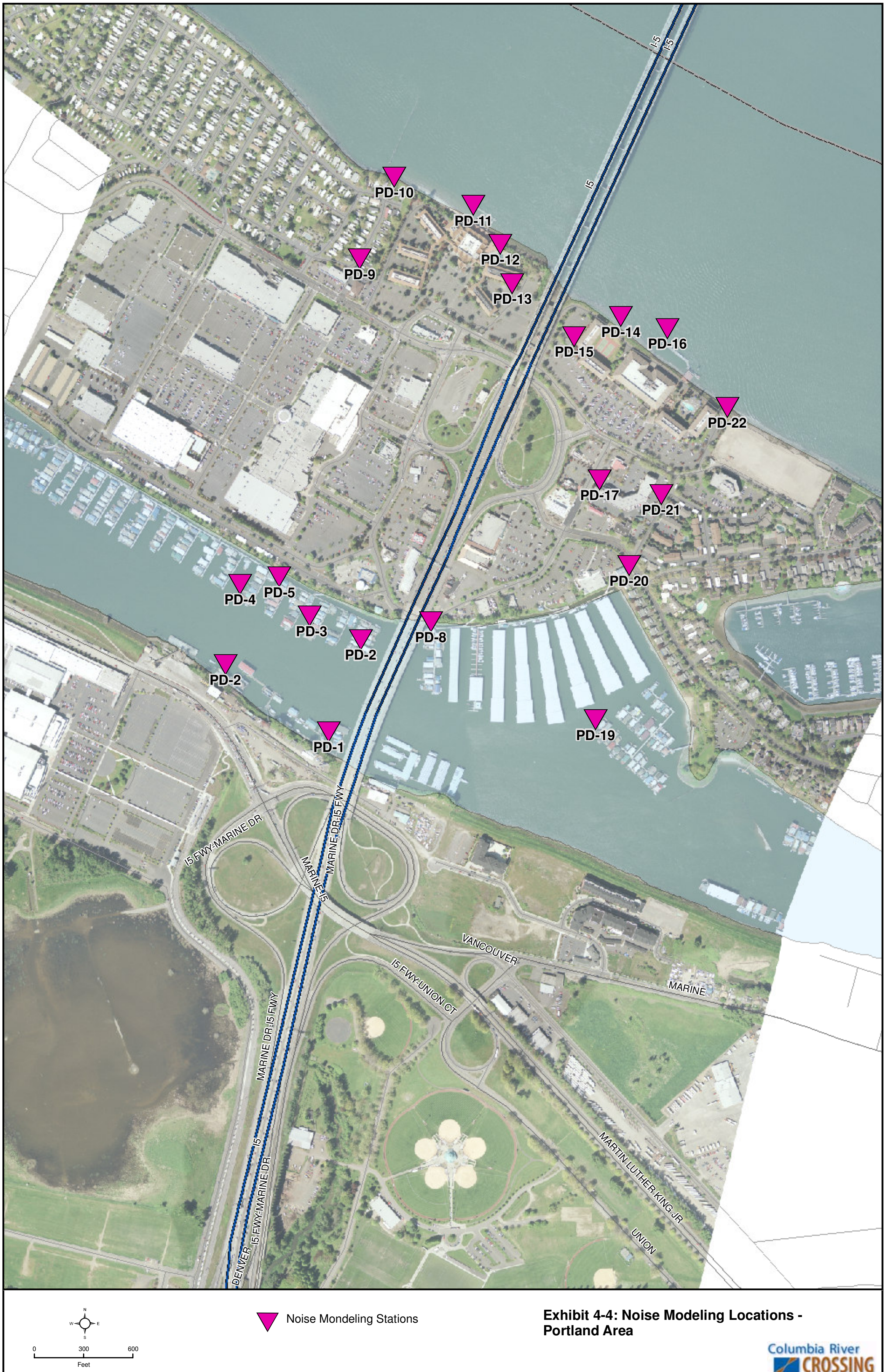

Exhibit 4-4: Noise Modeling Locations - Portland Area

Analysis by J. Koloszar; Analysis Date: 11/29/07; Plot Date: 11/29/07; File Name: NoiseModel_MM133.mxd

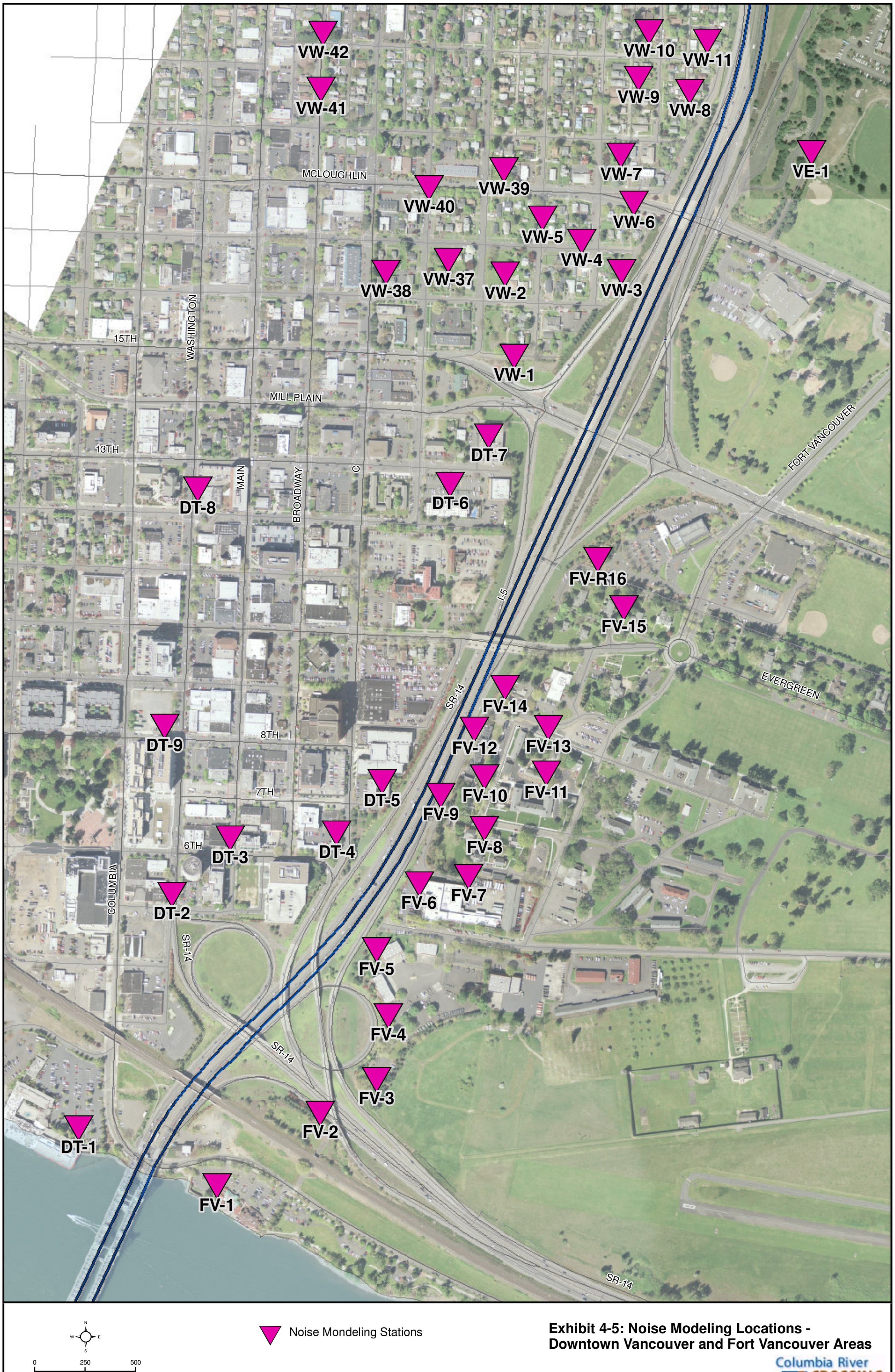

Exhibit 4-5: Noise Modeling Locations - Downtown Vancouver and Fort Vancouver Areas

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/29/07; Plot Date: 11/29/07; File Name: NoiseModel_MM133.mxd

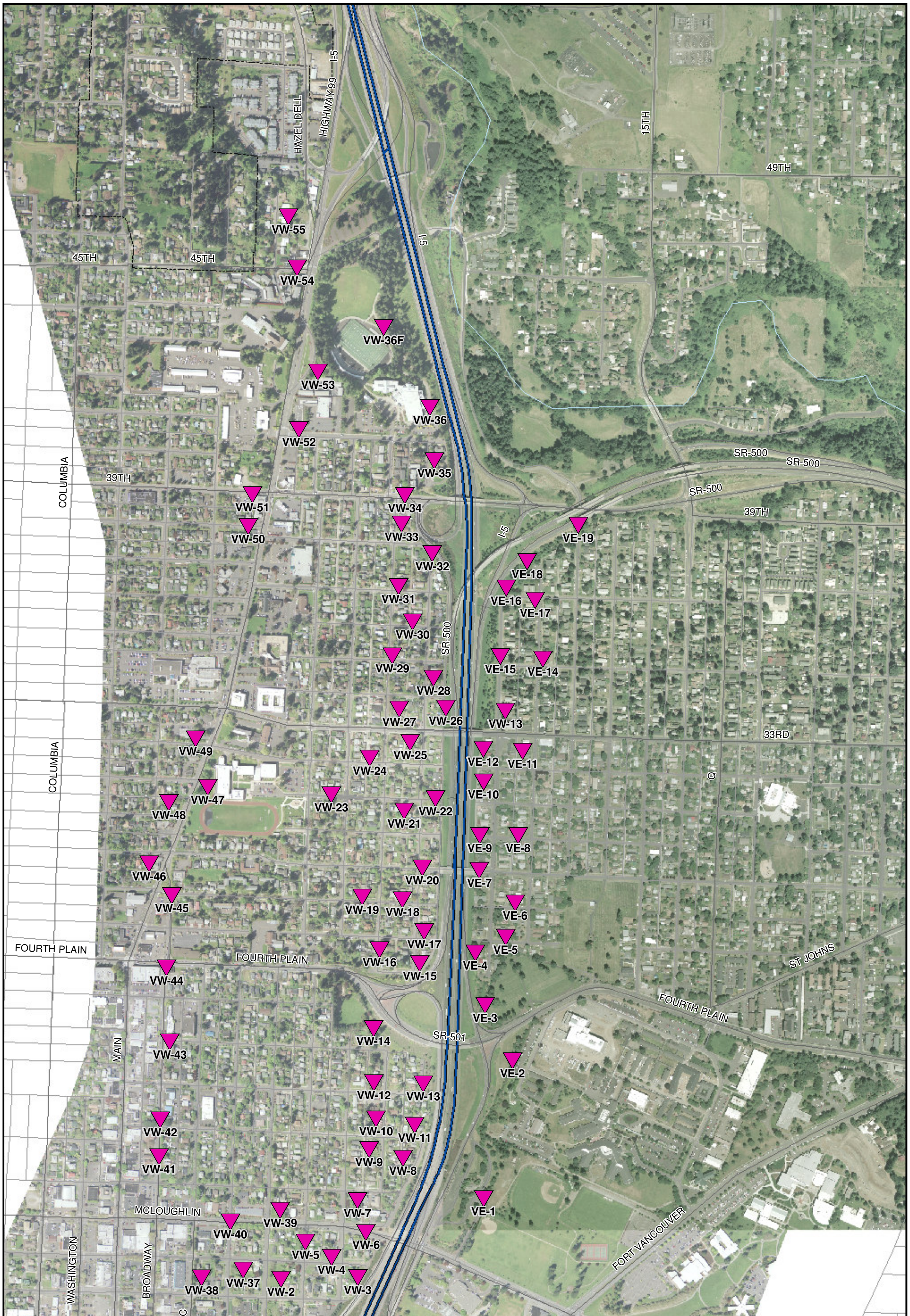

Exhibit 4-6: Noise Modeling Locations - North Vancouver

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/29/07; Plot Date: 11/29/07; File Name: NoiseModel_MM133.mxd

4.7 Segment A Delta Park to Mill Plain District

The following sections summarize the noise level for Portland, downtown Vancouver and Fort Vancouver. Separate discussions are provided for Portland and Vancouver because each has different applicable state traffic noise criteria and analysis methods.

4.7.1 Portland Existing Modeled Traffic Noise Levels

Current noise levels are projected to exceed the ODOT traffic noise criteria at 92 locations adjacent to I-5. There are an estimated 50 floating homes that exceed the criteria with existing levels of 66 to 73 dBA L_{eq}. All other noise impacts are at the Red Lion Columbia Center Hotel, which include all rooms facing toward I-5 with noise levels ranging from 67 to 71 dBA L_{eq}. Exhibit 4-7 provides a summary of the modeled noise levels and corresponding number of noise impacts.

Noise levels at the mall entrance, Safeway and other commercial land uses near I-5 are projected to have noise levels similar to the Red Lion Hotels, and should range from 64 to 70 dBA L_{eq}. Currently only the loading docks at the Safeway Building, a McDonalds restaurant, Hooter's Restaurant, a 76 gas station and several retail building are expected to exceed the ODOT 70 dBA L_{eq} criteria.

Exhibit 4-7. Existing Conditions Traffic Noise for Portland

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
PD-1	3	Res	65	**71**	3
PD-2	17	Res	65	**71**	17
PD-3	16	Res	65	**66**	16
PD-4	14	Res	65	58	
PD-5	7	Res	65	60	
PD-6	15	Res	65	50	
PD-7	24	Res	65	47	
PD-8	14	Res	65	**73**	14
PD-9	15	Res	65	56	
PD-10	5	Res	65	57	
PD-11	0	Vacant[6]	--	64	
PD-12	0	Vacant[6]	--	**67**	0
PD-13	0	Vacant[6]	--	**70**	0
PD-14	2	Hotel	65	**67**	2
PD-15	40	Hotel	65	**71**	40
PD-16	2	Hotel	65	62	
PD-17	12	Res	65	62	
PD-18	6	Res	65	59	
PD-19	14	Res	65	55	
PD-20	11	Res	65	56	

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
PD-21	24	Res	65	56	
PD-22	12	Res	65	55	

Notes:
1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impact criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. Residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria
6. Receivers PD-11 thru PD-13 represents a hotel that is vacant and not in use. The future use of this site is unknown. It is not considered noise sensitive for the purposes of this project.

4.7.2 Downtown Vancouver

There are seven traffic noise modeling locations in Downtown Vancouver that represent 62 noise sensitive properties. All land uses in this section are either multi-family residences or hotels and motels. Currently, all 62 identified noise sensitive land uses meet or exceed the WSDOT traffic noise criteria.

Within the downtown Vancouver area, traffic on I-5, SR 14, and the ramps on and off these two highways contribute to the overall noise environment. Noise from traffic operating on local surface streets such as Washington Street and Sixth Street is also a significant source of overall noise levels and, at many downtown locations, the dominant source of noise. For example, the mid-day measured noise level on the sidewalk in front of the noise sensitive residential Smith Towers was 69 dBA L_{eq}. Modeled results show that due to shielding from other buildings and the distance from the highway, projected noise levels at the Smith Tower exclusively from I-5, SR 14 and ramps are expected to be 61 dBA $L_{eq.}$

Receiver DT-2 is located at Fifth and Washington immediately adjacent the I-5/SR-14 ramps and does not represent a noise-sensitive area. This receiver was used in the noise model validation process but is not used for the noise impact and mitigation analysis. Therefore, DT-2 is not included in any of the forthcoming tables or discussion.

Exhibit 4-8 summarizes the modeled noise levels.

Exhibit 4-8. Downtown Vancouver Traffic Noise Levels

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
DT-1	2	Hotel	66	**67**	2
DT-3	24	Res	66	69[7]	24
DT-4	12	Hotel	66	**70**	12
DT-5	6	Res	66	**74**	6

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
DT-6	6	Hotel	66	**66**	6
DT-7	12	Res	66	**68**	12

Notes:
1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impact criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria
6. Undeveloped lands are not considered noise sensitive
7. Represents actual measured noise levels at this location which were dominated by local traffic. Peak-hour noise levels at the Smith Tower from I-5, SR 14 and ramps only are expected to be 61 dBA L_{eq}.

4.7.3 Fort Vancouver

There are 16 noise modeling locations on the Fort Vancouver and nearby areas. The 16 modeling locations represent 28 residences, 33 park residential equivalents and several commercial/office uses, including the FHWA offices and the Army National Guard motor pool. Noise levels on the Fort currently range from 61 to 73 dBA L_{eq} with the highest levels at unshielded areas along I-5 and SR 14. Currently there are an estimated 12 residences along with one commercial land use that exceed the WSDOT traffic criteria. The modeled results are listed in Exhibit 4-9.

Exhibit 4-9. Fort Vancouver Area Traffic Noise Levels

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
FV-1	16	Comm	71	65	
FV-2	4	Park	66	62	
FV-3	17	Park	66	62	
FV-4	11	Park	66	64	
FV-5	1	Comm	71	70	
FV-6	1	Comm	71	**73**	1
FV-7	6	Res	66	65	
FV-8	6	Res	66	64	
FV-9	8	Res	66	**71**	8
FV-10	10	Comm	71	65	
FV-11	10	Comm	71	62	
FV-12	2	Res	66	**70**	2
FV-13	1	Park	66	63	
FV-14	0	Undeveloped[6]	--	72	

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
FV-15	4	Res	66	61	
FV-16	2	Res	66	**68**	2

Notes:
1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impact criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria
6. Undeveloped lands are not considered noise sensitive

4.8 Segment B Mill Plain District to North Vancouver

Segment B includes the area north of Mill Plain to the northern project terminus. Due to the large number of noise sensitive properties, the analysis is split into two sections, one for the east side of I-5, and one for west side of I-5.

4.8.1 Traffic Noise Levels North of Mill Plain and East of I-5

There are 19 noise modeling locations for the area between Mill Plain and SR 500. The 19 locations represent 74 residences, a church, school, hospital and a cemetery. Noise levels at the modeling locations ranged from 55 to 74 dBA L_{eq}. Currently there are 16 locations that meet or exceed the WSDOT traffic noise criteria. Noise levels do not exceed the criteria at the hospital, school or church, but they do exceed the criteria at the VA Cemetery for locations near I-5. Exhibit 4-10 summarizes the existing noise levels and location of noise impacts.

Exhibit 4-10. Traffic Noise Levels East of I-5, North of Mill Plain

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
VE-1	6	School	66	63	
VE-2	1	Hospital	66	58	
VE-3	2	Cemetery	66	**70**	2
VE-4	10	Res	66	**74**	10
VE-5	8	Res	66	61	
VE-6	3	Res	66	58	
VE-7	2	Res	66	**67**	2
VE-8	2	Res	66	**67**	2
VE-9	1	Res	66	56	
VE-10	8	Res	66	64	
VE-11	4	Res	66	57	
VE-12	5	Res	66	64	
VE-13	3	Church	66	62	
VE-14	4	Res	66	55	

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
VE-15	10	Res	66	60	
VE-16	5	Res	66	64	
VE-17	5	Res	66	61	
VE-18	4	Res	66	61	
VE-19	3	Res	66	62	

Notes:
1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impact criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria

4.8.2 Traffic Noise levels West of I-5 North of Mill Plain

Noise levels along the west side of I-5 between Mill Plain and the Discovery Middle School ranged from 57 to 74 dBA L_{eq}. This area is represented by 37 modeling locations, including two for the Discovery Middle School and 35 for single family residences located between Mill Plain and E 40th Street. Currently, 12 of the 37 modeling locations which represent 52 residences and the Discovery School Parking area meet or exceed the criteria. The school was contacted to determine if this area was considered noise sensitive and the school assured the team that the area in question is not used for any school activities, and only serves as a parking lot. Exhibit 4-11 summarizes the existing noise levels and location of noise impacts.

Exhibit 4-11. Traffic Noise Levels West of I-5, North of Mill Plain

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
VW-1	2	Res	66	**67**	2
VW-2	4	Res	66	61	
VW-3	2	Res	66	**68**	2
VW-4	4	Res	66	63	
VW-5	3	Res	66	61	
VW-6	4	Res	66	**66**	4
VW-7	3	Res	66	64	
VW-8	8	Res	66	**71**	8
VW-9	7	Res	66	63	
VW-10	3	Res	66	61	
VW-11	4	Res	66	**67**	4
VW-12	4	Res	66	60	
VW-13	5	Res	66	63	
VW-14	2	Res	66	59	
VW-15	3	Res	66	**68**	3
VW-16	3	Res	66	64	

Rec's	Units[1]	Land Use[2]	Criteria[3]	Existing[4]	Impacts[5]
VW-17	4	Res	66	63	
VW-18	6	Res	66	61	
VW-19	4	Res	66	58	
VW-20	6	Res	66	**69**	6
VW-21	4	Res	66	61	
VW-22	5	Res	66	**67**	5
VW-23	4	Res	66	56	
VW-24	2	Res	66	56	
VW-25	4	Res	66	60	
VW-26	4	Res	66	**66**	4
VW-27	4	Res	66	60	
VW-28	8	Res	66	62	
VW-29	4	Res	66	57	
VW-30	4	Res	66	59	
VW-31	4	Res	66	56	
VW-32	3	Res	66	65	
VW-33	2	Res	66	60	
VW-34	4	Res	66	**68**	4
VW-35	8	Res	66	**68**	8
VW-36	2	School Parking	71	**73**	1
VW-36F	22	School	66	65	

Notes:

1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impacts criteria
4. Existing modeled noise levels from TNM version 2.5
5. Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria

4.9 Existing Noise Levels for HCT Analysis

Noise level reporting for the HCT existing conditions analysis uses the L_{dn} for residences and the peak-hour L_{eq} for other types of land use. The existing noise level data for the HCT analysis is taken from on-site measurements. Several of the locations used for the traffic noise analysis are also used for the HCT alternatives, if they are in the transit corridor. Exhibit 4-12 summarizes the locations for HCT analysis and the projected noise levels in L_{eq} and L_{dn}.

