INTERSTATE 5 COLUMBIA RIVER CROSSING

Noise and Vibration Technical Report for the Final Environmental Impact Statement

May 2011

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Cover Sheet

Interstate 5 Columbia River Crossing

Noise and Vibration Technical Report for the Final Environmental Impact Statement:

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TABLE OF CONTENTS

List of Exhibits

Appendices

ACRONYMS

ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
APE	Area of Potential Effect
API	Area of Potential Impact
BNSF	Burlington Northern Santa Fe Railroad
CD	collector-distributor
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
CRC	Columbia River Crossing
CTR	Commute Trip Reduction (Washington)
C-TRAN	Clark County Public Transit Benefit Area Authority
dB	Decibel
dBA	A-weighted decibel
DEIS	Draft Environmental Impact Statement
ECO	Employee Commute Options (Oregon)
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FEIS	Final Environmental Impact Statement
FHWA	Federal Highway Administration
ft	feet/foot
FTA	Federal Transit Administration
L_{dn}	24-hour, Time Weighted, A-weighted Sound Levels
L_{eq}	Energy Average Sound Levels
L_{max}	Maximum Noise Levels
L_{XX}	Sound level exceeded xx percent of the time
LPA	locally preferred alternative
LOS	Level of Service
LRV	light rail vehicle
mph	miles per hour
NAC	noise abatement criteria
NB	northbound
NEPA	National Environmental Policy Act
ODOT	Oregon Department of Transportation

OTC	Oregon Transportation Commission
R1	Model receiver designation
RCW	Revised Code of Washington
ROD	Record of Decision
ROW	right-of-way
RTC	Regional Transportation Council
SB	southbound
SR	State Route
SEPA	State Environmental Policy Act
SPUI	single-point urban interchange
TDM	transportation demand management
TNM	Traffic Noise Model
TriMet	Tri-County Metropolitan Transportation District
TSM	transportation system management
USDOT	U.S. Department of Transportation
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation
WTC	Washington Transportation Commission

1. Summary

1.1 Introduction

The purpose of this report is to evaluate the potential noise effects of the construction and operation of the Interstate 5 Columbia River Crossing (CRC) project. This study evaluates the full build out of the locally preferred alternative (LPA) with Design Options A and B. In addition, the effects of the LPA with highway phasing option are addressed.

1.2 Description of Alternatives

This technical report evaluates the CRC project's locally preferred alternative (LPA) and the No-Build Alternative. The LPA includes two design options: The preferred option, LPA Option A, which includes local vehicular access between Marine Drive and Hayden Island on an arterial bridge; and LPA Option B, which does not have arterial lanes on the light rail/multi-use path bridge, but instead provides direct access between Marine Drive and the island with collector-distributor (CD) lanes on the two new bridges that would be built adjacent to I-5. In addition to the design options, if funding availability does not allow the entire LPA to be constructed in one phase, some roadway elements of the project would be deferred to a future date. This technical report identifies several elements that could be deferred, and refers to that possible initial investment as LPA with highway phasing. The LPA with highway phasing option would build most of the LPA in the first phase, but would defer construction of specific elements of the project. The LPA and the No-Build Alternative are described in this section.

1.2.1 Adoption of a Locally Preferred Alternative

Following the publication of the Draft Environmental Impact Statement (DEIS) on May 2, 2008, the project actively solicited public and stakeholder feedback on the DEIS during a 60-day comment period. During this time, the project received over 1,600 public comments.

During and following the public comment period, the elected and appointed boards and councils of the local agencies sponsoring the CRC project held hearings and workshops to gather further public input on and discuss the DEIS alternatives as part of their efforts to determine and adopt a locally preferred alternative. The LPA represents the alternative preferred by the local and regional agencies sponsoring the CRC project. Local agency-elected boards and councils determined their preference based on the results of the evaluation in the DEIS and on the public and agency comments received both before and following its publication.

In the summer of 2008, the local agencies sponsoring the CRC project adopted the following key elements of CRC as the LPA:

- A replacement bridge as the preferred river crossing,
- Light rail as the preferred high-capacity transit mode, and
- Clark College as the preferred northern terminus for the light rail extension.