There are two basic transit alignment alternatives (Vancouver and I-5) and each of those has two alignment sub-options at their southern ends (Main/Broadway or Broadway for the Vancouver alignment, and 16th or McLoughlin for the I-5 alignment). The differences in projected noise and vibration impacts under the transit alignments and sub-options are included in the discussion where appropriate.

Exhibit 4-12. Existing L_{eq} and L_{dn} for HCT Noise Analysis

Rec #	Land Use[1]	Location[2]	Res[3]	Alternative[4]	L_{eq}[5]	L_{dn}[6]
PD-1	Res	Portland	3	Both[7]	66	69
PD-2	Res	Portland	17	Both[7]	66	69
PD-3	Res	Portland	16	Both[7]	64	67
PD-4	Res	Portland	14	Both[7]	63	63
PD-5	Res	Portland	7	Both[7]	63	63
PD-6	Res	Portland	15	Both[7]	61	61
PD-8	Res	Portland	14	Both[7]	66	69
PD-11	Res	Portland	0	Both[7]	64	65
DT-1	Res	Main Street	2	Both[7]	64	66
DT-3	Res	Main Street	24	Both[7]	69	71
DT-9	Res	Main Street	3	Both[7]	67	69
DT-8	Res	Main Street	40	Both[7]	66	67
VW-2	Res	16th Street	4	16th Street	61	60
VW-3	Res	16th Street	2	16th Street	65	66
VW-37	Res	16th Street	4	16th Street	61	60
VW-38	Res	16th Street	4	16th Street	60	60
VW-6	Res	McLoughlin Blvd	4	McLoughlin Blvd	67	68
VW-7	Res	McLoughlin Blvd	3	McLoughlin Blvd	66	67
VW-39	Res	McLoughlin Blvd	4	McLoughlin Blvd	63	62
VW-40	Res	McLoughlin Blvd	4	McLoughlin Blvd	63	62
VW-41	Res	Broadway	1	Broadway	64	64
VW-42	Res	Broadway	2	Broadway	64	64
VW-43	Res	Broadway	4	Broadway	64	64
VW-44	Res	Broadway	2	Broadway	64	64
VW-45	Res	Broadway	2	Broadway	65	65
VW-46	Res	Main Street	4	Main Street	69	69
VW-47	School	Main Street	3	Main Street	69	69
VW-48	Res	Main Street	8	Main Street	69	69
VW-49	Res	Main Street	4	Main Street	69	69
VW-50	Medical Center	Main Street	1	Main Street	69	69
VW-51	Res	Main Street	2	Main Street	69	69
VW-52	Res	Main Street	2	Main Street	69	69
VW-53	Fire	Main Street	1	Main Street	69	69
VW-54	Res	Main Street	3	Main Street	69	69
VW-55	Res	Main Street	60	Main Street	69	69
VW-56	Res	Main Street	3	Main Street	69	69
VE-1	Park	McLoughlin Blvd	6	I-5	61	60

Rec #	Land Use[1]	Location[2]	Res[3]	Alternative[4]	L_{eq}[5]	L_{dn}[6]
VE-2	Hospital	VA Medical Center	1	I-5	58	58
VE-3	Res	I-5	2	I-5	69	70
VE-13	Church	I-5	3	I-5	64	65
VE-15	Res	I-5	8	I-5	66	67
VE-16	Res	I-5	4	I-5	69	70
VE-18	Res	I-5	5	I-5	69	70

Notes:

1. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
2. General location of receiver
3. Number of representative residences or equivalents
4. Alternatives that use this receiver location
5. Peak-hour L_{eq} for institutional land uses
6. 24-hour L_{dn} for residential analysis
7. This receiver is used for both the I-5 and Vancouver alternative alignments

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5. Long-Term Effects

5.1 Introduction

This chapter describes the direct and indirect long-term noise and vibration impacts that would be expected from the I-5 CRC project alternatives and options. Section 5.2 through Section 5.6 address traffic noise impacts and Section 5.7 addresses transit noise and vibration impacts. Because the potential traffic noise effects would be similar or in some cases identical across the project alternatives and options, the traffic noise discussion is organized by project corridor subareas (e.g., Portland subarea).

Following the traffic noise impacts discussion for each subarea, the HCT noise and vibration impacts analysis is provided. Because the potential HCT noise and vibration effects vary substantially across the project alternatives and options, the HCT effects discussion is organized by the HCT project alternatives (LRT versus BRT).

5.2 Portland Subarea Traffic Noise

This section describes the potential noise impacts from the No-Build Alternative, the effects common to all build alternatives and the effects that differ across the build alternatives within the Portland area.

5.2.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for Portland area receivers (“PD”) as shown on Exhibit 4-1. No-Build Alternative noise levels are projected to exceed the ODOT traffic noise criteria at the same 92 locations adjacent to I-5 as under the existing conditions. There are an estimated 50 floating homes that exceed the criteria with existing levels of 67 to 74 dBA L_{eq}. With the No-Build Alternative these levels would increase by 1 dBA over the existing noise levels, an increase typically not discernable by a person with normal hearing. All other noise impacts are at the Red Lion Columbia Center hotel, and include all rooms facing toward I-5 with noise levels ranging from 68 to 72 dBA L_{eq}. Exhibit 5-1 provides a summary of the modeled noise level and number of noise impacts associated with the No-Build Alternative.

Noise levels at the mall entrance, Safeway and other commercial land uses near I-5 are projected to increase by 1 to 2 dBA, and should range from 65 to 71 dBA L_{eq} under the No-Build Alternative. The loading docks at the Safeway Building, the ODOT permit station, a McDonalds restaurant, Hooter’s Restaurant, a Union 76 gas station and several retail buildings are expected to exceed the ODOT 70 dBA L_{eq} criteria.

Exhibit 5-1. Portland Area No-Build Alternative Traffic Noise Levels

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	No-Bld[5]	Change[6]	Impacts[7]
PD-1	3	Res	65	**71**	**72**	1	3
PD-2	17	Res	65	**71**	**72**	1	17
PD-3	16	Res	65	**66**	**67**	1	16
PD-4	14	Res	65	58	59	1	
PD-5	7	Res	65	60	61	1	
PD-6	15	Res	65	50	51	1	
PD-7	24	Res	65	47	48	1	
PD-8	14	Res	65	**73**	**74**	1	14
PD-9	15	Res	65	56	58	2	
PD-10	5	Res	65	57	58	1	
PD-11	0	Undeveloped[8]	--	64	65	1	0
PD-12	0	Undeveloped[8]	--	67	68	1	0
PD-13	0	Undeveloped[8]	--	70	71	1	0
PD-14	2	Hotel	65	**67**	**68**	1	2
PD-15	40	Hotel	65	**71**	**72**	1	40
PD-16	2	Hotel	65	62	63	1	
PD-17	12	Res	65	62	63	1	
PD-18	6	Res	65	59	60	1	
PD-19	14	Res	65	55	56	1	
PD-20	11	Res	65	56	58	2	
PD-21	24	Res	65	56	58	2	
PD-22	12	Res	65	55	56	1	

Notes:

1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impacts criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. No-Build modeled noise levels
6. Change in noise, No-Build minus Existing
7. Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria under the No-Build Alternative
8. Undeveloped lands are not considered noise sensitive

5.2.2 Traffic Noise Effects Common to All Build Alternatives

Traffic noise levels were projected for the full build alternatives. Modeled results show that at some receiver locations in the Portland area, future traffic noise levels would differ slightly (1 to 2 dBA) between the replacement and supplemental alternatives. This difference would not be perceptible to a person with normal hearing.

There is a difference in the potential number of traffic impacts between the replacement and supplemental alternatives. With the supplemental alternatives, five potentially impacted residences would be displaced. Therefore, the overall number of potential traffic noise impacts would be five less than with the replacement alternatives. When comparing the replacement with the supplemental crossing, note that there is a difference in five residential traffic noise impacts but there would be no noticeable difference in the traffic noise levels in the Portland area.

The Safeway, ODOT permit station, a McDonalds restaurant, Hooter's Restaurant, a Union 76 gas station and several retail building currently adjacent to I-5 would be displaced under the build alternatives. The nearest commercial and retail uses, including the mall entrance, Office Depot on the west side of I-5, or the Chevron gas station and First Interstate Bank are predicted to have future build traffic noise levels ranging from 64 to 72 dBA L_{eq}. Commercial and retail buildings expected to exceed the ODOT criteria included Office Depot and a restaurant on the west side of I-5, and the Chevron gas station, and two fast-food restaurants on the east side of I-5

Exhibit 5-2 shows the future build traffic noise levels along with the existing and No-Build Alternative noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts common to all build alternatives. Exhibit 5-2 also lists both the replacement and supplemental crossing projected traffic noise levels and highlights where future noise level impacts differ between the build alternatives.

Exhibit 5-2. Portland Area Traffic Noise Levels for Build Alternatives

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	Build Alternatives: Replace[5]	Build Alternatives: Supp[6]	Replacement Alternative: Change from Exist[7]	Replacement Alternative: Change from No-Build[8]	Impacts[9]: Replace	Impacts[9]: Supp	Notes
PD-1	3	Res	65	**71**	**73**	**73**	2	1	3	0[10]	Increases in noise are due to increases in traffic volumes along the new structure. Number of impacts remains the same as existing.
PD-2	17	Res	65	**71**	**74**	**74**	3	2	17	17	
PD-3	16	Res	65	**66**	**69**	**68**	3	2	16	16	
PD-4	14	Res	65	58	60	60	2	1			
PD-5	7	Res	65	60	64	63	4	3			
PD-6	15	Res	65	50	54	54	4	3			
PD-7	24	Res	65	47	51	51	4	3			
PD-8	14	Res	65	**73**	**73**	**74**	0	-1	14	12[11]	See PD-1 comment above
PD-9	15	Res	65	56	61	59	5	3			
PD-10	5	Res	65	57	63	61	6	5			
PD-11	0	Hotel	65	64	**70**	**68**	6	5			Red Lion Hotel not currently in use.
PD-12	0	Hotel	65	**67**	**73**	**71**	6	5			
PD-13	0	Hotel	65	**70**	**75**	**73**	5	4			
PD-14	2	Hotel	65	**67**	**66**	**68**	-1	-2	2	2	Red Lion Hotel rooms facing I-5 and outdoor area along the shoreline
PD-15	40	Hotel	65	**71**	**70**	**71**	-1	-2	40	40	
PD-16	2	Hotel	65	62	61	63	-1	-2			
PD-17	12	Res	65	62	62	63	0	-1			
PD-18	6	Res	65	59	60	60	1	0			
PD-19	14	Res	65	55	58	58	3	2			
PD-20	11	Res	65	56	58	58	2	0			
PD-21	24	Res	65	56	57	58	1	-1			
PD-22	12	Res	65	55	55	56	0	-1			

1. Number of residences or residential equivalents
2. Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail
3. Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington
4. Existing modeled noise levels from FHWA TNM
5. Future noise levels with replacement of the existing bridge
6. Future noise levels with the supplemental bridge
7. Change in noise levels, Build Replacement compared to Existing
8. Change in noise levels, Build Replacement compared to No-Build
9. Number of impacts under the Build Replacement and the Supplemental Alternative
10. Under the Supplemental Alternative PD-1 would be displaced, eliminating the 3 potential noise impacts.
11. Under the Supplemental Alternative, 2 residential land uses in the PD-8 group would be displaced, eliminating 2 of the 14 potential noise impacts.

5.3 Downtown Vancouver Subarea Traffic Noise

This section describes the potential noise impacts from the No-Build Alternative, the effects common to all build alternatives and the effects that differ across the build alternatives within downtown Vancouver.

5.3.1 No-Build Alternative Traffic Noise

No-Build Alternative traffic noise levels were projected for Downtown Vancouver area receivers ("DT") as shown on Exhibit 5-3. No-Build Alternative traffic noise levels are projected to exceed the WSDOT traffic noise criteria at the same 62 noise-sensitive land uses as under the existing conditions. Noise levels would increase by 0 to 2 dBA under the No-Build Alternative when compared to the current noise level estimates. The No-Build Alternative peak-hour traffic noise level at receiver DT-3 from I-5, SR 14 and ramps only would be is 61 dBA- L_{eq}; which is not an impact under the WSDOT traffic noise criteria. However, the higher measured level of 69 dBA-L_{eq} is used to better represent what is expected to be the total noise environment at this location. Exhibit 5-3 summarizes the modeled noise levels and number of impacts within downtown Vancouver.

Exhibit 5-3. Downtown Vancouver No-Build Alternative Traffic Noise Levels

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	No-Bld[5]	Change[6]	Impacts[7]
DT-1	2	Hotel	66	**67**	**68**	1	2
DT-3	24	Res	66	69[9]	69[9]	2	24
DT-4	12	Hotel	66	**70**	**70**	0	12
DT-5	6	Res	66	**74**	**75**	1	6
DT-6	6	Hotel	66	**66**	**67**	1	6
DT-7	12	Res	66	**68**	**69**	1	12

Notes:

1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impacts criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. No-Build modeled noise levels
6. Change in noise, No-Build minus Existing
7. Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria under the No-Build Alternative
8. Undeveloped lands are not considered noise sensitive
9. Represents actual measured noise levels at this location which were dominated by local traffic.

5.3.2 Traffic Noise Effects Common to All Build Alternatives

Traffic noise levels were projected for the full build alternatives. Modeled results show that in downtown Vancouver future traffic noise levels would be the same at all receivers except DT-1. The shift in alignment and roadway profiles between the Replacement and Supplemental Crossing alternatives would create a 3 dBA difference in future traffic noise levels at DT-1. However, the noise sensitive land use represented by DT-1 would be impacted by I-5 traffic noise under all build alternatives as well as the No-Build Alternative. Thus, there is no change in the number of traffic noise impacts across the full set of alternatives. The overall number of potential traffic noise impacts within downtown Vancouver would be 62 for the all alternatives. Twenty-four of the noise impacts are at the Smith Towers, where the major noise source and reason for noise impact is traffic on Washington and East Sixth Streets.

Exhibit 5-4 shows the future build traffic noise levels along with the existing and No-Build Alternative noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts common to all build alternatives. The difference in future noise levels at receiver, DT-1, is noted.

Exhibit 5-4. Downtown Vancouver Area Traffic Noise Levels for Build Alternatives

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	Build Alternatives		Replacement Alternative		Impacts[9]		Notes
					Replace[5]	Supp[6]	Change from Exist[7]	Change from No-Build[8]	Replace	Supp	
DT-1	2	Hotel	66	**67**	**73**	**70**[10]	6	5	2	2	Red Lion SW of existing bridge
DT-3	24	Hotel	66	69[9]	69[11]	69[11]	0	0	24	24	
DT-4	6	Hotel	66	**70**	**70**	**70**	0	0	6	6	Apartments and hotels located along I-5 just north of the city center exit to Fourth Plain Boulevard
DT-5	12	Res	66	**74**	**74**	**74**	0	-1	12	12	
DT-6	6	Hotel	66	**66**	**70**	**70**	4	3	6	6	
DT-7	12	Res	66	**68**	**70**	**70**	2	1	12	12	

Notes:
1. Number of residences or residential equivalents
2. Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail
3. Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington
4. Existing modeled noise levels from FHWA TNM
5. Future noise levels with replacement of the existing bridge
6. Future noise levels with the supplemental bridge
7. Change in noise levels, Build Replacement compared to Existing
8. Change in noise levels, Build Replacement compared to No-Build
9. Number of impacts under the Build Replacement and the Supplemental Alternative
10. Future traffic noise level for the Supplemental Crossing alternative differs for this receiver by 3 dBA
11. Represents the actual measured noise levels from traffic on Washington and East Sixth Streets.

5.4 Fort Vancouver Subarea Traffic Noise

This section describes the potential noise impacts from the No-Build Alternative, the effects common to all build alternatives and the effects that differ across the build alternatives within the Fort Vancouver area.

5.4.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for Fort Vancouver area receivers ("FV") as shown on Exhibit 5-5. Noise levels on the Fort under the No-Build Alternative are projected to range from 62 to 74 dBA L_{eq} with the highest levels at unshielded areas along I-5 and SR 14. In general, noise levels are projected to increase by 1 dBA over existing conditions throughout the Fort. Currently there are an estimated 12 residences and residential equivalents and one commercial land uses that exceed the WSDOT traffic criteria. Under the No-Build Alternative the number of residential noise impacts would increase to 18 with six new impacts near Officers Row. An additional commercial impact would also occur raising the number of commercial impacts to two. The modeled results for the No-Build Alternative within the Fort Vancouver area are given in Exhibit 5-5.

Exhibit 5-5. Fort Vancouver Area No-Build Traffic Noise levels

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	No-Bld[5]	Change[6]	Impacts[7]
FV-1	16	Comm	71	65	66	1	
FV-2	4	Park	66	62	63	1	
FV-3	17	Park	66	62	63	1	
FV-4	11	Park	66	64	65	1	
FV-5	1	Comm	71	70	**71**	1	1
FV-6	1	Comm	71	**73**	**74**	1	1
FV-7	6	Res	66	65	**66**	1	6
FV-8	6	Res	66	64	65	1	
FV-9	8	Res	66	**71**	**72**	1	8
FV-10	10	Comm	71	65	66	1	
FV-11	10	Comm	71	62	63	1	
FV-12	2	Res	66	**70**	**71**	1	2
FV-13	1	Park	66	63	64	1	
FV-14	0	Undeveloped[8]	--	72	73	1	
FV-15	4	Res	66	61	62	1	
FV-16	2	Res	66	**68**	**69**	1	2

Notes:
1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impacts criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. No-Build modeled noise levels
6. Change in noise, No-Build minus Existing
7. Number of residences, hotel rooms, or residential equivalents expected to exceed the traffic noise criteria under the No-Build Alternative
8. Undeveloped lands are not considered noise sensitive

5.4.2 Traffic Noise Effects Common to All Build Alternatives

Traffic noise levels were modeled for the full build alternatives. Modeled results show that under all the build alternatives there are 26 noise impacts in the Fort Vancouver area.

Exhibit 5-6 shows the future build alternatives traffic noise levels along with the existing and No-Build noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts common to all build alternatives. Two receivers, FV-1 (commercial) and FV-2 (park) would have different noise levels depending on which build alternative, but the neither receiver would be impacted by traffic noise under any of the build alternatives.

Exhibit 5-6. Fort Vancouver Traffic Noise Levels for Build Alternatives

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	Build Alternatives		Replacement Alternative		Impacts[9]		Notes
					Replace[5]	Supp[6]	Change from Exist[7]	Change from No-Build[8]	Replace	Supp	
FV-1	16	Comm	71	65	61	66[10]	-4	-5			
FV-2	4	Park	66	62	60	62[11]	-2	-3			Park area along the shore and historic tree site
FV-3	17	Park	66	62	63	63	1	0			
FV-4	11	Comm	71	64	**67**	**67**	3	2			
FV-5	1	Comm	71	70	**74**	**74**	4	3	1	1	
FV-6	1	Comm	71	**73**	**76**	**76**	3	2	1	1	FHWA offices
FV-7	6	Res	66	65	**69**	**69**	4	3	6	6	Central area of the Fort, including officers' housing, the hospital and areas planned for future development
FV-8	6	Res	66	64	**68**	**68**	4	3	6	6	
FV-9	8	Res	66	**71**	**73**	**73**	2	1	8	8	
FV-10	10	Comm	71	65	69	69	4	3			
FV-11	10	Comm	66	62	65	65	3	2			
FV-12	2	Res	66	**70**	**72**	**72**	2	1	2	2	
FV-13	1	Park	66	63	65	65	2	1			
FV-14	0	Undeveloped[12]	n/a	72	73	73	1	0	0	0	Provided for future reference only: possible future hospital development
FV-15	4	Res	66	61	62	62	1	0			Northern edge of the Fort residential housing
FV-16	2	Res	66	**68**	**67**	**67**	-1	-2	2	2	

1. Number of residences or residential equivalents
2. Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail
3. Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. Future noise levels with replacement of the existing bridge
6. Future noise levels with the supplemental bridge
7. Change in noise levels, Build Replacement compared to Existing
8. Change in noise levels, Build Replacement compared to No-Build
9. Number of impacts under the Build Replacement and the Supplemental Alternative
10. Future traffic noise level for the Supplemental alternative differs for this receiver by 5 dBA
11. Future traffic noise level for the Supplement alternative differs for this receiver by 2 dBA
12. Undeveloped lands are not considered noise sensitive

5.5 East of I-5 / Mill Plain to North Vancouver Subarea Traffic Noise

The section covers the area east of I-5 and north of Mill Plain to the northern project terminus. This section describes the potential noise impacts from the No-Build Alternative, the effects common to all build alternatives and the effects that differ across the build alternatives within this area east of I-5. The existing noise wall that extends from a point just south of East 27th Street to East 33rd Street and varies in height from 6 feet to 8 feet was included in the model. The residence at the south end of K-Street, represented by VE-4 receives no shielding benefit from the existing wall. The break in the wall at East 29th is accounted for in the model.