The preferences for a replacement crossing and for light rail transit were identified by all six local agencies. Only the agencies in Vancouver – the Clark County Public Transit Benefit Area Authority (C-TRAN), the City of Vancouver, and the Regional Transportation Council (RTC) –

preferred the Vancouver light rail terminus. The adoption of the LPA by these local agencies does not represent a formal decision by the federal agencies leading this project – the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) – or any federal funding commitment. A formal decision by FHWA and FTA about whether and how this project should be constructed will follow the FEIS in a Record of Decision (ROD).

1.2.2 Description of the LPA

The LPA includes an array of transportation improvements, which are described below. When the LPA differs between Option A and Option B, it is described in the associated section. For a more detailed description of the LPA, including graphics, please see Chapter 2 of the FEIS.

1.2.2.1 Multimodal River Crossing

Columbia River Bridges

The parallel bridges that form the existing I-5 crossing over the Columbia River would be replaced by two new parallel bridges. The eastern structure would accommodate northbound highway traffic on the bridge deck, with a bicycle and pedestrian path underneath; the western structure would carry southbound traffic, with a two-way light rail guideway below. Whereas the existing bridges have only three lanes each with virtually no shoulders, each of the new bridges would be wide enough to accommodate three through-lanes and two add/drop lanes. Lanes and shoulders would be built to full design standards.

The new bridges would be high enough to provide approximately 95 feet of vertical clearance for river traffic beneath, but not so high as to impede the take-offs and landings by aircraft using Pearson Field or Portland International Airport to the east. The new bridge structures over the Columbia River would not include lift spans, and both of the new bridges would each be supported by six piers in the water and two piers on land.

North Portland Harbor Bridges

The existing highway structures over North Portland Harbor would not be replaced; instead, they would be retained to accommodate all mainline I-5 traffic. As discussed at the beginning of this chapter, two design options have emerged for the Hayden Island and Marine Drive interchanges. The preferred option, LPA Option A, includes local vehicular access between Marine Drive and Hayden Island on an arterial bridge. LPA Option B does not have arterial lanes on the light rail/multi-use path bridge, but instead provides direct access between Marine Drive and the island with collector-distributor lanes on the two new bridges that would be built adjacent to I-5.

LPA Option A: Four new, narrower parallel structures would be built across the waterway, three on the west side and one on the east side of the existing North Portland Harbor bridges. Three of the new structures would carry on- and off-ramps to mainline I-5. Two structures west of the existing bridges would carry traffic merging onto or exiting off of I-5 southbound. The new structure on the east side of I-5 would serve as an on-ramp for traffic merging onto I-5 northbound.

The fourth new structure would be built slightly farther west and would include a two-lane arterial bridge for local traffic to and from Hayden Island, light rail transit, and a multi-use path for pedestrians and bicyclists. All of the new structures would have at least as much vertical clearance over the river as the existing North Portland Harbor bridges.

LPA Option B: This option would build the same number of structures over North Portland Harbor as Option A, although the locations and functions on those bridges would differ, as described below. The existing bridge over North Portland Harbor would be widened and would receive seismic upgrades.

LPA Option B does not have arterial lanes on the light rail/multi-use path bridge. Direct access between Marine Drive and the island would be provided with collector-distributor lanes. The structures adjacent to the highway bridge would carry traffic merging onto or exiting off of mainline I-5 between the Marine Drive and Hayden Island interchanges.

1.2.2.2 Interchange Improvements

The LPA includes improvements to seven interchanges along a 5-mile segment of I-5 between Victory Boulevard in Portland and SR 500 in Vancouver. These improvements include some reconfiguration of adjacent local streets to complement the new interchange designs, as well as new facilities for bicyclists and pedestrians along this corridor.

Victory Boulevard Interchange

The southern extent of the I-5 project improvements would be two ramps associated with the Victory Boulevard interchange in Portland. The Marine Drive to I-5 southbound on-ramp would be braided over the I-5 southbound to the Victory Boulevard/Denver Avenue off-ramp. The other ramp improvement would lengthen the merge distance for northbound traffic entering I-5 from Denver Avenue. The current merging ramp would be extended to become an add/drop (auxiliary) lane which would continue across the river crossing.