5.5.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for "VE" designated receivers as shown on Exhibit 2-18. Future No-Build Alternative noise levels at the modeling locations in this area range from 57 to 76 dBA L_{eq}, an increase of 1 to 2 dBA over the existing noise levels. Currently there are 16 locations that meet or exceed WSDOT traffic noise criteria and the number and locations of the noise impacts would remain the same under the No-Build Alternative. Noise levels do not exceed the criteria at the hospital, school or church, but do exceed the criteria at the VA Cemetery for areas within the cemetery near I-5. Exhibit 5-7 summarizes the projected No-Build noise levels and location of noise impacts.

Exhibit 5-7. Traffic Noise Levels East of I-5, North of Mill Plain

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	No-Bld[5]	Change[6]	Impacts[7]
VE-1	6	School	66	63	64	1	
VE-2	1	Hospital	66	58	60	2	
VE-3	2	Cemetery	66	70	71	1	2
VE-4	10	Res	66	74	76	2	10
VE-5	8	Res	66	61	62	1	
VE-6	3	Res	66	58	60	2	
VE-7	2	Res	66	67	68	1	2
VE-8	2	Res	66	67	68	1	2
VE-9	1	Res	66	56	57	1	
VE-10	8	Res	66	64	65	1	
VE-11	4	Res	66	57	58	1	
VE-12	5	Res	66	64	65	1	
VE-13	3	Church	66	62	63	1	
VE-14	4	Res	66	55	57	2	
VE-15	10	Res	66	60	61	1	
VE-16	5	Res	66	64	65	1	
VE-17	5	Res	66	61	62	1	

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	No-Bld[5]	Change[6]	Impacts[7]
VE-18	4	Res	66	61	63	2	
VE-19	3	Res	66	62	64	2	

Notes:

1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impacts criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. No-Build modeled noise levels
6. Change in noise, No-Build minus Existing
7. Number of residences, hotel rooms, or residential equivalents expected to exceed the traffic noise criteria under the No-Build Alternative

5.5.2 Traffic Noise Effects Common to All Build Alternatives

Traffic noise levels were modeled for the full build alternatives. Modeled results show that there would be no difference in the future traffic noise levels or the potential number of traffic impacts between the Replacement and Supplemental alternatives in the area east of I-5 and north of Mill Plain. Under all build alternatives there are 37 noise impacts in this area.

Exhibit 5-8 shows the future build alternatives traffic noise levels along with the existing and No-Build noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts common to all build alternatives.

Exhibit 5-8. Future Traffic Noise Level for Replacement Alternative: North of Mill Plain East of I-5

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	Build Alternatives		Replacement Alternative		Impacts[9]		Notes
					Replace[5]	Supp[6]	Change from Exist[7]	Change from No-Build[8]	Replace	Supp	
VE-1	6	School	66	63	64	64	1	0			
VE-2	1	Hospital	66	58	65	65	7	5			
VE-3	2	Cemetery	66	**70**	**72**	**72**	2	1	2	2	VA Cemetery
VE-4	10	Res	66	**74**	**76**	**76**	2	0	10	10	End of noise wall
VE-5	8	Res	66	61	63	63	2	1			
VE-6	3	Res	66	58	61	61	3	1			
VE-7	2	Res	66	**67**	**69**	**69**	2	1	2	2	Opening in the noise wall
VE-8	2	Res	66	**67**	**69**	**69**	2	1	2	2	
VE-9	1	Res	66	56	58	58	2	1			
VE-10	8	Res	66	64	**66**	**66**	2	1	8	8	
VE-11	4	Res	66	57	59	59	2	1			
VE-12	5	Res	66	64	**66**	**66**	2	1	5	5	
VE-13	3	Church	66	62	64	64	2	1			
VE-14	4	Res	66	55	58	58	3	1			
VE-15	10	Res	66	60	62	62	2	1			
VE-16	5	Res	66	64	**66**	**66**	2	1	5	5	End of noise wall
VE-17	5	Res	66	61	63	63	2	1			
VE-18	4	Res	66	61	65	65	4	2			
VE-19	3	Res	66	62	**66**	**66**	4	2	3	3	Noise from SR500

Notes:

1. Number of residences or residential equivalents
2. Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail
3. Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. Future noise levels with replacement of the existing bridge
6. Future noise levels with the supplemental bridge
7. Change in noise levels, Build Replacement compared to Existing
8. Change in noise levels, Build Replacement compared to No-Build
9. Number of impacts under the Build Replacement and the Supplemental Alternative

5.6 West of I-5 / Mill Plain to North Vancouver Subarea Traffic Noise

The section covers the area west of I-5 and north of Mill Plain to the northern project terminus. This section describes the potential noise impacts from the No-Build Alternative, the effects common to all build alternatives and the effects that differ across the build alternatives within this area west of I-5. The 8-foot existing noise wall that extends from East 26th Street to East 37th Street was included in the model. The breaks in the wall at East 29th and East 33rd are accounted for in the model.

5.6.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for "VW" designated receivers as shown on Exhibit 4-6. Noise levels along the west side of I-5 between Mill Plain and the Discovery Middle School are projected to range from 57 to 74 dBA L_{eq}. Noise levels are predicted to increase by 1 to 4 dBA within this area. Under the No-Build Alternative, residential noise impacts are predicted to increase to 80 from the currently estimated 52 residential noise impacts. The Discovery School Parking area would continue to have noise levels that exceed the criteria. An additional area of the school including the eastern edge of the football field north of the school would also be impacted under the No-Build Alternative.

Exhibit 5-9 provides the projected No-Build noise levels and location of noise impacts.

Exhibit 5-9. Traffic Noise Levels West of I-5, North of Mill Plain

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	No-Bld[5]	Change[6]	Impacts[7]
VW-1	2	Res	66	**67**	68	1	2
VW-2	4	Res	66	61	62	1	
VW-3	2	Res	66	**68**	**69**	1	2
VW-4	4	Res	66	63	64	1	
VW-5	3	Res	66	61	62	1	
VW-6	4	Res	66	**66**	**67**	1	4
VW-7	3	Res	66	64	65	1	
VW-8	8	Res	66	**71**	**72**	1	8
VW-9	7	Res	66	63	64	1	
VW-10	3	Res	66	61	63	2	
VW-11	4	Res	66	**67**	**68**	1	4
VW-12	4	Res	66	60	61	1	
VW-13	5	Res	66	63	64	1	
VW-14	2	Res	66	59	60	1	
VW-15	3	Res	66	**68**	**70**	2	3
VW-16	3	Res	66	64	**65**	1	3
VW-17	4	Res	66	63	64	1	
VW-18	6	Res	66	61	62	1	
VW-19	4	Res	66	58	59	1	
VW-20	6	Res	66	**69**	**70**	1	6

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	No-Bld[5]	Change[6]	Impacts[7]
VW-21	4	Res	66	61	62	1	
VW-22	5	Res	66	**67**	**68**	1	5
VW-23	4	Res	66	56	57	1	
VW-24	2	Res	66	56	57	1	
VW-25	4	Res	66	60	61	1	
VW-26	4	Res	66	**66**	**67**	1	4
VW-27	4	Res	66	60	62	2	
VW-28	8	Res	66	62	63	1	
VW-29	4	Res	66	57	59	2	
VW-30	4	Res	66	59	61	2	
VW-31	4	Res	66	56	58	2	
VW-32	3	Res	66	65	**69**	4	3
VW-33	2	Res	66	60	63	3	
VW-34	4	Res	66	**68**	**72**	4	4
VW-35	8	Res	66	**68**	**70**	2	8
VW-36	2	School Parking	71	**73**	**74**	1	2
VW-36F	22	School	66	65	**66**	1	22

Notes:
1. Number of residences, hotel rooms, or residential equivalence
2. Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
3. Traffic noise impacts criteria
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. No-Build modeled noise levels
6. Change in noise, No-Build minus Existing
7. Number of residences, hotel rooms, or residential equivalents expected to exceed the traffic noise criteria under the No-Build Alternative

5.6.2 Traffic Noise Effects Common to All Build Alternatives

Traffic noise levels were modeled for the four full build alternatives. Modeled results show that there would be no difference in the future traffic noise levels or in the potential number of traffic impacts between the replacement and supplemental alternatives in the area west of I-5 and north of Mill Plain. Under all build alternatives there are 117 noise impacts in this area. This would be an increase of 62 residential impacts above what is projected with the No-Build Alternative.

Exhibit 5-10 shows the future build alternatives traffic noise levels along with the existing and No-Build noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts common to all build alternatives. Six receivers have a difference of 1 dBA between the build alternatives, the remainder are expected to have the same noise levels.

Exhibit 5-10. Future Traffic Noise Level for Replacement Alternative: North of Mill Plain West of I-5

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	Build Alternatives		Replacement Alternative		Impacts[9]		Notes
					Replace[5]	Supp[6]	Change from Exist[7]	Change from No-Bld[8]	Replace	Supp	
VW-1	2	Res	66	**67**	**69**	**69**	2	1	2	2	No existing sound wall in this area
VW-2	4	Res	66	61	62	62	1	0			
VW-3	2	Res	66	**68**	**71**	**70**	3	2	2	2	
VW-4	4	Res	66	63	65	65	2	1			
VW-5	3	Res	66	61	62	62	1	0			
VW-6	4	Res	66	**66**	**67**	**67**	1	0	4	4	
VW-7	3	Res	66	64	65	65	1	0			
VW-8	8	Res	66	**71**	**73**	**73**	2	1	8	8	
VW-9	7	Res	66	63	**66**	**66**	3	2	7	7	
VW-10	3	Res	66	61	**66**	**65**	5	3	3	3	
VW-11	4	Res	66	**67**	**70**	**70**	3	2	4	4	
VW-12	4	Res	66	60	62	62	2	1			
VW-13	5	Res	66	63	**66**	**66**	3	2	5	5	
VW-14	2	Res	66	59	60	60	1	0			
VW-15	3	Res	66	**68**	**71**	**71**	3	1	3	3	Along Mill Plain and I-5 Ramps
VW-16	3	Res	66	64	**66**	**66**	2	1	3	3	
VW-17	4	Res	66	63	**66**	**66**	3	2	4	4	
VW-18	6	Res	66	61	**66**	**65**	5	2	6	6	
VW-19	4	Res	66	58	60	60	2	1			
VW-20	6	Res	66	**69**	**73**	**72**	4	3	6	6	Opening in noise walls
VW-21	4	Res	66	61	**66**	**66**	5	2	4	4	
VW-22	5	Res	66	**67**	**70**	**70**	3	2	5	5	
VW-23	4	Res	66	56	58	58	2	1			
VW-24	2	Res	66	56	59	58	3	2			
VW-25	4	Res	66	60	63	62	3	2			
VW-26	4	Res	66	**66**	**69**	**69**	3	2	4	4	Opening in noise wall

Rec's	Res[1]	Land Use[2]	Criteria[3]	Existing[4]	Build Alternatives		Replacement Alternative		Impacts[9]		Notes
					Replace[5]	Supp[6]	Change from Exist[7]	Change from No-Bld[8]	Replace	Supp	
VW-27	4	Res	66	60	63	63	3	1			
VW-28	8	Res	66	62	**66**	**66**	4	1	8	8	
VW-29	4	Res	66	57	60	60	3	1			
VW-30	4	Res	66	59	62	62	3	1			
VW-31	4	Res	66	56	58	58	2	0			
VW-32	3	Res	66	65	**66**	**66**	1	-3	3	3	
VW-33	2	Res	66	60	61	61	1	-2			
VW-34	4	Res	66	**68**	**66**	**66**	-2	-6	4	4	Near 39th Street
VW-35	8	Res	66	**68**	**73**	**73**	5	3	8	8	No existing sound wall
VW-36	2	School	66	**73**	**78**	**78**	5	4	2	2	Discovery Middle School parking and football field
VW-36F	22	School	66	65	**69**	**69**	4	3	22	22	

Notes:

1. Number of residences or residential equivalents
2. Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail
3. Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington
4. Existing modeled noise levels from TNM version 2.5 with impacts in bold red type
5. Future noise levels with replacement of the existing bridge
6. Future noise levels with the supplemental bridge
7. Change in noise levels, Build Replacement compared to Existing
8. Change in noise levels, Build Replacement compared to No-Build
9. Number of impacts under the Build Replacement and the Supplemental Alternative

5.7 HCT Noise and Vibration Effects

The noise and vibration analyses results for the HCT alternatives are provided in following sections. First, the potential noise levels that would occur with the No-Build Alternative (no HCT) are explained, followed by the effects that would occur under the various HCT mode and alignment alternatives. Finally, the HCT vibration impacts analysis is provided.

There are two basic transit alignment alternatives (Vancouver and I-5) and each of those has two alignment sub-options at their southern ends (Main/Broadway or Broadway for the Vancouver alignment, and 16th or McLoughlin for the I-5 alignment). The differences in projected noise and vibration impacts under the transit alignments and sub-options are included in the discussion where appropriate.

Because the potential HCT noise effects vary substantially depending on the transit mode, the following noise discussion is organized by the LRT and BRT mode options as coupled with the highway alignment options (Replacement and Supplemental). The HCT noise and vibration analysis is then further detailed by the transit alignment options.

5.7.1 No-Build Noise Levels along the HCT Corridors

Noise levels along the HCT corridors will continue to increase as traffic volumes increase. Overall, noise levels are projected to increase the most along I-5 and Main Street north of Mill Plain, where levels are projected to increase by 2 to 4 dBA. Noise levels in the core downtown areas are only predicted to increase by 1 dBA. Increases along McLoughlin and 16th Street should only increase by 1 dBA except for locations close to I-5, where noise level may increase by up to 4 dBA L_{eq}.

Exhibit 5-11 provides a summary of future No-Build noise levels along the proposed HCT corridors.

Exhibit 5-11. Projected Future No-Build L_{eq} and L_{dn} for HCT Corridors

Rec #	Land Use[1]	Res[2]	Alternative Corridor[3]	Existing Noise Levels[4]		No-Build Noise Levels[5]		Change from Existing[6]	
				L_{eq}	L_{dn}	L_{eq}	L_{dn}	L_{eq}	L_{dn}
PD-1	Res	3	Both[7]	66	69	69	70	3	1
PD-2	Res	17	Both[7]	66	69	69	70	3	1
PD-3	Res	16	Both[7]	64	67	67	69	3	2
PD-4	Res	14	Both[7]	63	63	65	65	2	2
PD-5	Res	7	Both[7]	63	63	65	65	2	2
PD-6	Res	15	Both[7]	61	61	63	63	2	2
PD-8	Res	14	Both[7]	66	69	68	70	7	4
PD-11	Res	0	Both[7]	64	65	64	65	0	0
DT-1	Res	2	Both[7]	64	66	65	67	1	1
DT-3	Res	24	Both[7]	69	71	70	71	1	0
DT-9	Res	3	Both[7]	67	69	68	69	1	0

Rec #	Land Use[1]	Res[2]	Alternative Corridor[3]	Existing Noise Levels[4]		No-Build Noise Levels[5]		Change from Existing[6]	
				L_{eq}	L_{dn}	L_{eq}	L_{dn}	L_{eq}	L_{dn}
DT-8	Res	40	Both[7]	66	67	67	68	1	1
VW-2	Res	4	16th Street	61	60	62	61	1	1
VW-3	Res	2	16th Street	65	66	69	70	4	4
VW-37	Res	4	16th Street	61	60	62	61	1	1
VW-38	Res	4	16th Street	60	60	61	61	1	1
VW-6	Res	4	McLoughlin Blvd	67	68	68	69	1	1
VW-7	Res	3	McLoughlin Blvd	66	67	67	68	1	1
VW-39	Res	4	McLoughlin Blvd	63	62	64	63	1	1
VW-40	Res	4	McLoughlin Blvd	63	62	64	63	1	1
VW-41	Res	1	Broadway	64	64	66	66	2	2
VW-42	Res	2	Broadway	64	64	66	66	2	2
VW-43	Res	4	Broadway	64	64	66	66	2	2
VW-44	Res	2	Broadway	64	64	66	66	2	2
VW-45	Res	2	Broadway	65	65	67	67	2	2
VW-46	Res	4	Main Street	69	69	72	72	3	3
VW-47	School	3	Main Street	69	69	72	72	3	3
VW-48	Res	8	Main Street	69	69	72	72	3	3
VW-49	Res	4	Main Street	69	69	72	72	3	3
VW-50	Medical Center	1	Main Street	69	69	72	72	3	3
VW-51	Res	2	Main Street	69	69	72	72	3	3
VW-52	Res	2	Main Street	69	69	72	72	3	3
VW-53	Fire	1	Main Street	69	69	72	72	3	3
VW-54	Res	3	Main Street	69	69	72	72	3	3
VW-55	Res	60	Main Street	69	69	72	72	3	3
VW-56	Res	3	Main Street	69	69	72	72	3	3
VE-1	Park	6	I-5	61	60	64	63	3	3
VE-2	Hospital	1	I-5	66	69	60	60	2	2
VE-3	Res	2	I-5	66	69	71	72	2	2
VE-13	Church	3	I-5	64	67	65	66	1	1
VE-15	Res	8	I-5	63	63	67	68	1	1
VE-16	Res	4	I-5	63	63	70	71	1	1
VE-18	Res	5	I-5	61	61	70	71	1	1

Notes:

1. Land use: Res = residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands
2. Number of representative residences or equivalents
3. Alternatives that use this receiver location
4. Existing Peak-hour L_{eq} for institutional land uses and 24-hour Ldn for residential analysis
5. No-Build alternative Peak-hour L_{eq} for institutional land uses and 24-hour Ldn for residential analysis
6. Change in noise from existing to No-Build
7. This receiver is used for both the I-5 and Vancouver alternative alignments

5.7.2 Light Rail Transit (LRT) Alternatives

The following sections summarize the potential LRT noise impacts under the replacement and supplemental alternatives.

5.7.2.1 Light Rail Transit with Replacement Crossing (Alternative 3)

Under the Hayden Island adjacent alignment there are seven predicted floating home LRT noise impacts, with 21 LRT floating home noise impacts under the Offset alternative. There would be no impacts in downtown Vancouver.

There are 16 moderate noise impacts predicted along McLoughlin Boulevard. No direct noise impacts are expected for the Fly-over. Under the 16th Street Option, there are 10 predicted moderate noise impacts.

Under the two-way Broadway Alternative, there are 24 projected noise impacts along the west side of Broadway, from 19th Street to 25th Street. With the couplet alignment, no noise impacts are projected on Broadway. No noise impacts are predicted along Main Street at any noise sensitive properties.

Exhibit 5-12 is a summary of the LRT impacts for each alignment alternative. Exhibits 5-13 through 5-15 provide aerial views of the LRT noise impacts discussed in this section.

Exhibit 5-12. LRT Noise Levels and Impacts by Transit alignment with Replacement Crossing Alternative

Alignment	Area	Existing L_{dn} Range[1]		Train L_{dn} Range[2]		Combined L_{dn} Range[3]		Impacts	
		Min	Max	Min	Max	Min	Max	Mod[4]	Sev[5]
I-5 Offset	Floating Homes	61	69	55	63	62	69	21	0
I-5 Adjacent	Floating Homes	60	68	55	64	61	69	7	0
Washington 2-Way	Downtown	71	71	56	58	71	71	0	0
McLoughlin	D St to I-5	62	65	56	61	64	67	16	0
I-5 Over Fly-Over	I-5 North of 33rd	70	70	57	61	70	70	0	0
16th Street	C St to I-5	61	70	59	62	63	70	10	0
Broadway 2-way	19th to 29th	64	66	55	63	65	67	24	0
Main Street 2-way	Main North of 29th	70	70	60	60	70	70	0	0
Broadway-Main Couplet	19th to 29th	64	66	55	57	65	66	0	0

Notes:
1. Existing range of day-night noise levels expected within the noted Area.
2. Predicted range of day-night noise levels expected within the noted Area due to proposed LRT operations
3. Existing Ldn range plus Train Ldn range and compared to the FTA Impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*.
4. Moderate Impacts – Per FTA impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*. FTA requires that mitigation be evaluated for all areas where moderate impacts are projected, although consideration of factors such as cost effectiveness can be incorporated into the decision about whether to specify mitigation for a particular area.
5. Severe Impacts - Per FTA impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*. FTA considers severe impact to be a “significant adverse effect” in the context of the National Environmental Protection Act (NEPA). Noise impacts in the severe range represent the most compelling need for mitigation.

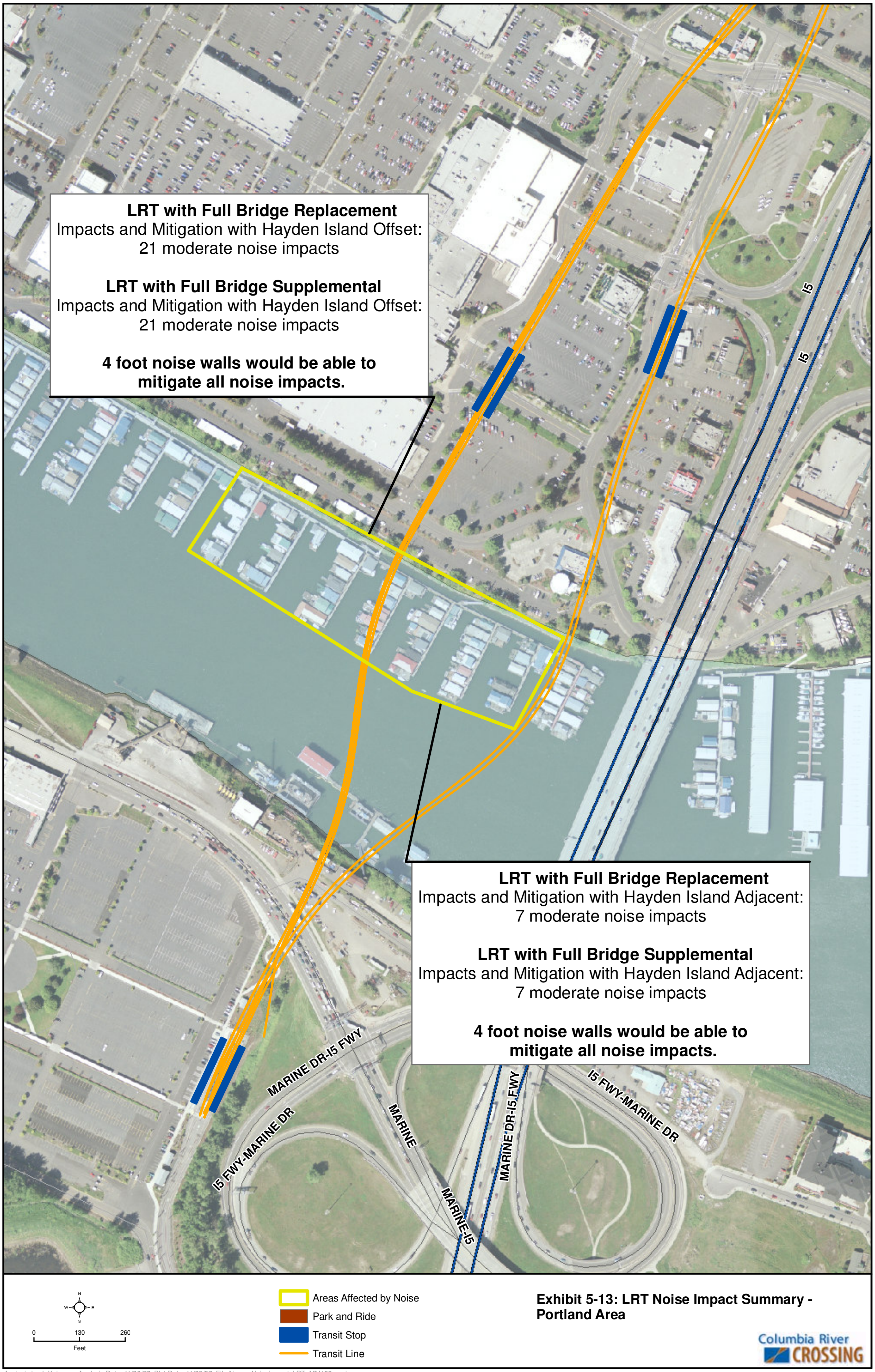


Exhibit 5-13: LRT Noise Impact Summary - Portland Area

Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseimpactsLRT_MM133.mxd

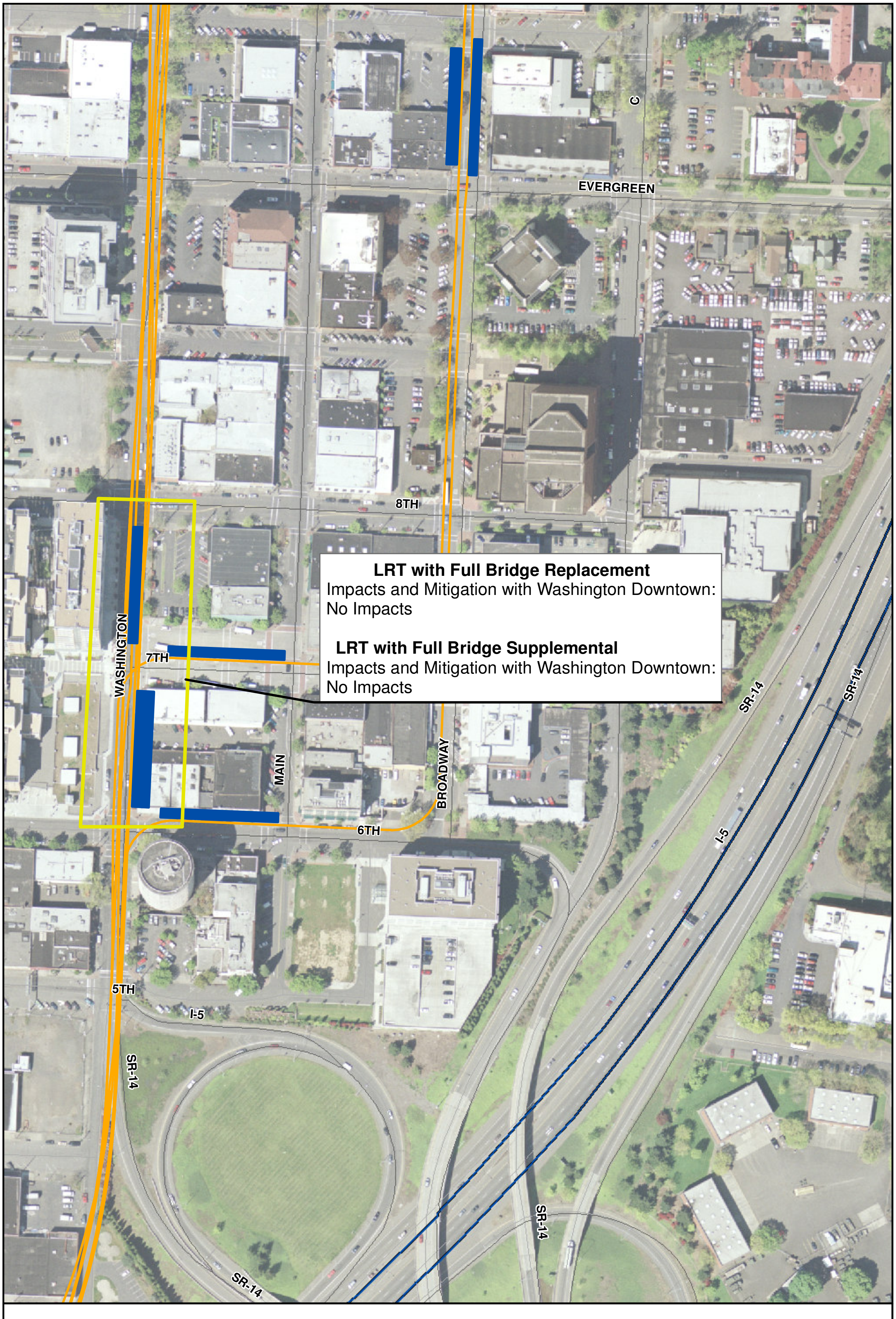


Exhibit 5-14: LRT Noise Impact Summary - Downtown Vancouver Area

Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseimpactsLRT_MM133.mxd

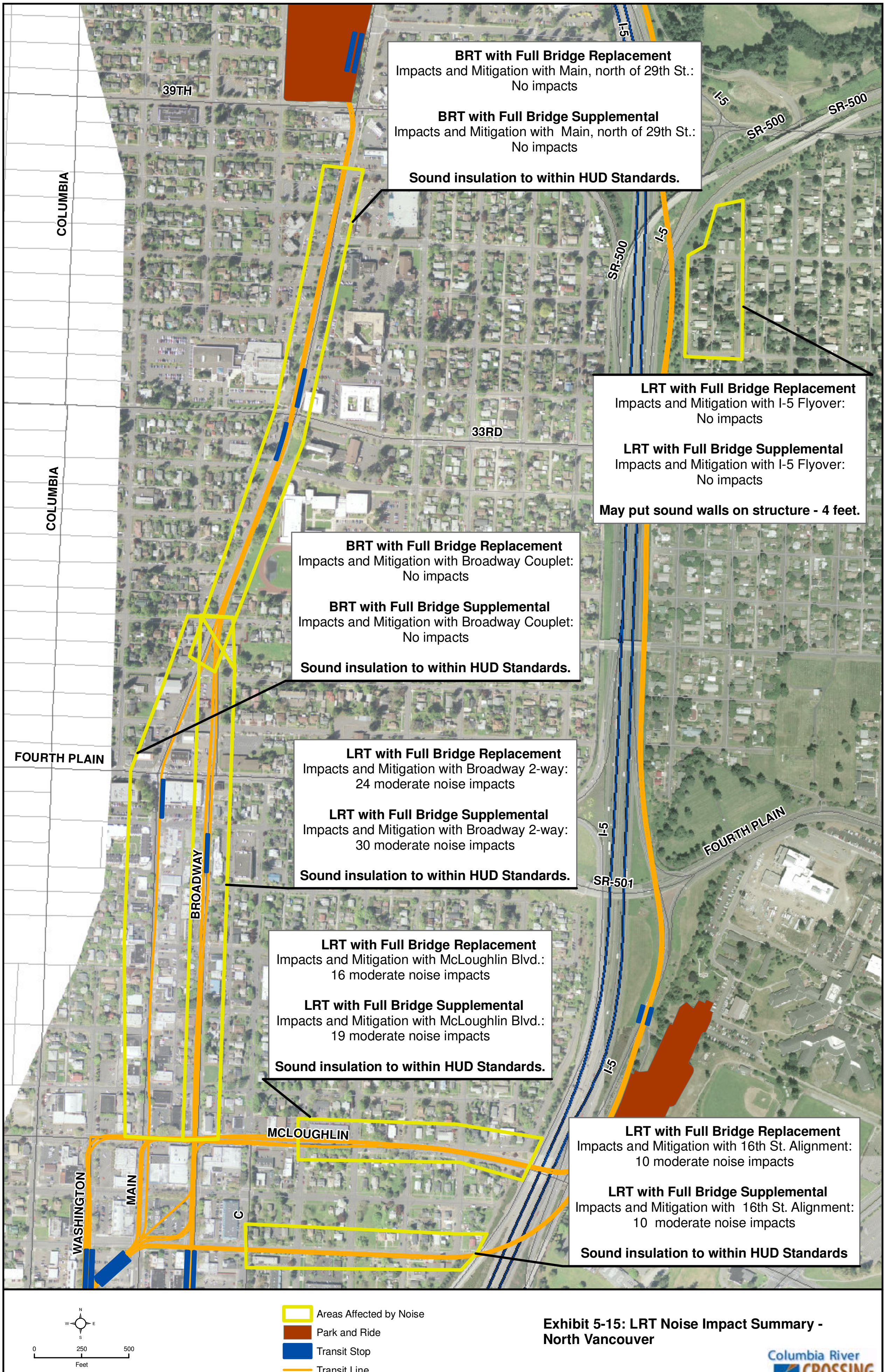


Exhibit 5-15: LRT Noise Impact Summary - North Vancouver

Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseimpactsLRT_MM133.mxd

5.7.2.2 Light Rail Transit with Supplemental Crossing (Alternative 5)

With the Supplemental Bridge, LRT headways would increase slightly during off-peak hours. The light rail is predicted to cause 7 impacts at the floating homes under the Hayden Island Adjacent alternative and 21 impacts under the Hayden Island Offset alternative. No noise impacts are projected in Downtown Vancouver areas.

There are 19 moderate noise impacts predicted along McLoughlin Boulevard. Again, no direct noise impacts are expected for the Fly over. The 16th Street Alternative is projected to cause up to 10 noise impacts, which is the same as under the Replacement Crossing alternative.

Thirty moderate noise impacts are predicted along the west side of Broadway Street between East 19th Street and East 29th Street. There are no noise impacts under the Broadway Couplet or north of East 29th Street along Main Street. Exhibit 5-16 summarizes of the LRT impacts for each alignment alternative.

Exhibit 5-16. LRT Noise Levels and Impacts by Transit alignment with Supplemental Crossing Alternative

Alignment	Area	Existing L_{dn} Range[1]		Train L_{dn} Range[2]		Combined L_{dn} Range[3]		Impacts	
		Min	Max	Min	Max	Min	Max	Mod[4]	Sev[5]
I-5 Offset	Floating Homes	61	69	56	63	62	69	21	0
I-5 Adjacent	Floating Homes	60	68	55	64	61	69	7	0
Washington 2-Way	Downtown	71	71	60	60	71	71	0	0
McLoughlin	D St to I-5	62	65	57	62	64	67	19	0
I-5 Over Fly-Over	I-5 North of 33rd	70	70	57	61	70	70	0	0
16th Street	C St to I-5	61	70	59	63	63	70	10	0
Broadway 2-way	19th to 29th	64	66	55	64	65	67	30	0
Main Street 2-way	Main North of 29th	70	70	60	61	61	61	0	0
Broadway-Main Couplet	19th to 29th	64	66	55	58	58	58	0	0

Notes:
1. Existing range of day-night noise levels expected within the noted Area.
2. Predicted range of day-night noise levels expected within the noted Area due to proposed LRT operations
3. Existing Ldn range plus Train Ldn range and compared to the FTA Impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*.
4. Moderate Impacts – Per FTA impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*. FTA requires that mitigation be evaluated for all areas where moderate impacts are projected, although consideration of factors such as cost effectiveness can be incorporated into the decision about whether to specify mitigation for a particular area.
5. Severe Impacts - Per FTA impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*. FTA considers severe impact to be a “significant adverse effect” in the context of the National Environmental Protection Act (NEPA). Noise impacts in the severe range represent the most compelling need for mitigation.

5.7.3 Bus Rapid Transit (BRT) Alternative

The following sections summarize the potential BRT noise impacts under the Replacement and Supplemental Crossing alternatives. Exhibits 5-17 through 5-19 provide aerial views of the BRT noise impacts discussed in this section.

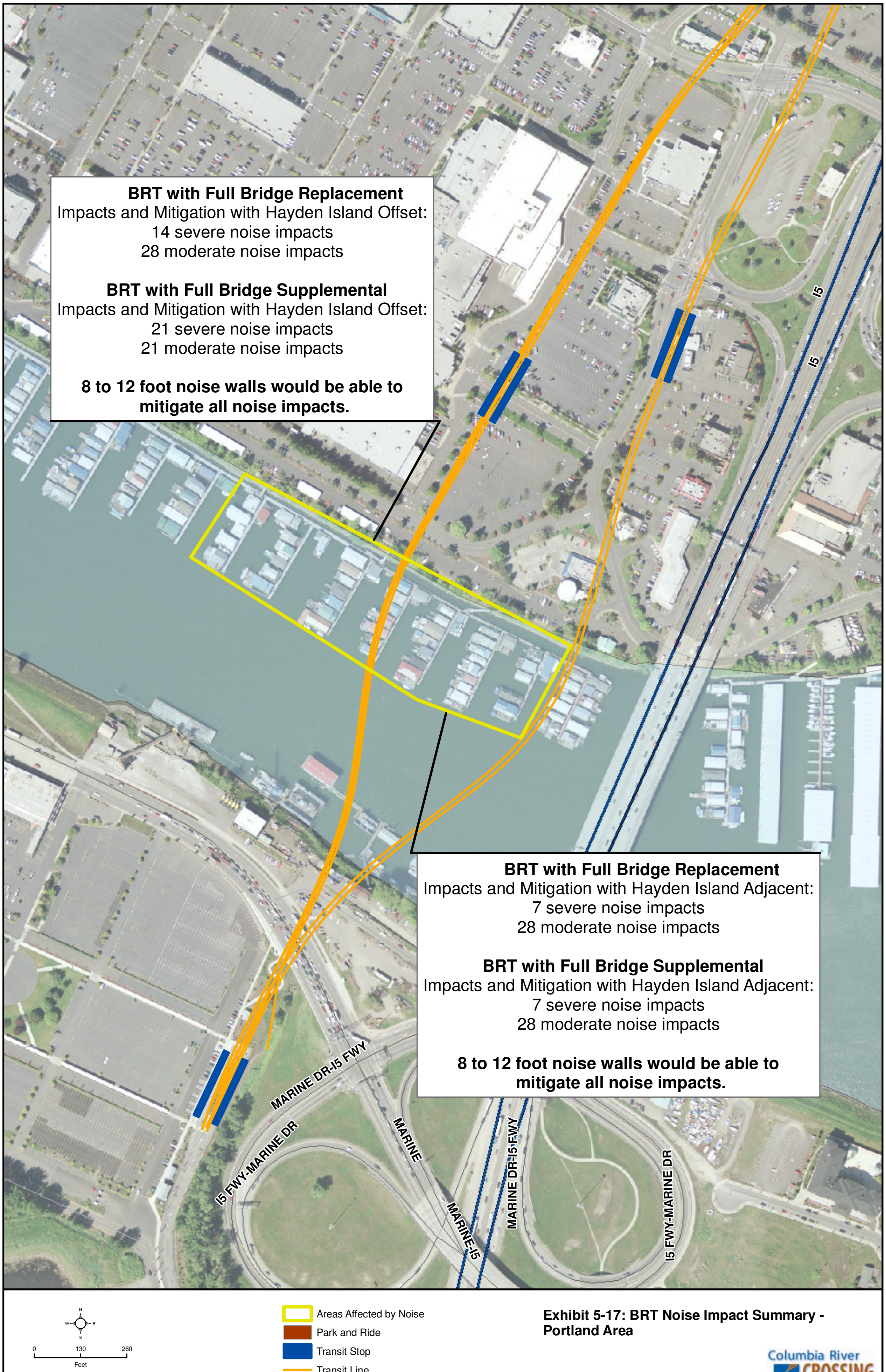
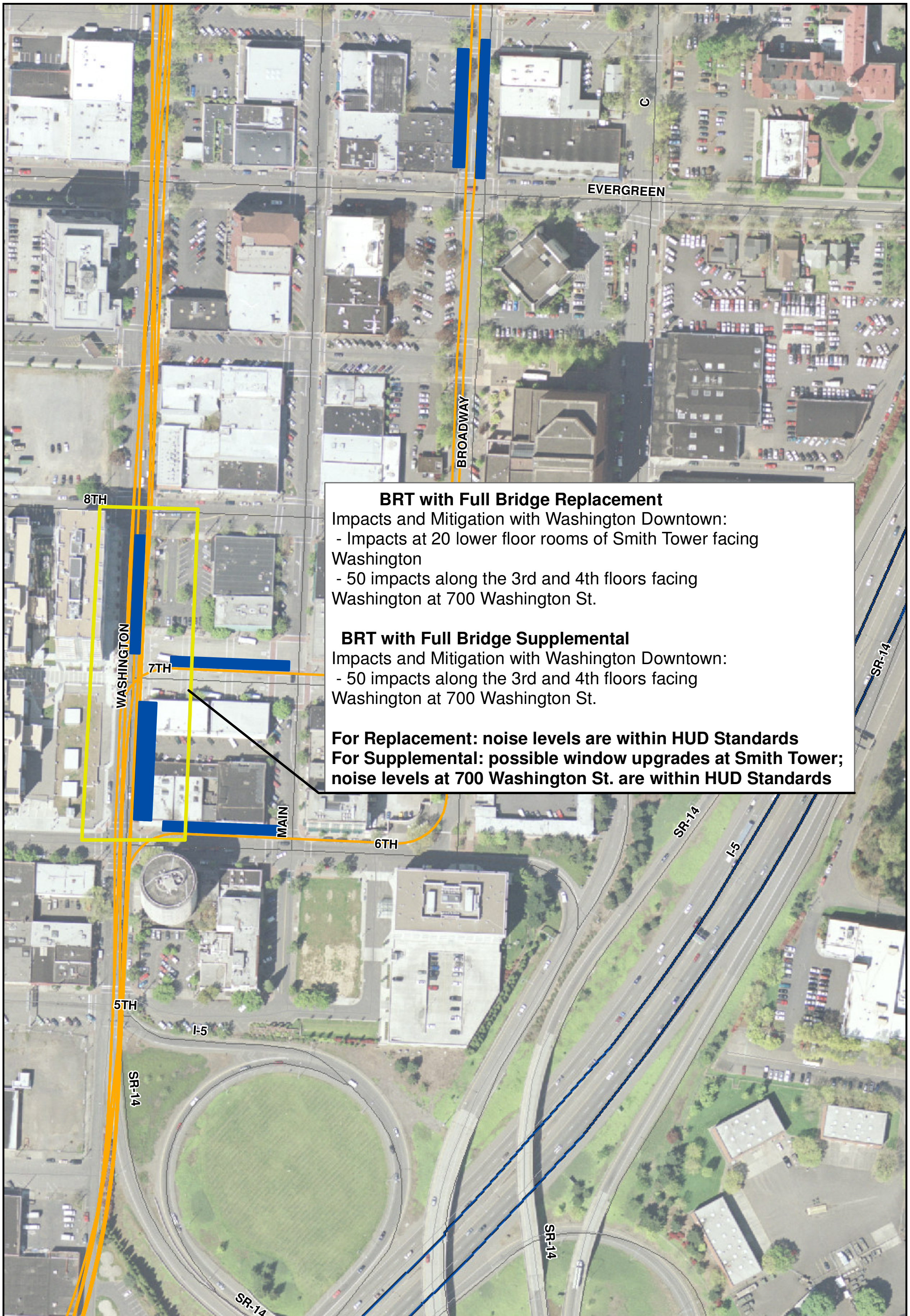