***Potential phased construction option*:** The aforementioned southbound ramp improvements to the Victory Boulevard interchange may not be included with the CRC project. Instead, the existing connections between I-5 southbound and Victory Boulevard could be retained. The braided ramp connection could be constructed separately in the future as funding becomes available.

Marine Drive Interchange

All movements within this interchange would be reconfigured to reduce congestion for motorists entering and exiting I-5 at this location. The interchange configuration would be a single-point urban interchange (SPUI) with a flyover ramp serving the east to north movement. With this configuration, three legs of the interchange would converge at a point on Marine Drive, over the I-5 mainline. This configuration would allow the highest volume movements to move freely without being impeded by stop signs or traffic lights.

The Marine Drive eastbound to I-5 northbound flyover ramp would provide motorists with access to I-5 northbound without stopping. Motorists from Marine Drive eastbound would access I-5 southbound without stopping. Motorists traveling on Martin Luther King Jr. Boulevard westbound to I-5 northbound would access I-5 without stopping at the intersection.

The new interchange configuration changes the westbound Marine Drive and westbound Vancouver Way connections to Martin Luther King Jr. Boulevard and to northbound I-5. These two streets would access westbound Martin Luther King Jr. Boulevard farther east. Martin Luther King Jr. Boulevard would have a new direct connection to I-5 northbound.

In the new configuration, the connections from Vancouver Way and Marine Drive would be served, improving the existing connection to Martin Luther King Jr. Boulevard east of the interchange. The improvements to this connection would allow traffic to turn right from Vancouver Way and accelerate onto Martin Luther King Jr. Boulevard. On the south side of Martin Luther King Jr. Boulevard, the existing loop connection would be replaced with a new connection farther east.

A new multi-use path would extend from the Bridgeton neighborhood to the existing Expo Center light rail station and from the station to Hayden Island along the new light rail line over North Portland Harbor.

LPA Option A: Local traffic between Martin Luther King Jr. Boulevard/Marine Drive and Hayden Island would travel via an arterial bridge over North Portland Harbor. There would be some variation in the alignment of local streets in the area of the interchange between Option A and Option B. The most prominent differences are the alignments of Vancouver Way and Union Court.

LPA Option B: With this design option, there would be no arterial traffic lanes on the light rail/multi-use path bridge over North Portland Harbor. Instead, vehicles traveling between Martin Luther King Jr. Boulevard/ Marine Drive and Hayden Island would travel on the collector-distributor bridges that would parallel each side of I-5 over North Portland Harbor. Traffic would not need to merge onto mainline I-5 to travel between the island and Martin Luther King Jr. Boulevard/Marine Drive.

***Potential phased construction option*:** The aforementioned flyover ramp could be deferred and not constructed as part of the CRC project. In this case, rather than providing a direct eastbound Marine Drive to I-5 northbound connection by a flyover ramp, the project improvements to the interchange would instead provide this connection through the signal-controlled SPUI. The flyover ramp could be constructed separately in the future as funding becomes available.

Hayden Island Interchange

All movements for this interchange would be reconfigured. The new configuration would be a split tight diamond interchange. Ramps parallel to the highway would be built, lengthening the ramps and improving merging speeds. Improvements to Jantzen Drive and Hayden Island Drive would include additional through, left-turn, and right-turn lanes. A new local road, Tomahawk Island Drive, would travel east-west through the middle of Hayden Island and under the I-5 interchange, improving connectivity across I-5 on the island. Additionally, a new multi-use path would be provided along the elevated light rail line on the west side of the Hayden Island interchange.

LPA Option A: A proposed arterial bridge with two lanes of traffic, one in each direction, would allow vehicles to travel between Martin Luther King Jr. Boulevard/ Marine Drive and Hayden Island without accessing I-5.

LPA Option B: With this design option there would be no arterial traffic lanes on the light rail/multi-use path bridge over North Portland Harbor. Instead, vehicles traveling between Martin Luther King Jr. Boulevard/Marine Drive and Hayden Island would travel on the collector-distributor bridges that parallel each side of I-5 over North Portland Harbor.

SR 14 Interchange

The function of this interchange would remain largely the same. Direct connections between I-5 and SR 14 would be rebuilt. Access to and from downtown Vancouver would be provided as it is today, but the connection points would be relocated. Downtown Vancouver I-5 access to and from the south would be at C Street rather than Washington Street, while downtown connections to and from SR 14 would be made by way of Columbia Street at 4th Street.

The multi-use bicycle and pedestrian path in the northbound (eastern) I-5 bridge would exit the structure at the SR 14 interchange, and then loop down to connect into Columbia Way.

Mill Plain Interchange

This interchange would be reconfigured into a SPUI. The existing "diamond" configuration requires two traffic signals to move vehicles through the interchange. The SPUI would use one efficient intersection and allow opposing left turns simultaneously. This would improve the capacity of the interchange by reducing delay for traffic entering or exiting the highway.

This interchange would also receive several improvements for bicyclists and pedestrians. These include bike lanes and sidewalks, clear delineation and signing, short perpendicular crossings at the ramp terminals, and ramp orientations that would make pedestrians highly visible.

Fourth Plain Interchange

The improvements to this interchange would be made to better accommodate freight mobility and access to the new park and ride at Clark College. Northbound I-5 traffic exiting to Fourth Plain would continue to use the off-ramp just north of the SR 14 interchange. The southbound I-5 exit to Fourth Plain would be braided with the SR 500 connection to I-5, which would eliminate the non-standard weave between the SR 500 connection and the off-ramp to Fourth Plain as well as the westbound SR 500 to Fourth Plain Boulevard connection.

Additionally, several improvements would be made to provide better bicycle and pedestrian mobility and accessibility, including bike lanes, neighborhood connections, and access to the park and ride.

SR 500 Interchange

Improvements would be made to the SR 500 interchange to add direct connections to and from I-5. On- and off-ramps would be built to directly connect SR 500 and I-5 to and from the north, connections that are currently made by way of 39th Street. I-5 southbound traffic would connect to SR 500 via a new tunnel underneath I-5. SR 500 eastbound traffic would connect to I-5 northbound on a new on-ramp. The 39th Street connections with I-5 to and from the north would be eliminated. Travelers would instead use the connections at Main Street to connect to and from 39th Street.

Additionally, several improvements would be made to provide better bicycle and pedestrian mobility and accessibility, including sidewalks on both sides of 39th Street, bike lanes, and neighborhood connections.

***Potential phased construction option*:** The northern half of the existing SR 500 interchange would be retained, rather than building new connections between I-5 southbound to SR 500 eastbound and from SR 500 westbound to I-5 northbound. The ramps connecting SR 500 and I-5 to and from the north could be constructed separately in the future as funding becomes available.

1.2.2.3 Transit

The primary transit element of the LPA is a 2.9-mile extension of the current Metropolitan Area Express (MAX) Yellow Line light rail from the Expo Center in North Portland, where it currently ends, to Clark College in Vancouver. The transit element would not differ between LPA and LPA with highway phasing. To accommodate and complement this major addition to the region's transit system, a variety of additional improvements are also included in the LPA:

- Three park and ride facilities in Vancouver near the new light rail stations.
- Expansion of Tri-County Metropolitan Transportation District's (TriMet's) Ruby Junction light rail maintenance base in Gresham, Oregon.
- Changes to C-TRAN local bus routes.
- Upgrades to the existing light rail crossing over the Willamette River via the Steel Bridge.

Operating Characteristics

Nineteen new light rail vehicles (LRV) would be purchased as part of the CRC project to operate this extension of the MAX Yellow Line. These vehicles would be similar to those currently used by TriMet's MAX system. With the LPA, LRVs in the new guideway and in the existing Yellow Line alignment are planned to operate with 7.5-minute headways during the "peak of the peak" (the two-hour period within the 4-hour morning and afternoon/evening peak periods where demand for transit is the highest) and 15-minute headways during off-peak periods.