Exhibit 5-17: BRT Noise Impact Summary - Portland Area

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: Noiseimpacts_MM133.mxd



Areas Affected by Noise
Park and Ride
Transit Stop
Transit Line

Exhibit 5-18: BRT Noise Impact Summary - Downtown Vancouver Area

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseimpactsBRT_MM133.mxd

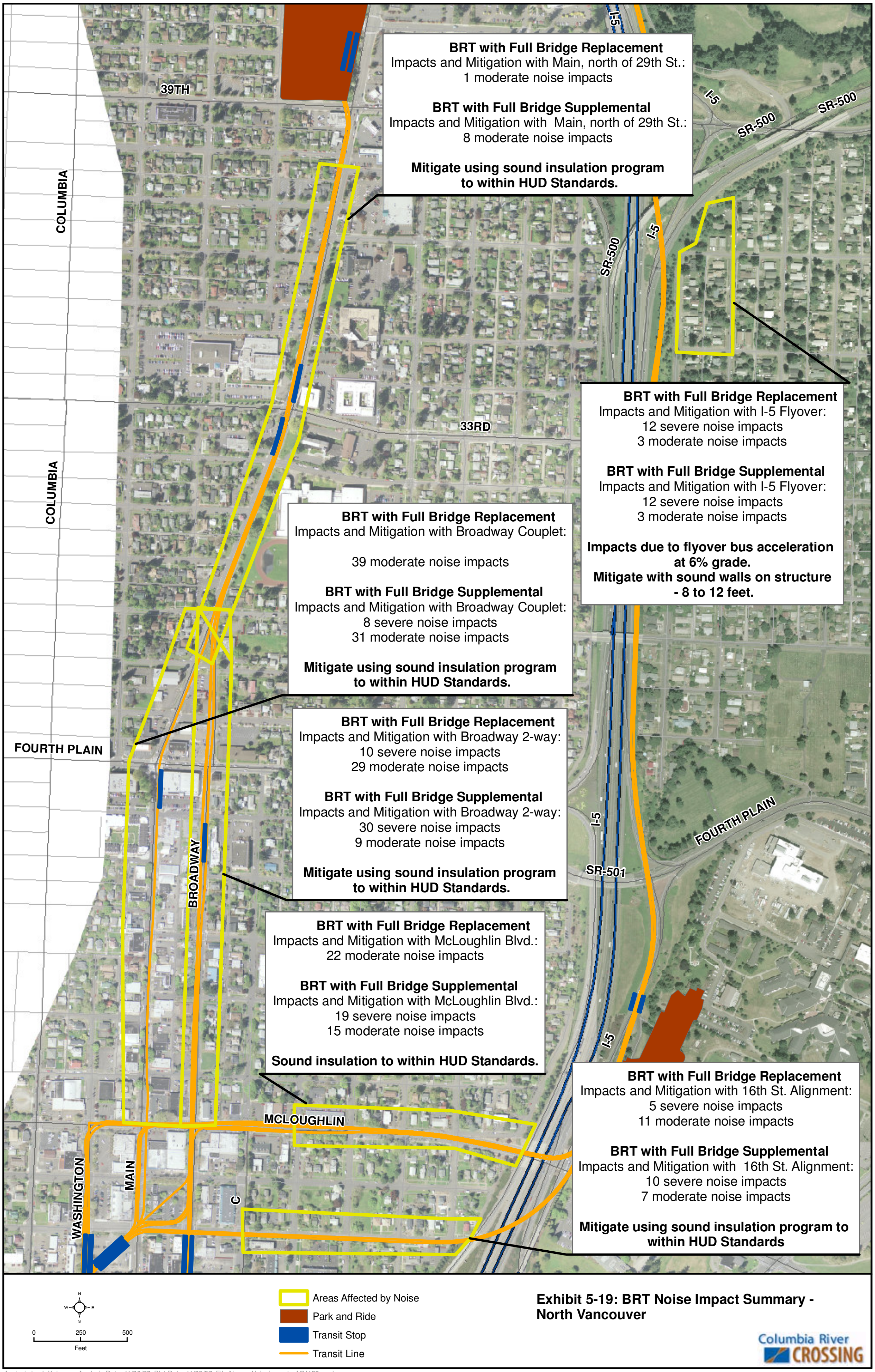


Exhibit 5-19: BRT Noise Impact Summary - North Vancouver

Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseImpacts_MM133.mxd

5.7.3.1 Bus Rapid Transit with Replacement Crossing (Alternative 2)

Under BRT with the replacement crossing alternative there are 42 projected floating home noise impacts for the Hayden Island adjacent alignment, and 35 floating home noise impacts for the Off-set Alternative. The Hayden Island offset alignment would have 14 impacts considered severe under the FTA criteria, which is also considered a significant impact under NEPA guidelines. The adjacent alternative would have seven severe noise impacts.

Noise impacts are also projected at the lowest residential floors of 700 Washington Street, however the interior noise levels are predicted to be within the HUD guidelines.

The McLoughlin Boulevard route would result in 22 noise impacts. An additional 12 severe noise impacts and three moderate noise impacts are predicted along the I-5 fly-over due to the BRT alignment being aerial with a 6 percent grade. The 16th Street alignment is projected to have 11 moderate noise impacts and 5 severe noise impacts. Again, the severe noise impacts are considered significant under NEPA guidelines.

The two-way Broadway alignment would result in 29 moderate and 10 severe impacts. The couplet would have the same number of impacts; however there are no severe impacts under the couplet. North of 29th Street, only one single family residence was identified with noise impact. There would be no noise impact at the Fire Station at 27th Street or the Vancouver School of Arts Academics.

Exhibit 5-20 summarizes the BRT impacts for each alignment alternative.

Exhibit 5-20. BRT Noise Levels and Impacts by Transit alignment with Replacement Crossing Alternative

Alignment	Area	Existing L_{dn} Range[1]		Train L_{dn} Range[2]		Combined L_{dn} Range[3]		Impacts	
		Min	Max	Min	Max	Min	Max	Mod[4]	Sev[5]
I-5 Offset	Floating Homes	61	69	60	68	64	70	28	14
I-5 Adjacent	Floating Homes	60	68	60	68	63	71	28	7
Washington 2-Way	Downtown	71	71	64	64	71	71	0	0
McLoughlin	D St to I-5	62	65	61	65	66	68	22	0
I-5 Over Fly-Over	I-5 North of 33rd	70	70	68	72	72	74	3	12
16th Street	C St to I-5	61	70	63	66	65	71	11	5
Broadway 2-way	19th to 29th	64	66	61	68	66	69	29	10
Main Street 2-way	Main North of 29th	70	70	64	64	71	71	1	0
Broadway-Main Couplet	19th to 29th	64	66	62	65	66	68	39	0

1. Existing range of day-night noise levels expected within the noted Area.
2. Predicted range of day-night noise levels expected within the noted Area due to proposed LRT operations
3. Existing Ldn range plus Train Ldn range and compared to the FTA Impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*.
4. Moderate Impacts – Per FTA impact criteria as given in Exhibit 2 5. FTA Transit Noise Impact Criteria. FTA requires that mitigation be evaluated for all areas where moderate impacts are projected, although consideration of factors such as cost effectiveness can be incorporated into the decision about whether to specify mitigation for a particular area.
5. Severe Impacts - Per FTA impact criteria as given in Exhibit 2 5. FTA Transit Noise Impact Criteria. FTA considers severe impact to be a “significant adverse effect” in the context of the National Environmental Protection Act (NEPA). Noise impacts in the severe range represent the most compelling need for mitigation.

5.7.3.2 Bus Rapid Transit with Supplemental Crossing (Alternative 4)

Under BRT with the supplemental crossing, the number of buses per hour would increase, resulting in a slight increase in noise levels throughout the corridor. The number of noise impacts at floating homes would remain the same as under the Replacement Crossing alternative. In downtown Vancouver, noise impacts would occur at 700 Washington Street and the lower residential floors of the Smith Tower.

Projected noise impacts along McLoughlin Boulevard would be highest under the BRT alternative, with 15 moderate noise impacts and 19 severe noise impacts. Noise impacts are projected at all residences along McLoughlin Boulevard with the BRT alternative. The 19 projected severe impacts would be considered significant impacts under NEPA guidelines, and the FTA recommends avoiding severe impacts whenever possible. Under the 16th Street alignment, there are 10 severe and 7 moderate noise impacts.

There are 9 moderate and 30 severe noise impacts predicted along Broadway between East 18th and 29th Streets. An additional 8 moderate noise impacts would also be expected along Main Street, north of 29th Street, including the Fire Department on East 27th Street. Under the couplet alignment, the noise impacts would be reduced to 31 moderate and 8 severe noise impacts. Again, severe impacts are considered significant impacts under NEPA guidelines, and the FTA recommended avoiding sever impacts whenever possible. Exhibit 5-21 is a summary of the BRT impacts for each alignment alternative.

Exhibit 5-21. BRT Noise Levels and Impacts by Transit Alignment with Supplemental Crossing Alternative

Alignment	Area	Existing L_{dn} Range[1]		Train L_{dn} Range[2]		Combined L_{dn} Range[3]		Impacts	
		Min	Max	Min	Max	Min	Max	Mod	Sev
I-5 Offset	Floating Homes	61	69	62	69	64	70	21	21
I-5 Adjacent	Floating Homes	60	68	61	70	64	72	28	7
Washington 2-Way	Downtown	71	71	65	66	71	71	3	0
McLoughlin	D St to I-5	62	65	62	67	67	69	15	19
I-5 Over Fly-Over	I-5 North of 33rd	70	70	0	0	70	70	3	12
16th Street	C St to I-5	61	70	64	68	67	71	10	7
Broadway 2-way	19th to 29th	64	66	63	69	66	70	9	30
Main Street 2-way	Main North of 29th	70	70	65	66	71	71	8	0
Broadway-Main Couplet	19th to 29th	64	66	64	66	67	68	31	8

1. Existing range of day-night noise levels expected within the noted Area.
2. Predicted range of day-night noise levels expected within the noted Area due to proposed LRT operations
3. Existing Ldn range plus Train Ldn range and compared to the FTA Impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*.
4. Moderate Impacts – Per FTA impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*. FTA requires that mitigation be evaluated for all areas where moderate impacts are projected, although consideration of factors such as cost effectiveness can be incorporated into the decision about whether to specify mitigation for a particular area.
5. Severe Impacts - Per FTA impact criteria as given in Exhibit 2 5. *FTA Transit Noise Impact Criteria*. FTA considers severe impact to be a “significant adverse effect” in the context of the National Environmental Protection Act (NEPA). Noise impacts in the severe range represent the most compelling need for mitigation.

5.7.4 HCT Vibration Impacts

Vibration impacts are only considered for the LRT vehicles, as buses rarely produce vibration levels high enough to meet the criteria. Although all vehicular traffic causes ground-borne vibration, the vibration is not usually perceptible because of the vibration isolation characteristics of the pneumatic tires and the suspension systems. Complaints about building vibration caused by traffic are usually associated with a discontinuity in the road such as a bump, pothole, or wide expansion joint. Therefore, vibration from Bus Rapid Transit is not considered in this study.

Vibration impacts resonate from the LRT wheel/rail interface and are influenced by wheel/rail roughness, transit vehicle suspension, train speed, track construction, location of switches and crossovers, and the geologic strata underlying the track. Vibration generated by a passing light rail train propagates through the ground and into building foundations, causing the building to vibrate. Ground-borne vibrations from light rail trains are of such a low level that, for this project, there is essentially no possibility of structural damage to buildings near the route. Thus, 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.

The procedures used to evaluate potential impacts from ground-borne vibration and ground-borne noise follows those outlined in the FTA manual, *Transit Noise and Vibration Impact* Assessment, May 2006. Vibration impacts are estimated based on extensive field vibration tests performed by Wilson, Ihrig, & Associates, Inc for Tri-Met light rail operations. In addition to the field data collected, the magnitude of the vibration forces are estimated based on analyzing the combined effects of the proposed LRT train's suspension, the wheel and rail condition, and the track support system. Once the magnitude of the vibration forces that the passing train would transmit to the track is calculated, the last step is to project how that vibration would propagate through the soil and eventually into the nearby buildings.

To what degree the train induced vibration would propagate through the soil was based on the vibration propagation measurements at four locations in Vancouver near the proposed HCT alignment alternatives as described above in Section 2.6.5.1 *Vibration Measurement Locations*. The combination of the magnitude of vibration forces and the soil's propagation characteristic provides an estimate of vibration at the ground surface as a function of the horizontal distance from the surface tracks. Adjustments are then used to account for train speed, mitigation measures, and building foundation. In addition, a 5-decibel safety factor has been incorporated into all of the ground-borne vibration and ground-borne noise projections. The purpose of the safety factor is to account for the normal fluctuations in ground-borne vibration and to ensure that the projections tend to be on the conservative side.

There would be no vibration impacts predicted in Portland because the alignment is on a structure and all vibration sensitive receivers are located along the Columbia River. There are 12 residential locations along the McLoughlin Boulevard that would have predicted vibration levels within the safety factors for vibration impacts. Under the 16th Street alignment, there would be 5 predicted vibration impacts. There would be an additional 35 vibration impacts predicted along the I-5 alignment in the retain cut section, from 26th to 33rd Streets along the east side of I-5. Up to 24 vibration impacts are predicted along the Broadway alignment, and eight vibration impacts are predicted along Main Street. There is no vibration impact expected at the Medical Center, but vibration levels would exceed the residential criteria at the Fire Department on 37th Street.

Exhibit 5-22 is a summary of the potential vibration impacts by location.

Exhibit 5-22. Light Rail Vibration Impact Summary

Alignment Alternative	Area	Impact Criteria (VdB)[1]	Predicted Level (VdB)[2]	Vibration Impact[3]
All	Portland (residential) Portland (Commercial)	72 75	<62 <65	0 0
Washington	Downtown Vancouver (residential) Downtown Vancouver (Commercial)	72 75	69 to 71 71 to 74	0 0
I-5 via McLoughlin	McLoughlin (residential) McLoughlin (Commercial)	72 75	72 to 73 61 to 73	12 0
I-5 via McLoughlin Full	I-5, 26th to 33rd (residential)	72	74 to 76	35
I-5 via 16th Street	16th Street (residential)	72	78	5
Broadway 2-way or Couplet	Broadway (residential) Broadway (commercial)	72 75	72 to 73 72 to 73	24 0
Vancouver	Main north of 29th Street (residential) Main north of 29th Street(commercial)	72 75	72 to 73 72 to 73	8 0

Notes:
1. As established by the FTA manual, *Transit Noise and Vibration Impact Assessment*, May 2006.
2. Based on expected magnitude of LRT ground-borne vibration and vibration propagation characteristics of soils along the HCT proposed alignments.
3. Number of impacted structures that require the consideration of LRT vibration mitigation.

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6. Temporary Effects

6.1 Construction Noise and Vibration Analysis

This analysis considers the temporary noise effects that construction would cause in the project area. These effects would end when project construction is completed.

6.1.1 Construction Equipment

Equipment required to complete the project includes normal construction equipment that is used for many roadway and structural activities. Exhibit 6-1 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.

Exhibit 6-1. Construction Equipment List, Use, and Reference Maximum Noise Levels

Equipment	Typical Expected Project Use	Lmax[1]	Source[2]
Air Compressors	Used for pneumatic tools and general maintenance - all	70 - 76	a, b, c
Backhoe	General construction and yard work	78 - 82	b, c
Concrete Pump	Pumping concrete	78 - 82	b, c
Concrete Saws	Concrete removal, utilities access	75 - 80	b, c
Crane	Materials handling, removal, and replacement	78 - 84	b, c
Excavator	General construction and materials handling	82 - 88	b, c
Forklifts	Staging area work and hauling materials	72	a, b, c
Haul Trucks	Materials handling, general hauling	86	b, c
Jackhammers	Pavement removal	74 - 82	b, c
Loader	General construction and materials handling	86	b, c
Pavers	Roadway paving	88	b
Pile Drivers	Support for structure and hillside	99 - 105	b, c
Power Plants	General construction use, nighttime work	72	b, c
Pumps	General construction use, water removal	62	b, c
Pneumatic Tools	Miscellaneous construction work	78 - 86	c
Service Trucks	Repair and maintenance of equipment	72	b, c
Tractor Trailers	Material removal and delivery	86	c
Utility Trucks	General project work	72	b
Vibratory equipment	Shore up hillside to prevent slides and soil compacting	82 - 88	b, c
Welders	General project work	76	b, c

Notes:

1. Maximum noise level as measured at a distance of 50 feet under normal operation.
2. Sources of noise levels presented:

   a) Portland, Oregon Area Projects: Light rail, I-5 Preservation and Hawthorn Bridge construction projects

   b) Other measured date from Portland area projects

   c) USDOT construction noise documentation and other construction noise sources

6.1.2 Project Construction Phases and Noise Levels

Several different construction phases would be required to complete the replacement or supplemental crossing and HCT project. To provide the reader with a general understanding of how loud the construction might be, we have performed an analysis that assumes worst-case noise levels based on four expected construction activities. The actual noise levels experienced during construction would generally be lower than those given in this report. The noise levels we have presented here are for periods of maximum construction activity.

Typical construction phases for the CRC project would include:

- Preparation for construction of new structures
- Construction of new structures and roadway paving
- Miscellaneous activities, including striping, lighting, and signs
- Demolition of existing structures

6.1.2.1 Preparation

Major noise-producing equipment used during the preparation stage could include concrete pumps, cranes, excavator, haul trucks, loader, tractor trailers, and vibratory equipment. Maximum noise levels could reach 82 to 86 dBA at the nearest residences (50 to 100 feet) for normal construction activities during this phase.

Other major noise sources that may be required during this phase would include the use of vibratory and impact equipment, such as pile driving and vibratory sheet installations. The purpose of these activities would be to supply support for the new structure and to shore up hillsides to stop slides before retaining walls are installed. Pile driving noise levels are discussed in a separate section below.

Other less notable noise-producing equipment expected during this phase include backhoe, air compressors, forklifts, pumps, power plants, service trucks, and utility trucks.

6.1.2.2 Construction

The loudest noise sources in use during construction of the new bridge would include cement mixers, concrete pumps, pavers, haul trucks, and tractor trailers. The cement mixers and concrete pumps would be required for construction of the superstructure. The pavers and haul trucks would be used to provide the final surface on the roadway and to construct the transitions from the at-grade roadway to the new structures. Maximum noise levels would range from 82 to 94 dBA at the closest receiver locations.

6.1.2.3 Miscellaneous Activities

Following the heavy construction, general construction such as installation of bridge railing, signage, roadway striping, and other general activities would still need to occur.

These less intensive activities are not expected to produce noise levels above 80 dBA at 50 feet except during rare occasions, and even then only for short periods.

6.1.2.4 Demolition

Demolition of the existing structures would require heavy equipment such as concrete saws, cranes, excavators, hoe-rams, haul trucks, jackhammers, loaders, and tractor trailers. Maximum noise levels could reach 82 to 92 dBA at the nearest residences.

Exhibit 6-2 provides the noise levels for each of the four typical construction phases as measured at 50 feet from the construction activity. The noise levels in Exhibit 6-2 are the typical maximums and would only occur periodically during the heaviest periods of construction. Actual hourly noise levels could be substantially lower than those stated depending on the level of activity at that time and the distance from the work site to the noise sensitive properties.

Exhibit 6-2. Noise Levels for Typical Construction Phases

Scenario[a]	Equipment[b]	Lmax[c]	Leq[d]
Construction preparation	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 new structures and roadway 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, including striping, lighting and signs	Air compressors, backhoe, crane, forklifts, haul trucks, loader, pumps, service trucks, tractor trailers, utility trucks, welders	91	83
Demolition of existing structures	Air compressors, backhoe, concrete saws, crane, excavator, forklifts, haul trucks, jackhammers, loader, power plants, pneumatic tools, pumps, service trucks, utility trucks	93	88

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.

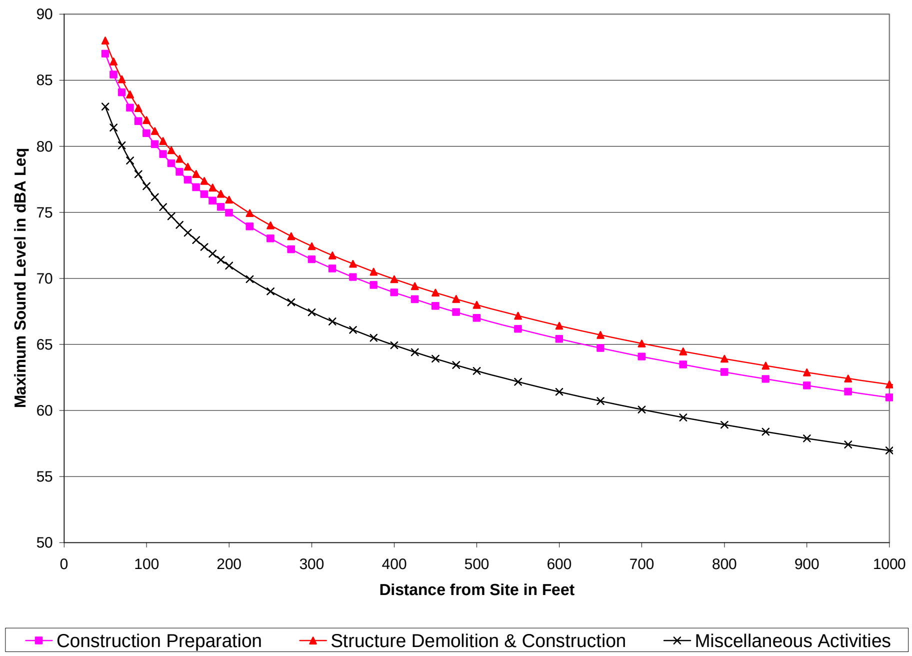
[b] Normal equipment in operation under the given scenario.

[c] Lm (dBA) is an average maximum noise emission for the construction equipment under the given scenario. For this type of equipment and activities, the Lm is approximately equal to the L_{01}.

[d] Leq (dBA) is an energy average noise emission for construction equipment operating under the given scenario. For this type of equipment, the Leq is approximately equal to the L50.