Light Rail Alignment and Stations

Oregon Light Rail Alignment and Station

A two-way light rail alignment for northbound and southbound trains would be constructed to extend from the existing Expo Center MAX station over North Portland Harbor to Hayden Island. Immediately north of the Expo Center, the alignment would curve eastward toward I-5, pass beneath Marine Drive, then rise over a flood wall onto a light rail/multi-use path bridge to cross North Portland Harbor. The two-way guideway over Hayden Island would be elevated at approximately the height of the rebuilt mainline of I-5, as would a new station immediately west of I-5. The alignment would extend northward on Hayden Island along the western edge of I-5, until it transitions into the hollow support structure of the new western bridge over the Columbia River.

Downtown Vancouver Light Rail Alignment and Stations

After crossing the Columbia River, the light rail alignment would curve slightly west off of the highway bridge and onto its own smaller structure over the Burlington Northern Santa Fe (BNSF) rail line. The double-track guideway would descend on structure and touch down on Washington Street south of 5th Street, continuing north on Washington Street to 7th Street. The elevation of 5th Street would be raised to allow for an at-grade crossing of the tracks on Washington Street. Between 5th and 7th Streets, the two-way guideway would run down the center of the street. Traffic would not be allowed on Washington between 5th and 6th Streets and would be two-way between 6th and 7th Streets. There would be a station on each side of the street on Washington between 5th and 6th Streets.

At 7th Street, the light rail alignment would form a couplet. The single-track northbound guideway would turn east for two blocks, then turn north onto Broadway Street, while the single-track southbound guideway would continue on Washington Street. Seventh Street will be converted to one-way traffic eastbound between Washington and Broadway with light rail operating on the north side of 7th Street. This couplet would extend north to 17th Street, where the two guideways would join and turn east.

The light rail guideway would run on the east side of Washington Street and the west side of Broadway Street, with one-way traffic southbound on Washington Street and one-way traffic northbound on Broadway Street. On station blocks, the station platform would be on the side of the street at the sidewalk. There would be two stations on the Washington-Broadway couplet, one pair of platforms near Evergreen Boulevard, and one pair near 15th Street.

East-west Light Rail Alignment and Terminus Station

The single-track southbound guideway would run in the center of 17th Street between Washington and Broadway Streets. At Broadway Street, the northbound and southbound alignments of the couplet would become a two-way center-running guideway traveling east-west on 17th Street. The guideway on 17th Street would run until G Street, then connect with McLoughlin Boulevard and cross under I-5. Both alignments would end at a station east of I-5 on the western boundary of Clark College.

Park and Ride Stations

Three park and ride stations would be built in Vancouver along the light rail alignment:

- Within the block surrounded by Columbia, Washington 4th and 5th Streets, with five floors above ground that include space for retail on the first floor and 570 parking stalls.
- Between Broadway and Main Streets next to the stations between 15th and 16th Streets, with space for retail on the first floor, and four floors above ground that include 420 parking stalls.
- At Clark College, just north of the terminus station, with space for retail or C-TRAN services on the first floor, and five floors that include approximately 1,910 parking stalls.

Ruby Junction Maintenance Facility Expansion

The Ruby Junction Maintenance Facility in Gresham, Oregon, would need to be expanded to accommodate the additional LRVs associated with the CRC project. Improvements include additional storage for LRVs and other maintenance material, expansion of LRV maintenance bays, and expanded parking for additional personnel. A new operations command center would also be required, and would be located at the TriMet Center Street location in Southeast Portland.

Local Bus Route Changes

As part of the CRC project, several C-TRAN bus routes would be changed in order to better complement the new light rail system. Most of these changes would re-route bus lines to downtown Vancouver where riders could transfer to light rail. Express routes, other than those listed below, are expected to continue service between Clark County and downtown Portland. The following table (Exhibit 1-1) shows anticipated future changes to C-TRAN bus routes.