Using the information given in Exhibit 6-2, typical construction noise levels were projected for several distances from the project work area. Exhibit 6-3 graphs a general noise level versus distance for the Columbia River Crossing project phases of construction.

Exhibit 6-3. Noise Level versus Distance for Typical Construction Phases



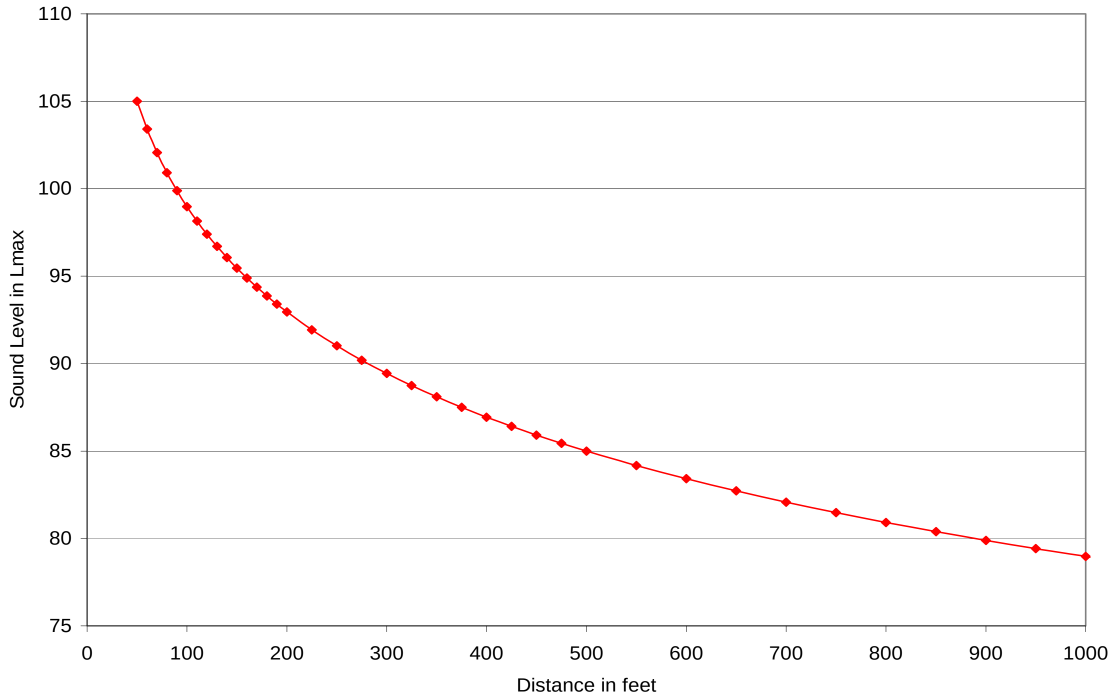
6.1.3 Pile Driving

Pile driving will be required for either bridge alternative and will be used to support the permanent structures. Pile driving can produce maximum short-term noise levels of 99 to 105 dBA at 50 feet. Actual levels can vary and would depend on the distance and topographical conditions between the pile-driving location and the receiver location. Exhibit 6-4 is a graph of maximum pile driving noise levels versus distance from 50 to 1,000 feet.


MARINE PILE DRIVER

Noise from pile driving also has the potential to affect fish and wildlife. Pile driving has the potential to produce noise levels of 190 dB at 150 feet from the source in deep water. However, noise attenuates more quickly in shallow water where most piles would be driven. Studies have shown that waterborne noise levels of 180 dB or more can injure fish and potentially cause mortality.

Exhibit 6-4. Noise Level versus Distance for Typical Construction Phases



6.1.4 Construction Vibration Effects

Vibration associated with general construction can result in vibration effects to surrounding receivers. Major vibration-producing activities would occur primarily during demolition and preparation for the new bridges. Activities that have the potential to produce a high level of vibration include pile driving, vibratory shoring, soil compacting, and some hauling and demolition activities. Vibration effects from pile driving or vibratory sheet installations could occur within 50 to 100 feet of from this construction activity. It is unlikely that vibration levels would exceed 0.5 inch per second at distances greater than 100 feet from the construction sites.

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7. Mitigation for Long-Term Effects

7.1 Introduction

When project-related noise impacts are identified, traffic noise mitigation measures must be considered. Mitigation measures that meet applicable feasibility and reasonableness criteria may be recommended for inclusion into the project. Feasibility deals primarily with engineering considerations such as whether substantial noise level reductions can be achieved or whether there will be a negative effect on property access. Reasonableness assesses the practicality of the abatement measure given a number of factors. Such factors include cost, amount of noise reduction, and future absolute traffic noise levels.

Several different traffic noise abatement measures are evaluated whenever noise impacts are expected. Under WSDOT policy, the six abatement measures listed in FHWA *Procedures for Abatement of Highway Traffic Noise and Construction Noise,* 23 CFR 772, US Code of Federal Regulations, 1996 must be considered:

1. Traffic management measures (e.g., traffic control devices and signing for prohibition of certain vehicle types, time-use restrictions for certain vehicle types, modified speed limits, and exclusive land designations).
2. Alteration of horizontal and vertical alignments.
3. Acquisition of property rights (either in fee or lesser interest) for construction of noise barriers.
4. Construction of noise barriers (including landscaping for aesthetic purposes) whether within or outside the highway right-of-way. Interstate construction funds may not participate in landscaping.
5. Acquisition of real property or interests therein (predominantly unimproved property) to serve as a buffer zone to preempt development which would be adversely impacted by traffic noise. This measure may be included in Type I projects only.
6. Noise insulation of public use or nonprofit institutional structures.

7.1.1 Traffic Management Measures

Each of the traffic management measures listed above were considered to be either impracticable or in direct conflict with the objectives of this project as published in the *CRC I-5/Columbia River Crossing Statement of Purpose and Need Statement,* January 2007. Lowering the speed limits would have the affect of lowering traffic noise levels, however, lower travel speeds would conflict with the project objective to improve travel times throughout the Bridge Influence Area (BIA). Similarly, restricting or prohibiting truck traffic use on the project roadways would reduce noise levels at nearby receivers since trucks are louder than cars. However, I-5 is part of the National Truck Network and impairing freight movement on this important freight freeway would render the project itself an unnecessary endeavor.

7.1.2 Highway Design Measures

Highway design measures include altering the roadway alignment and depressing roadway cut sections. Alteration of roadway alignment could decrease noise levels by moving the noise source farther away from the affected receivers. However, noise impacts occur along both sides of the project roadway. Subsequently, altering the particular alignments would lower noise levels for residences on one side of the freeway, but would increase noise levels for residences on the other side of the freeway.

Lowering the I-5 vertical alignment in the downtown Vancouver area and farther north might be possible starting at a point where the elevated I-5 bridge structure would return to ground elevation near East Mill Plain Boulevard. Depressing the I-5 vertical alignment would lower the source of the vehicle noise from the sensitive receivers and the resulting cut and retaining walls would effectively block the line of sight between the vehicles and the residences along the freeway. Altering the vertical alignment would effectively lower noise levels; however, the costs and impacts associated with this highway design measure are not likely to meet the WSDOT criteria for reasonableness.

7.1.3 Noise Barriers

Construction of noise barriers between the roadways and the affected receivers would reduce noise levels by physically blocking the transmission of traffic-generated noise. Barriers can be constructed as walls or earthen berms. Earthen berms require more right-of-way than walls, and are usually constructed with a 3-to-1 slope. Noise barriers should be high enough to break the line-of-sight between the noise source and the receiver. They must also be long enough to prevent significant flanking of noise around the ends of the walls.

Two areas near the I-5 and SR 500 interchange were evaluated for a possible berm or a berm-noise wall combination. Along the east side of the I-5 corridor between East 33rd Street and East 37th Street, there is currently an available land buffer that ranges in width from 150 feet near 33rd Street down to 100 feet near 37th Street. Another possible location for an earthen berm or berm-wall combination is on the west side of I-5 north of East 39th along the Discovery Middle School outdoor field. Because the final alignment of the project is unknown at this time, berms and berm-wall combinations will be considered again in the FEIS and again in the final design phase.

7.1.4 Acquisition of Property Rights for Construction of Noise Barriers

Depending on the final placement of any recommended noise barrier mitigation (berms or walls) additional property rights may be needed for the construction of the noise barriers. Under WSDOT policy, noise barriers are normally evaluated and constructed within WSDOT’s rights of way. There may be cases in which department right of way is not the most prudent location for abatement, but abatement may be reasonable if constructed on adjacent property. WSDOT notes that in these cases:

- The department's mitigation cost reasonableness allowance is limited to normal cost for abatement on department right of way;

- The adjacent property owners allow access and easements as necessary to construct and maintain the abatement; and
- Any additional cost to acquire access, acquire property, provide alternative access, or provide additional infrastructure to accommodate access must be added to the barrier cost calculation and compared to the normal reasonableness cost allowance of the abatement to determine whether the proposed abatement is reasonable.

During final design, noise abatement recommendations may change due to design changes and actual right-of-way acquisitions.

7.1.5 Noise Insulation (public use or nonprofit institutional structures)

Architectural treatment for noise mitigation may be used for public or non-profit institutional buildings such as schools, churches or libraries. Building-retrofits are considered on a case-by-case basis and determined during the final design stage. Some possible mitigation measures to reduce interior noise levels below the impact criteria are described below.

7.1.5.1 Ventilation Systems

In public buildings where windows are used for ventilation, noise impacts may occur. Closing the windows is often sufficient to reduce interior noise levels below the impact level. To re-establish the ventilation provided by the windows, ventilation systems are needed. A forced air ventilation system can re-establish proper air circulation while providing effective noise mitigation. The air intakes should be on the north side of the building or in the same proximity as the windows. Air intakes on the roof or on the south side of the building may take in abnormally hot air and should be avoided.

7.1.5.2 Storm Windows

The installation of storm windows is often coupled with a ventilation system to provide increased noise reduction. Storm windows also reduce winter heat losses. The money saved in heating should offset any operation or maintenance costs associated with the ventilation system.

7.1.5.3 Air Conditioning

Air conditioning systems may be used in place of ventilation systems when they can be installed at the same or lower cost.

Some air conditioners, however, generate their own noise levels and may negate the traffic noise reductions. Ventilation systems can also be designed so the school or non-profit institution can add air conditioning at a later date.

7.2 ODOT Noise Mitigation Reasonability and Feasibility Criteria

In accordance with the ODOT Traffic Noise Manual, when traffic noise impacts are identified, noise abatement measures must be considered for those developments that existed prior to the date of public knowledge of the project. This includes identifying:

- Noise abatement measures which are reasonable and feasible and which are likely to be incorporated in the project.
- Noise impacts for which no apparent solution is available and an explanation of why noise abatement was not recommended.

In evaluating whether a particular noise abatement measure is feasible, ODOT requires the following:

- Noise abatement measures must obtain substantial noise reductions to be considered feasible. A substantial noise reduction is a reduction of at least 5 dBA.

In addition, ODOT policy states that:

- Abatement measures achieving high noise reductions have more benefit than those getting low noise reductions.
- Noise barriers that provide noise mitigation to a large number of residences have more benefit and may warrant a higher cost than those that mitigate a few residences.

For residential areas, all benefited residences must be considered in determining a noise barrier cost per residence. A benefited residence is any impacted or non-impacted residence that gets a reduction of 5 dBA or more. A reasonable cost will be a typical maximum of $25,000 per benefited residence. The typical maximum of $25,000 can be exceeded, but shall not be higher than $35,000 per residence. To exceed the $25,000 limit, one or more of the following conditions must occur:

- Equity and fairness, if other noise abatement measures are present or proposed in the area
- Logical termini for walls, close a gap between walls
- Strong public support for mitigation
- A noise increase of 10 dBA or more
- High noise levels, Leq 70 dBA or higher
- The residence was constructed prior to 1976

7.3 WSDOT Noise Mitigation Cost Effectiveness Criteria

WSDOT has established a criterion for noise barrier mitigation cost effectiveness. The decision to recommend or not recommend that a noise barrier be implemented will normally be determined based on the factors given below:

- Noise levels in the design year approach or exceed the noise abatement criteria in Exhibit 2-12.
- A majority of the front-line receivers must obtain a minimum 5 dBA insertion loss, and at least one receiver has at least a 7 dBA reduction.
- The noise mitigation cost per residence (or residential equivalent) is at or less than indicated in Exhibit 7-1. This is determined by counting all residences (including owner occupied, rental units, mobile homes) benefited by the noise barrier in any subdivision and/or given development, and dividing that number into the total cost of the noise abatement measure. A benefited receiver is one that receives at least a 3 dBA reduction from the proposed noise barrier. Each unit in a multi family building will be counted as a separate residence. The table below shows that as the predicted future noise level increases, it is reasonable to implement more costly measures, if necessary, to mitigate traffic noise.

Exhibit 7-1. Allowance for Impacts Caused by Total Traffic Noise Levels (WSDOT)

Design Year Traffic Noise Decibel Level	Allowed Cost Per Household w/3dBA Reduction[1]	Equivalent Wall Surface Area Per Household
66 dBA	$37,380	65.0 Sq. Meters (700 Sq. Ft)
67 dBA	$41,110	71.5 Sq. Meters (770 Sq. Ft.)
68 dBA	$44,640	77.7 Sq. Meters (836 Sq. Ft.)
69 dBA	$48,270	84.0 Sq. Meters (904 Sq. Ft.)
70 dBA	$51,900	90.3 Sq. Meters (972 Sq. Ft)
71 dBA	$55,530	96.6 Sq. Meters (1040 Sq. Ft.)
72 dBA	$59,160	103.0 Sq. Meters (1108 Sq. Ft.)
73 dBA	$62,790	109.2 Sq. Meters (1176 Sq. Ft.)
74 dBA	$66,420	115.6 Sq. Meters (1244 Sq. Ft)

[1] Based on $53.40 per square foot construction cost. Applies to Washington area only.

The use of the property should be included when considering the reasonableness of abatement. For example, churches and parks may be in use only during specific hours or days of the week. Noise barriers will be considered where land use is changing rapidly if there is local zoning or ordinances to control the new development of noise-sensitive land uses adjacent to transportation corridors. The relationship of the location of a noise barrier to the receptors to be protected will be considered in making a reasonableness determination.

7.4 Mitigation Common to All Build Alternatives

Noise mitigation was considered for all receivers where noise levels exceed the ODOT or WSDOT traffic noise criteria. After reviewing the locations of the predicted noise impacts, it was determined that noise barriers were likely the only feasible form of noise mitigation. Because the same noise wall configurations are recommended for all of the full build alternatives, this traffic noise mitigation discussion is organized by project corridor subareas (e.g., Portland subarea).

7.4.1 Special Considerations for Noise Mitigation

Prior to discussing the noise mitigation for the Portland Segment, it is important for the readers to understand that the actual mitigation will depend greatly on the alternatives selected. For example, if the I-5 adjacent BRT alternative was selected, the BRT alignment would be place next to I-5, and would have a large noise wall along the west side to eliminate the noise impacts from BRT operations. Because the BRT alignment would be directly adjacent to I-5, it is likely that the noise walls on the west side of I-5 would not be needed, as the noise walls for the BRT alignment would also be sufficient to mitigate the noise from I-5. This wall would also be built by the FTA portion of the project, and therefore would not be required to meet ODOT noise mitigation standards. Also, because the BRT is adjacent to I-5, there would be no need for noise walls on the east side of the BRT alignment, as the eastern I-5 walls would be sufficient to mitigate the BRT noise traveling east.

Conversely, if the BRT was off-set, then noise walls would still be required on the west side of I-5, and the BRT would need walls on both sides of the alignment. If the light rail option adjacent to I-5 was selected, the typical 4-foot wall for light rail mitigation may not be sufficient to mitigate noise from I-5. If so, rather than place walls on I-5, the walls on the LRT structure would be increased in height to provide the necessary noise reductions. In this case, only the *added height of the wall* due to the traffic noise on I-5 would be subject to the ODOT criteria.

Until a final alternative is selected, it is difficult to directly commit to a specific mitigation methodology. However, this analysis makes it clear that some combination noise mitigation would be effective at providing reasonable and feasible noise mitigation for virtually all locations with noise impacts. Once a final alignment is selected, the noise mitigation will be adapted to fit within the project requirements and also meet any requirements set forth by ODOT or WSDOT.

There are currently several residential noise impacts identified near the opening in the sound walls in North Vancouver, at the East 29th and 33rd Street overpasses. During final design additional methods of extending or wrapping the noise barriers will be examined. It may be possible, once all the details on retaining walls is available, to design walls that could reduce or eliminate the impacts in these areas.

Finally, the FTA provides residential sound insulation as a form of mitigation from noise impacts. Therefore, institutional *and* residential noise impacts related to BRT or LRT operations can be mitigated with sound insulation programs. Under the FHWA regulations, only institutional uses, such as a school, library or hospital, can be offered sound insulation for noise impacts.

7.4.2 Portland Subarea Traffic Noise Mitigation

To mitigate traffic noise impacts that would occur to the 36 floating homes (represented by PD-1 through PD-3) a noise wall was evaluated along the west side of the proposed bridge crossing. A second noise wall was considered for impacts to the 14 residences represented by PD-8 on the east side of the proposed bridge crossing. Two modeling locations were added near PD-8 (PD-8a and PD-8b) to help determine the required length of the wall. Exhibit 7-4 provides an aerial view of the two bridge noise wall locations.

This west side bridge noise wall would provide a 13 dBA average noise reduction at front-line receivers represented by PD-1 and P-2. The weighted average reduction for all receivers exceeding the criteria would be 11 dBA. All of the traffic noise impacts predicted at the 36 floating homes would be mitigated and the noise wall would provide a noise reduction benefit of 5 dBA for 7 more homes in the area.

The east side bridge noise wall would provide a 9 to 10 dBA reduction for the 14 residences and would mitigate all of the projected traffic noise impacts in this area.

Exhibit 7-2 provides a summary of the two proposed noise walls in the Portland subarea. The noise level reduction performance and the overall cost are provided for each wall. The west side bridge noise wall meets the ODOT criteria for noise wall reasonability and feasibility and is recommended as part of this project for all full build alternatives. The east side noise wall meets ODOT's feasibility requirement but exceeds the typical maximum $25,000 per benefited receiver. Because the future area noise levels are expected to be as high as 73 dBA Leq, ODOT policy allows the $25,000 limit to be exceeded by up to $35,000 per benefited receiver. Therefore, the east side bridge noise wall is also recommended to be included as part of the project design.

Exhibit 7-2. Portland Subarea Noise Wall Reduction and Cost Summary (ODOT)

Receiver #	Build Noise Levels[1]	Build Noise Levels w/Mitigation[2]	Noise Reduction[3]	Benefited Homes[4]	Cost per benefited Receiver[5]
West side Bridge Noise Wall					
PD-1	73	60	13	3	$15,491 (Recommended)
PD-2	74	61	13	17	
PD-3	69	60	9	16	
PD-5	64	59	5	7	
East side Bridge Noise Wall					
PD-8	73	63	10	5	$29,166 (Recommended)
PD-8a	73	64	9	4	
PD-8b	73	64	9	5	

Notes:
1. Future noise levels with no mitigation
2. Future noise levels wit h mitigation
3. Noise reduction provided by wall
4. Number of homes with 5 dBA or more noise reduction benefit (ODOT Policy)
5. Cost per benefited receiver based on $25 per square foot construction costs and the number of benefited homes listed (Oregon only)

Exhibit 7-3 provides details on wall heights, lengths, and overall costs for the two proposed noise walls. Exhibit 7-4 shows an aerial view of the two proposed noise walls.

Exhibit 7-3. Portland Subarea Noise Wall Details and Overall Cost (ODOT)

Wall Description	Heights along noise wall (ft)[1]			Length (ft)[2]	Wall Area (sq. ft)[3]	Total Cost[4]
	Min	Avg	Max			
West side of I-5 Bridge	12	12	12	2220	26644	$666,100
East side of I-5 Bridge	6	9.43	12	1732	16333	$408,325

Notes:
1. Minimum, average and maximum noise wall heights in feet
2. Length of proposed noise wall in feet
3. Total noise wall surface area in square feet
4. Cost of noise wall based on $25 per square foot construction cost (ODOT)

Additional noise impacts are likely at some of the nearby commercial structures under all build alternatives. Because retail outlets, such as service stations and shopping areas want unrestricted visual exposure to I-5 traffic, no noise mitigation was evaluated for these locations.

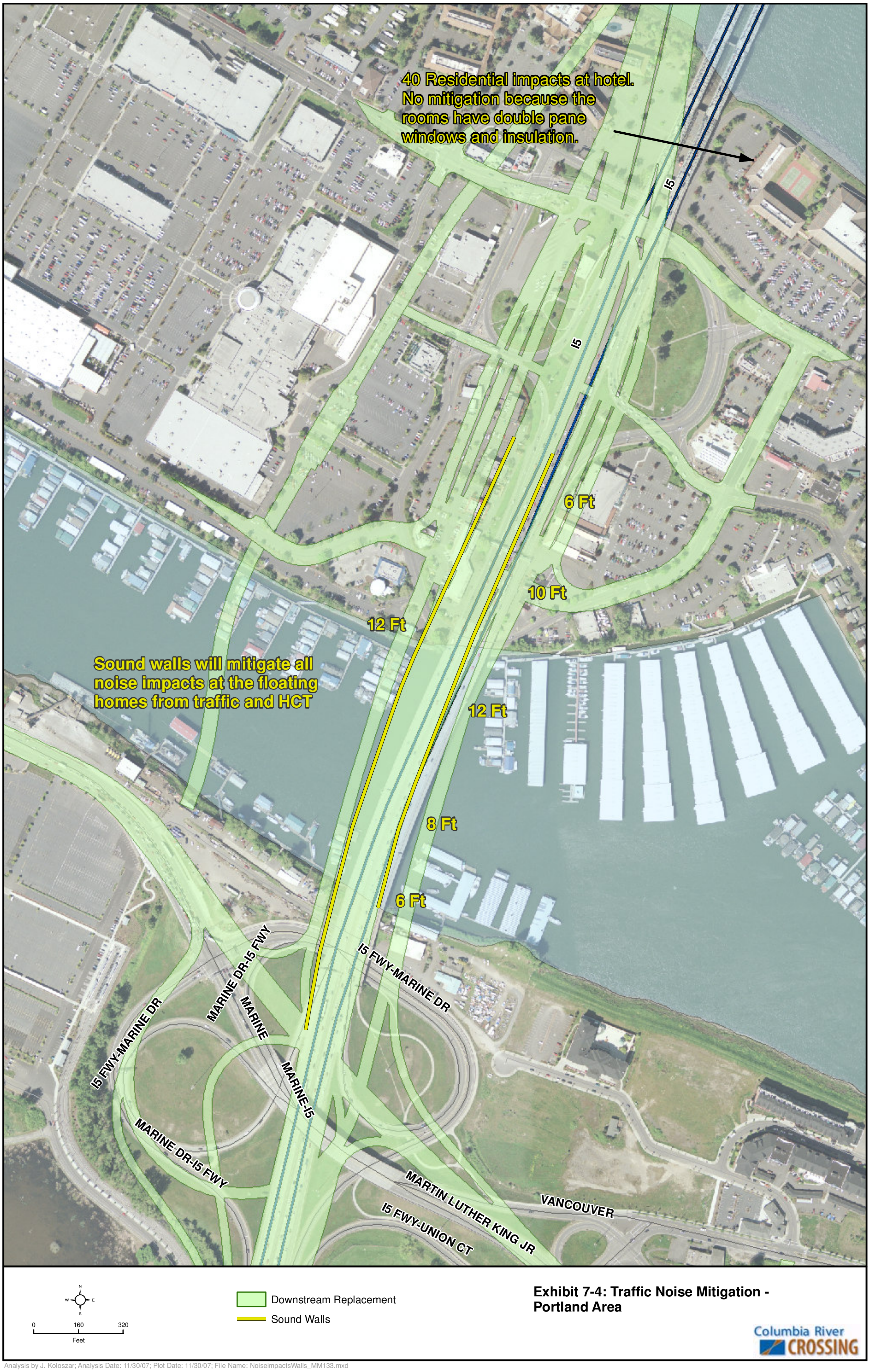

Exhibit 7-4: Traffic Noise Mitigation - Portland Area

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7.4.3 Downtown Vancouver Subarea Traffic Noise Mitigation

Mitigation was evaluated for the 38 traffic noise impacts predicted for the downtown Vancouver subarea. A majority of the projected impact sites are located on upper floors of buildings (e.g., hotels) where noise walls are not effective in reducing traffic noise levels and cannot meet WSDOT minimum 5 dBA insertion loss requirement. While the small number of first floor impacts could be mitigated with several noise walls placed along I-5, the I-5 on/off ramps and the SR 14 on/off ramps, the WSDOT cost-effectiveness criteria could not be met given the relatively high cost compared to the relatively low number of benefited residential equivalents. No noise wall mitigation is recommended in the downtown Vancouver subarea.

7.4.4 West of I-5 / Mill Plain to North Vancouver Subarea Traffic Noise Mitigation

To mitigate the 117 residential traffic noise impacts that would occur west of I-5 from E. Mill Plain to the northern project terminus, a noise wall was evaluated along the west side of I-5. Several openings would be required to allow for I-5 overpasses at E. Fourth Plain Boulevard, E. 29th Street, E. 33rd Street and E. 39th Street. A substantial wall opening would be required at Fourth Plain due to topography changes and roadway alignments in and around this I-5 overpass. Noise modeling results show that the opening in the wall at Fourth Plain would be wide enough to render the north and south wall segments acoustically independent from each other. That is, the height of the wall south of Fourth Plain would not influence the noise levels at residences to the north of Fourth Plain. Therefore, for the purposes of this mitigation analysis one wall was evaluated to mitigate the traffic impacts between Mill Plain and Fourth Plain and another wall to mitigate the remaining traffic noise impacts north of Fourth Plain.

Exhibit 7-7 provides an aerial view of the two evaluated noise walls.

The noise wall between Mill Plain and Fourth Plain would provide a 9 dBA average noise reduction at front-line receivers. All of the traffic noise impacts predicted at the 35 residences would be mitigated and the noise wall would provide a noise reduction benefit of 3 dBA or more for 20 additional homes in the area.

The noise wall from Fourth Plain to just north of the SR 500 interchange would provide an 8 dBA average noise reduction at front-line receivers. All traffic noise impacts predicted at the 82 residences would be mitigated except for the six residences represented by VW-20 that would be near the required opening in the noise wall. In addition, the noise wall would provide a noise reduction benefit of 3 dBA or more for 22 additional homes in the area.

Exhibit 7-5 provides a summary of the two proposed noise walls along the west side of I-5 north of E. Mill Plain. The noise level reduction performance and the available capital for mitigation are provided for each wall. Both noise walls meet the WSDOT cost-effectiveness criteria and are recommended as part of this project for all full build alternatives.

Exhibit 7-5. West of I-5/Mill Plain to SR 500 Noise Wall Reduction Summary

Receiver #	Build Noise Levels[1]	Build Noise Levels w/Mitigation[2]	Noise Reduction[3]	Benefited Homes[4]	Capital Available for Mitigation[5]
E. Mill Plain to E. Fourth Plain Noise Wall					
VW-1	69	62	7	2	$96,540
VW-2	62	59	3	4	$149,520
VW-3	71	61	10	2	$111,060
VW-4	65	61	4	4	$149,520
VW-5	62	59	3	3	$112,140
VW-6	67	62	5	4	$164,440
VW-7	65	62	3	3	$112,140
VW-8	74	64	10	8	$531,360
VW-9	66	60	6	7	$261,660
VW-10	66	60	6	3	$112,140
VW-11	76	65	11	4	$265,680
VW-12	65	60	5	4	$149,520
VW-13	73	64	9	5	$313,950
VW-14	63	59	4	2	$74,760
Total Available for Noise Mitigation					**$2,604,430**
E. Fourth Plain to north of SR 500 Noise Wall					
VW-15	72	62	10	3	$177,480
VW-16	63	60	3	3	$112,140
VW-17	69	64	5	4	$193,080
VW-18	66	63	4	6	$224,280
VW-19	61	59	2	0	$0
VW-20	76	72	4	6	$398,520
VW-21	68	62	5	4	$178,560
VW-22	78	65	13	5	$332,100
VW-23	58	57	2	0	$0
VW-24	59	57	2	0	$0
VW-25	65	60	5	4	$149,520
VW-26	69	62	7	4	$193,080
VW-27	63	60	4	4	$149,520
VW-28	68	62	7	8	$357,120
VW-29	61	58	3	4	$149,520
VW-30	63	60	3	4	$149,520
VW-31	59	56	3	4	$149,520
VW-32	66	61	5	3	$112,140
VW-33	60	58	3	2	$74,760
VW-34	66	62	3	4	$149,520
VW-35	73	65	8	8	$502,320
VW-36	78	70	8	2	$132,840
VW-36F	69	63	5	22	$1,061,940
Total Available for Noise Mitigation					**$4,947,480**

Notes:

1. Future noise levels with no mitigation
2. Future noise levels with mitigation
3. Noise reduction provided by wall. In Washington a 3 dBA reduction qualifies a home as benefiting from a wall.
4. Number of homes with 3 dBA or more noise reduction benefit (Washington)
5. Allowable cost per benefited receiver based on $53.40 per square foot and a sliding scale adjusted according to the design year traffic noise level (WSDOT)

Exhibit 7-6 provides a noise wall cost analysis based on WSDOT cost-effectiveness criteria for the two noise barriers recommended for the west side of I-5 between Mill Plain Boulevard and Fourth Plain Boulevard.

Exhibit 7-6. I-5 West / Mill Plain to SR 500 Subarea Noise Wall Details and Cost Analysis

Wall Description	Heights along wall (ft)[1]			Length (ft)[2]	Wall Area (sq. ft)[3]	Cost[4]	Available Capital[5]	Residual Capital[6]
	Min	Avg	Max					
Along west side of I-5 Mill Plain to E. Fourth Plain	10	14.42	18	3,148	45,392	$2,423,909	$2,604,430	+$180,521
Along west side of I-5 4th Plain to SR 500	8	13.32	16	6692	89,866	$4,798,888	$4,947,480	+$148,592

Notes:
1. Minimum, average and maximum noise wall heights in feet
2. Length of proposed noise wall in feet
3. Total noise wall surface area in square feet
4. Cost of noise wall based on $53.40 per square foot from WSDOT criteria for cost evaluation
5. Available mitigation capital from WSDOT criteria for cost evaluation
6. Residual mitigation capital: positive value is within the allowable capital based on WSDOT criteria; negative value exceeds the criteria

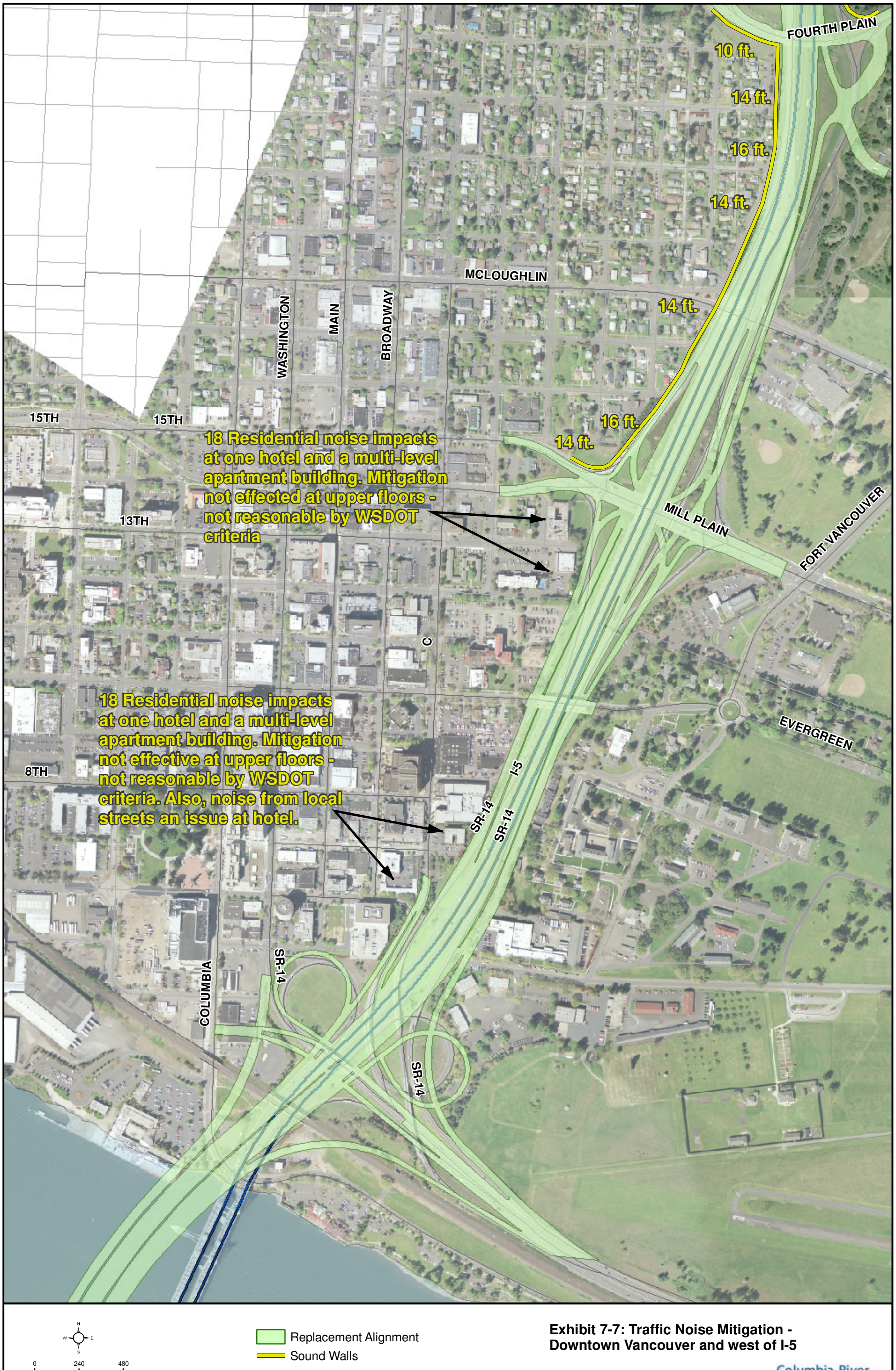

Exhibit 7-7: Traffic Noise Mitigation - Downtown Vancouver and west of I-5

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Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseimpactsWalls_MM133.mxd

7.4.5 Fort Vancouver Subarea Traffic Noise Mitigation

Two commercial/office traffic noise impacts are projected to occur in the Fort Vancouver subarea just east of I-5. A noise wall was evaluated along the east side of I-5 to mitigate the two impacts.

The noise wall would provide 11 to 12 dBA noise reduction at the two commercial/office receivers, thereby meeting the WSDOT minimum insertion loss criteria. However, the cost of the wall would be $722,058, which exceeds the total capital available for mitigation of $132,840 by $589,218. Therefore, the noise wall to mitigate the traffic noise impacts near FV-5 and FV-6 is not recommended.

A noise wall was also evaluated for the 24 residential traffic noise impacts within the Fort Vancouver sub area represented by receivers FV-7 through FV-13, FV-15 and FV-16. FV-14 represents an undeveloped area and therefore is not included. A noise wall along the east side of I-5 would provide a 9 dBA average noise reduction at front-line receivers. All traffic noise impacts predicted at the 24 residential uses would be mitigated. In addition, the noise wall would provide a noise reduction benefit of 3 dBA or more for 21 additional residential uses in the Fort Vancouver area.

If the commercial/office land uses represented by FV-5 and FV-6 are included in Fort Vancouver barrier just to the north, then the entire wall would not be cost-effective. Without these two receivers the barrier meets WSDOT cost-effectiveness criteria. Furthermore, FV-5 is a motor pool and is not considered a noise sensitive property that would benefit from mitigation.

Exhibit 7-8 provides a summary of the proposed Fort Vancouver noise walls along the east side of I-5. The noise level reduction performance and the available capital for mitigation are also provided. The Fort Vancouver noise wall meets the WSDOT cost-effectiveness criteria and is recommended as part of this project for all full build alternatives.

Exhibit 7-8. Fort Vancouver Subarea Noise Wall Reduction Summary

Receiver #	Build Noise Levels[1]	Build Noise Levels w/Mitigation[2]	Noise Reduction[3]	Benefited Homes[4]	Capital Available for Mitigation[5]
FV-7	69	60	9	6	$289,620
FV-8	68	59	9	6	$267,840
FV-9	73	63	10	8	$502,320
FV-10	69	60	9	10	$482,700
FV-11	65	58	7	10	$373,800
FV-12	72	63	9	2	$118,320
FV-13	65	60	5	1	$37,380
FV-15	62	60	2	0	$0
FV-16	67	64	3	2	$82,220
Total Available for Noise Mitigation					**$2,154,200**

Notes:
1. Future noise levels with no mitigation
2. Future noise levels with mitigation
3. Noise reduction provided by wall. In Washington a 3 dBA reduction qualifies a home as benefiting from a wall.
4. Number of homes with 3 dBA or more noise reduction benefit (Washington)
5. Allowable cost per benefited receiver based on $53.40 per square foot and a sliding scale adjusted according to the design year traffic noise level (WSDOT)

Exhibit 7-9 provides a noise wall cost analysis based on WSDOT cost-effectiveness criteria for the two noise barriers recommended for the west side of I-5 between Mill Plain and Fourth Plain Boulevards.

Exhibit 7-9. Fort Vancouver Subarea Noise Wall Details and Cost Analysis

Wall Description	Heights Along Wall (ft)[1]			Length (ft)[2]	Wall Area (sq. ft)[3]	Cost[4]	Available Capital[5]	Residual Capital[6]
	Min	Avg	Max					
Along east side of I-5 SR 14 to E. Mill Plain	12	15.15	16	2151	32,586	$2,423,909	$1,740,072	+$414,128

Notes:
1. Minimum, average and maximum noise wall heights in feet
2. Length of proposed noise wall in feet
3. Total noise wall surface area in square feet
4. Cost of noise wall based on $53.40 per square foot from WSDOT criteria for cost evaluation
5. Available mitigation capital from WSDOT criteria for cost evaluation
6. Residual mitigation capital: positive value is within the allowable capital based on WSDOT criteria; negative value exceeds the criteria

Exhibit 7-10 provides an aerial of the recommended noise wall for the Fort Vancouver area.

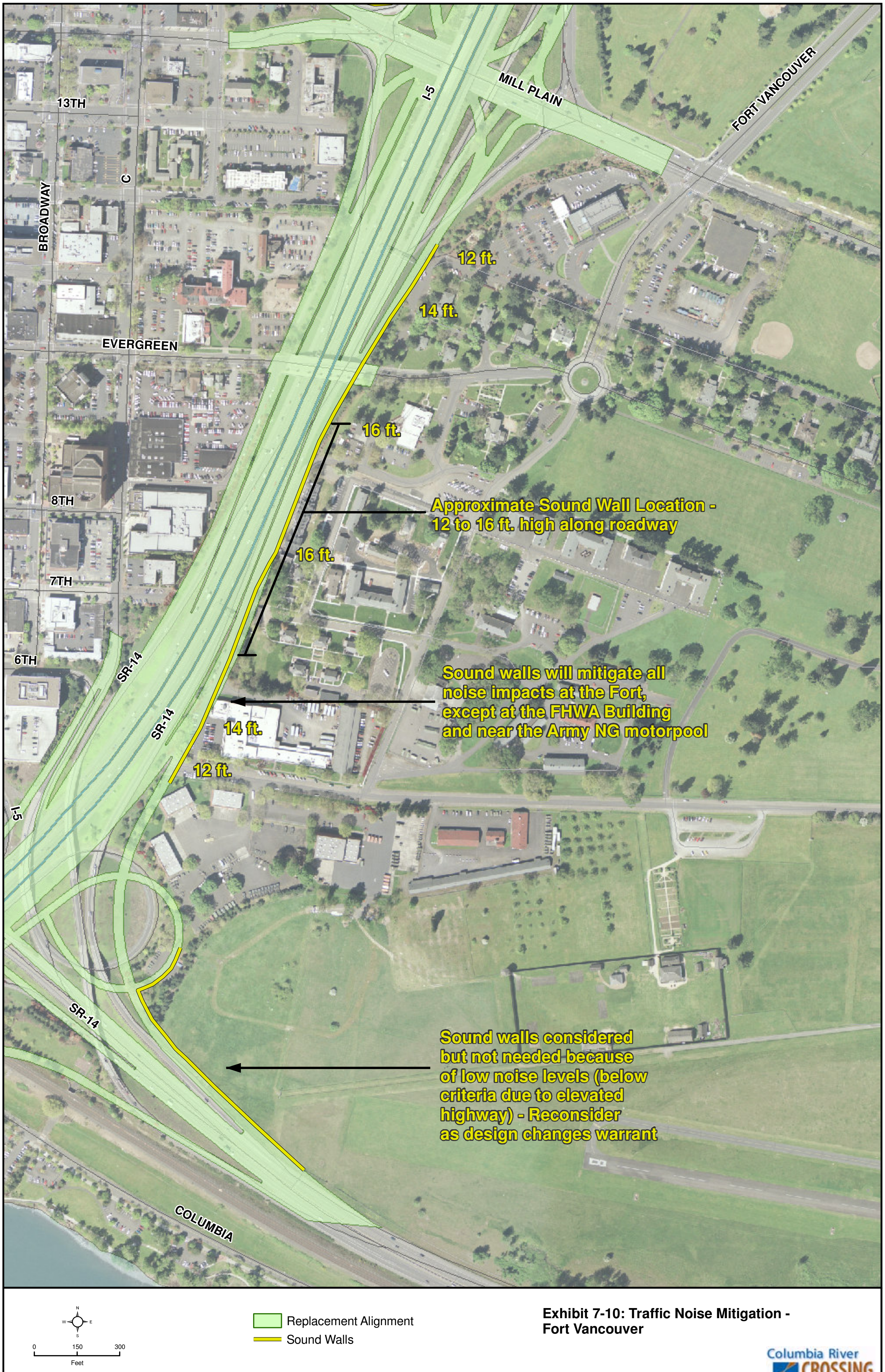

Exhibit 7-10: Traffic Noise Mitigation - Fort Vancouver

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Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseimpactsWalls_MM133.mxd

7.4.6 East of I-5 / Mill Plain to North Vancouver Subarea Traffic Noise Mitigation

A noise wall was evaluated along the east side of I-5, to mitigate the 37 residential traffic noise impacts that would occur between E. Fourth Plain and SR 500. Two openings would be required to allow for I-5 overpasses at E. 29th Street and E. 33rd Street. Noise modeling results show that the resulting two wall segments are acoustically dependent and should be treated as a single wall system when evaluating cost-effectiveness.

Exhibit 7-13 provides an aerial view of the two evaluated noise walls.

The noise wall east of I-5 would begin at the southern edge of the Vancouver Barracks Post Cemetery adjoining Fourth Plain and run north to about 500 feet past E. 37th Street. It would provide an 8 dBA average noise reduction at front-line receivers. All but four of the 35 traffic noise residential impacts would be mitigated and the noise wall would provide a noise reduction benefit of 3 dBA or more for 21 additional homes in the area.

Exhibit 7-11 provides a summary of the proposed noise wall along the east side of I-5 north of Fourth Plain. The noise level reduction performance and the available capital for mitigation are provided for the proposed wall.

Exhibit 7-12 provides the noise wall details and WSDOT cost analysis. The noise wall meets the WSDOT cost-effectiveness criteria and is recommended as part of this project for all full build alternatives.

Exhibit 7-11. East of I-5 / Mill Plain to North Vancouver Subarea Wall Reduction Summary

Receiver #	Build Noise Levels[1]	Build Noise Levels w/Mitigation[2]	Noise Reduction[3]	Benefited Homes[4]	Capital Available for Mitigation[5]
VE-3	72	65	7	2	$118,320
VE-4	76	64	12	10	$664,200
VE-5	65	62	3	8	$299,040
VE-6	62	60	2	0	$0
VE-7	71	**68**	3	2	$111,060
VE-8	77	**66**	11	2	$132,840
VE-9	59	57	2	0	$0
VE-10	73	65	8	8	$502,320
VE-11	60	58	2	0	$0
VE-12	73	65	8	5	$313,950
VE-13	65	64	1	0	$0
VE-14	60	56	4	4	$149,520
VE-15	62	60	2	0	$0
VE-16	66	61	5	5	$186,900
VE-17	63	60	3	5	$186,900
VE-18	59	56	3	4	$149,520

Receiver #	Build Noise Levels[1]	Build Noise Levels w/Mitigation[2]	Noise Reduction[3]	Benefited Homes[4]	Capital Available for Mitigation[5]
VE-19	58	57	1	0	$0
Total Available for Noise Mitigation					**$2,814,570**

Notes:
1. Future noise levels with no mitigation
2. Future noise levels wit h mitigation
3. Noise reduction provided by wall
4. Number of homes with 5 dBA or more noise reduction benefit
5. Cost per benefited receiver based on $25 per square foot construction costs and the number of benefited homes listed

Exhibit 7-12. East of I-5 / Mill Plain to North Vancouver Subarea Noise Wall Details and Cost Analysis

Wall Description	Heights along wall (ft)[1]			Length (ft)[2]	Wall Area (sq. ft)[3]	Cost[4]	Available Capital[5]	Residual Capital[6]
	Min	Avg	Max					
Along east side of I-5 4th Plain to SR 500	12	12.34	14	3,518	43,476	$2,679,094	$2,814,570	+$135,476

Notes:
1. Minimum, average and maximum noise wall heights in feet
2. Length of proposed noise wall in feet
3. Total noise wall surface area in square feet
4. Cost of noise wall based on $53.40 per square foot from WSDOT criteria for cost evaluation
5. Available mitigation capital from WSDOT criteria for cost evaluation
6. Residual mitigation capital: positive value is within the allowable capital based on WSDOT criteria; negative value exceeds the criteria

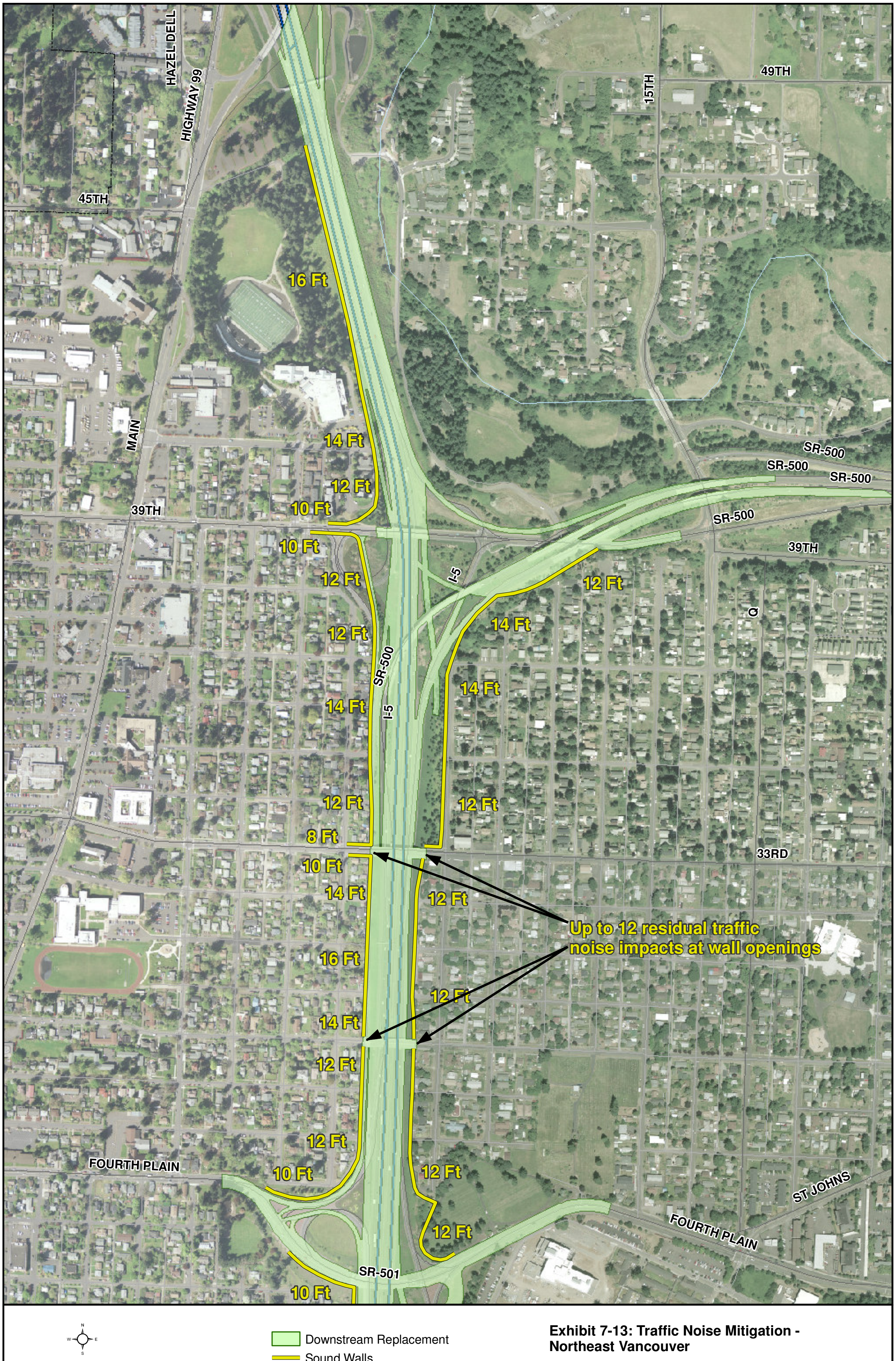

Exhibit 7-13: Traffic Noise Mitigation - Northeast Vancouver

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Analysis by J. Koloszar; Analysis Date: 11/30/07; Plot Date: 11/30/07; File Name: NoiseimpactsWalls_MM133.mxd

7.5 Mitigation for HCT Noise and Vibration Impacts

7.5.1 Possible LRT and BRT Noise Mitigation Measures

The noise analysis will be refined during project design to determine the details of the final mitigation measures. Possible mitigation measures for reducing noise impacts from the HCT operation are described below:

- Transit Noise Barriers – This is a common approach to reducing noise impacts from surface transportation sources. The primary requirements for effective noise barriers are that (1) barriers must be high enough and long enough to break the line-of-sight between the sound source and the receiver, (2) barriers must be of an impervious material with a minimum surface density of 4 lb/sq. ft. and (3) barriers must not have gaps or holes between the panels or at the bottom. Because many materials meet these requirements, the selection of materials for noise barriers is usually dictated by aesthetics, durability, cost, and maintenance considerations. For LRT transit system noise barriers typically range in height from 4 to 8 feet. For BRT, noise barriers constructed to a height to mitigate traffic noise are generally adequate provided BRT travel lanes adjoin the general traffic lanes.
- Track Lubrication at Curves (LRT) – Trackside lubrication can be effective in avoiding wheel squeal, which often occurs as light rail vehicles traverse tight-radius curves. This installation automatically deposits a small amount of “friction modifier” on the top of the rail, and has shown to effectively eliminate wheel squeal and associated complaints from nearby residents.
- Building Sound Insulation (LRT and BRT) – Sound insulation of residences and institutional buildings to improve the outdoor-to-indoor noise reduction has been widely applied around airports and has seen some application on transit projects. Although this approach has no effect on noise in exterior areas, it may be the best choice for sites where noise barriers are not feasible or desirable, and for buildings where indoor sensitivity is of most concern. Substantial improvements in building sound insulation (on the order of 5 to 10 dBA) can often be achieved by adding an extra layer of glazing to the windows, by sealing any holes in exterior surfaces that act as sound leaks, and by providing forced ventilation and air-conditioning so that windows do not need to be opened.
- Special Track work at Crossovers and Turnouts (LRT) – LRT noise levels can increase up to 6 dBA when wheels pass over gaps in the rails. Rail gaps would be required along the track alignment where turnouts are planned. It is recommended that turnouts be located as far away as possible from noise sensitive areas. If turnouts cannot be relocated away from sensitive areas, another approach is to use devices that would lessen the noise impacts caused by the rail gaps. Devices such as spring-rail, flange-bearing, or moveable-point frogs, close the gaps near the turnouts for those trains operating along the main track alignment. The increased noise associated with the rail gaps is limited to those relatively few trains actually using the turnouts.

7.5.2 Light Rail Transit Mitigation Measures

Exhibit 7-14 presents recommended residential noise mitigation treatments for Alternative 3 along with the number of residual impacts projected after mitigation.

Exhibit 7-14. Recommended Mitigation Measures for LRT with Replacement Crossing Alternative

Alignment	Area	Recommended Mitigation Measure	Number and Type of Impacts		
			Without Mitigation		Residual Impacts w/ Mitigation
			Moderate	Severe	
I-5 Adjacent	Floating Homes	Noise wall[1]	21	0	0
I-5 Offset	Floating Homes	Noise wall[1]	7	0	0
Washington 2-Way	Downtown	Mitigation not required	0	0	0
McLoughlin	D St to I-5	Sound insulation	16	0	0
I-5 Over Fly-Over	I-5 North of 33rd	Mitigation not required	0	0	0
16th Street	C St to I-5	Sound insulation	10	0	0
Broadway 2-way	19th to 29th	Sound insulation	24	0	0
Main Street 2-way	Main North of 29th	Mitigation not required	0	0	0
Broadway Couplet	19th to 29th	Mitigation not required	0	0	0

[1] Noise wall recommended for traffic noise impact mitigation would also mitigate LRT noise impact

Recommended residential noise mitigation treatments for Alternative 5 are presented in Exhibit 7-15, along with the number of residual impacts projected after mitigation.

Exhibit 7-15. Recommended Mitigation Measures for LRT with Supplemental Crossing Alternative

Alignment	Area	Recommended Mitigation Measure	Number and Type of Impacts		
			Without Mitigation		Residual Impacts w/ Mitigation
			Moderate	Severe	
I-5 Adjacent	Floating Homes	Noise wall[1]	21	0	0
I-5 Offset	Floating Homes	Noise wall[1]	7	0	0
Washington 2-Way	Downtown	Mitigation not required	0	0	0
McLoughlin	D St to I-5	Sound insulation	19	0	0
I-5 Over Fly-Over	I-5 North of 33rd	Mitigation not required	0	0	0
16th Street	C St to I-5	Sound insulation	10	0	0
Broadway 2-way	19th to 29th	Sound insulation	30	0	0
Main Street 2-way	Main North of 29th	Mitigation not required	0	0	0
Broadway Couplet	19th to 29th	Mitigation not required	0	0	0

[1] Noise wall recommended for traffic noise impact mitigation would also mitigate LRT noise impact

Because LRT wheel squeal is likely to occur at the proposed 90-degree curves at Main Street and McLoughlin or Main Street and 16th, it is recommended that provision for trackside lubricators be made during project design so that they can be installed if needed after project completion.

7.5.3 Bus Rapid Transit Mitigation Measures

Recommended residential noise mitigation treatments for Alternative 2 are presented in Exhibit 7-16, along with the number of residual impacts projected after mitigation.

Exhibit 7-16. Recommended Mitigation Measures for BRT with Replacement Crossing Alternative

Alignment	Area	Recommended Mitigation Measure	Number and Type of Impacts		
			Without Mitigation		Residual Impacts w/ Mitigation
			Moderate	Severe	
I-5 Adjacent	Floating Homes	Noise wall[1]	28	14	0
I-5 Offset	Floating Homes	Noise wall[1]	28	7	0
Washington 2-Way	Downtown	Sound insulation	0	0	0
McLoughlin	D St to I-5	Sound insulation	22	0	0
I-5 Over Fly-Over	I-5 North of 33rd	Noise wall on structure[2]	3	12	0
16th Street	C St to I-5	Sound insulation	11	5	0
Broadway 2-way	19th to 29th	Sound insulation	29	10	0
Main Street 2-way	Main North of 29th	Sound insulation	1	0	0
Broadway Couplet	19th to 29th	Sound insulation	39	0	0

[1] Noise wall recommended for traffic noise impact mitigation would also mitigate BRT noise impact
[2] This noise wall on structure would be in addition to any noise walls recommended for traffic noise

Recommended residential noise mitigation treatments for Alternative 4 are presented in Exhibit 7-17, along with the number of residual impacts projected after mitigation.

Exhibit 7-17. Recommended Mitigation Measures for BRT with Supplemental Crossing Alternative

Alignment	Area	Recommended Mitigation Measure	Number and Type of Impacts		
			Without Mitigation		Residual Impacts with Mitigation
			Moderate	Severe	
I-5 Adjacent	Floating Homes	Noise wall[1]	21	21	0
I-5 Offset	Floating Homes	Noise wall[1]	28	7	0
Washington 2-Way	Downtown	Sound insulation	3	0	0
McLoughlin	D St to I-5	Sound insulation	15	19	0
I-5 Over Fly-Over	I-5 North of 33rd	Noise wall on structure[2]	3	12	0
16th Street	C St to I-5	Sound insulation	10	7	0

Alignment	Area	Recommended Mitigation Measure	Number and Type of Impacts		
			Without Mitigation		Residual Impacts with Mitigation
			Moderate	Severe	
Broadway 2-way	19th to 29th	Sound insulation	9	30	0
Main Street 2-way	Main North of 29th	Sound insulation	8	0	0
Broadway Couplet	19th to 29th	Sound insulation	31	8	0

[1] Noise wall recommended for traffic noise impact mitigation would also mitigate BRT noise impact

[2] This noise wall on structure would be in addition to any noise walls recommended for traffic noise

7.5.4 LRT Vibration Mitigation Measures

Vibration impacts that exceed FTA criteria are considered significant and warrant mitigation, if reasonable and feasible. The assessment assumes that the LRT vehicle wheels and track are maintained in good condition with regular wheel truing and rail grinding. Beyond this, several approaches could reduce ground-borne vibration from LRT operation, as described below:

- Ballast Mats - Ballast mats are 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 strongly depends on the frequency of the vibration and design and support of the mat.
- Tire Derived Aggregate (TDA) - Also known as shredded tires, a typical TDA installation consists of an underlayment of 12 inches of nominally 3-inch size tire shreds or chips wrapped with filter fabric, covered with 12 inches of sub-ballast and 12 inches of ballast above that to the base of the ties. Tests suggest that the vibration attenuation properties of this treatment are midway between that of ballast mats and floating slab track. While this is a low-cost option, it has only recently been installed on two U.S. light rail transit systems (San Jose and Denver) and its long-term performance is unknown.
- Special Track work at Crossovers and Turnouts - Because the impacts of LRT wheels over rail gaps at track turnout locations increases LRT vibration by about 10 VdB, turnouts are a major source of vibration impact when they are located in sensitive areas. If turnouts cannot be relocated away from sensitive areas, another approach is to use spring rail or moveable point frogs in place of standard rigid frogs at turnouts. These devices allow the flangeway gap to remain closed in the main traffic direction for revenue service trains.

All vibration impacts identified in this analysis could be mitigated with ballast mats, resilient fasteners, or tire degraded aggregate (TDA). The selected vibration mitigation method would depend on the track type and level of vibration impact. The vibration projections of up to 76 VdB are all within the 5 VdB safety factor used for the analysis.

Exhibit 7-18 provides a summary of the location and length of potential vibration mitigation. More detailed analysis will be carried out during final design to refine the vibration estimates and to determine the vibration mitigation measures that will be incorporated into the project.

Exhibit 7-18. Potential Vibration Mitigation Measures for LRT Alternatives

Location	Exceeds Level	Potential Mitigation	Length and Location	Residual Impacts
McLoughlin Blvd	0.8 to 1.3 VdB	Resilient fasteners	1300 feet	No
Along I-5, 26th to 34th Streets	2.4 to 4.0 VdB	Resilient fasteners or TDA	1900 feet between E. 26th and 33rd Streets	No
Broadway 2-Way	Up to 9 VdB	Ballast mats	1500 feet between E. 19th and 25th Street	Possibly
Broadway couplet	0.5 to 1.0 VdB	Resilient fasteners	2500 feet between E. 19th and 28th Street	No
16th Street	5.7 VdB	Ballast Mats	275 feet from E to G Street on E 16th Street	No
Main Street, north of 29th Street	0.5 to 1.3 VdB	Resilient fasteners	450 feet on Main Street between E 29th and 30th Streets	No

8. Mitigation for Temporary Effects

8.1 Construction Noise Mitigation

Several construction noise abatement methods, including operational methods, equipment choice, or acoustical treatments, could be implemented to limit the effects of construction noise. The methods used may vary depending on the project's construction criteria. Operation of construction equipment could be prohibited within 500 feet of any occupied dwelling unit in evening or nighttime hours (7 p.m. to 7 a.m.) or on Sundays or holidays, when noise and vibration would have the most severe effect. All engine-powered equipment would be required to have mufflers installed according to the manufacturer's specifications, and would be required to comply with EPA equipment noise standards.

The project management team could limit activities that produce the highest noise levels (such as hauling, loading spoils, jackhammering, and using other demolition equipment) to 7:00 a.m. to 7:00 p.m. Maximum noise levels associated with pile driving could reach 105 dBA at distances of 50 feet. Mitigation of the noise associated with pile driving could include auguring rather than driving piles (however, using an augur is not likely to be feasible for this project), or limiting the time the activity can take place. Other less effective methods of reducing noise from pile driving could include coating the piles, using pile pads, or using piston mufflers.

The pile-driving effects on fish could be mitigated using wood piles instead of metal whenever possible and, if required, bubble curtains. A bubble curtain is a method used to reduce the level of waterborne noise from pile driving by placing a wall of bubbles between the pile and fish. This method has been used in Washington State and in California with substantial success and could be used for this project.

A construction log should be kept for each construction staging area. The log would contain general construction information such as the time an activity took place, type of equipment used, and any other information that may help with potential noise effects.

A complaint hot-line could be established to investigate noise complaints and compare them to the construction logs. A construction monitoring and complaint program could help to ensure that all equipment meets state, local, and any manufacturer's specifications for noise emissions. Equipment not meeting standards could be removed from service until proper repairs can be made, and the equipment re-tested for compliance. This procedure is recommended for haul trucks, loaders, excavators, and other equipment that would have extensive use at the construction sites and are major contributors to potential noise effects.

The following is a list of recommended noise mitigation measures that should be contained in the contract specifications:

- Require all engine-powered equipment to have mufflers installed according to the manufacturer's specifications.
- Require all equipment to comply with pertinent EPA equipment noise standards.
- Limit jackhammers, concrete breakers, saws, and other forms of demolition to daytime hours of 8:00 a.m. to 5:00 p.m. on weekdays with more stringent restrictions on weekends.
- Minimize noise by regular inspection and replacement of defective mufflers and parts that do not meet the manufacturer’s specifications.
- Install temporary or portable acoustic barriers around stationary construction noise sources and along the sides of the temporary bridge structures where feasible.
- Locate stationary construction equipment as far from nearby noise-sensitive properties as possible.
- Shut off idling equipment.
- Reschedule construction operations to avoid periods of noise annoyance identified in complaints.
- Notify nearby residents whenever extremely noisy work would be occurring.
- Substitute smart alarms for back-up beepers to reduce the potential for impacts during evening hours, and use spotters during nighttime and early morning hours.

Additional noise mitigation measures may be implemented as more detail on the actual construction processes is identified.

8.2 Construction Vibration Mitigation

The construction contract specifications could contain a section specific to vibration that could require vibration monitoring of all activities that may produce vibration levels at or above 0.5 inch per second whenever there are structures located near the construction activity. This would include pile driving, vibratory sheet installation, soil compacting, and other 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.

9. Permits and Approvals

9.1 Federal, State and Local

The CRC project will require nighttime construction activities. In order to perform nighttime construction, a noise variance would be required. The City of Portland Noise Control Office and the City of Portland Noise Review Board and is the permitting agency for a construction noise variance. The City of Vancouver would also be a permitting agency for nighttime construction. No other permits directly related to noise and vibration, except construction activities related to the water crossing, are anticipated. The permits related to the river crossing are discussed in the Ecosystems Technical Report.

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