Exhibit 1-1. Proposed C-TRAN Bus Routes Comparison

C-TRAN Bus Route	Route Changes
#4 - Fourth Plain	Route truncated in downtown Vancouver
#41 - Camas / Washougal Limited	Route truncated in downtown Vancouver
#44 - Fourth Plain Limited	Route truncated in downtown Vancouver

C-TRAN Bus Route	Route Changes
#47 - Battle Ground Limited	Route truncated in downtown Vancouver
#105 - I-5 Express	Route truncated in downtown Vancouver
#105S - I-5 Express Shortline	Route eliminated in LPA (The No-Build runs articulated buses between downtown Portland and downtown Vancouver on this route)

Steel Bridge Improvements

Currently, all light rail lines within the regional TriMet MAX system cross over the Willamette River via the Steel Bridge. By 2030, the number of LRVs that cross the Steel Bridge during the 4-hour PM peak period would increase from 152 to 176. To accommodate these additional trains, the project would retrofit the existing rails on the Steel Bridge to increase the allowed light rail speed over the bridge from 10 to 15 mph. To accomplish this, additional work along the Steel Bridge lift spans would be needed.

1.2.2.4 Tolling

Tolling cars and trucks that use the I-5 river crossing is proposed as a method to help fund the CRC project and to encourage the use of alternative modes of transportation. The authority to toll the I-5 crossing is set by federal and state laws. Federal statutes permit a toll-free bridge on an interstate highway to be converted to a tolled facility following the reconstruction or replacement of the bridge. Prior to imposing tolls on I-5, Washington and Oregon Departments of Transportation (WSDOT and ODOT) would have to enter into a toll agreement with U.S. Department of Transportation (USDOT). Recently passed state legislation in Washington permits WSDOT to toll I-5 provided that the tolling of the facility is first authorized by the Washington legislature. Once authorized by the legislature, the Washington Transportation Commission (WTC) has the authority to set the toll rates. In Oregon, the Oregon Transportation Commission (OTC) has the authority to toll a facility and to set the toll rate. It is anticipated that prior to tolling I-5, ODOT and WSDOT would enter into a bi-state tolling agreement to establish a cooperative process for setting toll rates and guiding the use of toll revenues.

Tolls would be collected using an electronic toll collection system: toll collection booths would not be required. Instead, motorists could obtain a transponder that would automatically bill the vehicle owner each time the vehicle crossed the bridge, while cars without transponders would be tolled by a license-plate recognition system that would bill the address of the owner registered to that license plate.

The LPA proposes to apply a variable toll on vehicles using the I-5 crossing. Tolls would vary by time of day, with higher rates during peak travel periods and lower rates during off-peak periods. Medium and heavy trucks would be charged a higher toll than passenger vehicles. The traffic-related impact analysis in this FEIS is based on toll rates that, for passenger cars with transponders, would range from $1.00 during the off-peak to $2.00 during the peak travel times (in 2006 dollars).

1.2.2.5 Transportation System and Demand Management Measures

Many well-coordinated transportation demand management (TDM) and transportation system management (TSM) programs are already in place in the Portland-Vancouver Metropolitan region and supported by agencies and adopted plans. In most cases, the impetus for the programs is from state-mandated programs: Oregon’s Employee Commute Options (ECO) rule and Washington’s Commute Trip Reduction (CTR) law.

The physical and operational elements of the CRC project provide the greatest TDM opportunities by promoting other modes to fulfill more of the travel needs in the project corridor. These include:

- Major new light rail line in exclusive right-of-way, as well as express bus and feeder routes;
- Modern bicycle and pedestrian facilities that accommodate more bicyclists and pedestrians, and improve connectivity, safety, and travel time;
- Park and ride lots and garages; and
- A variable toll on the highway crossing.

In addition to these fundamental elements of the project, facilities and equipment would be implemented that could help existing or expanded TSM programs maximize capacity and efficiency of the system. These include:

- Replacement or expanded variable message signs or other traveler information systems in the CRC project area;
- Expanded incident response capabilities;
- Queue jumps or bypass lanes for transit vehicles where multi-lane approaches are provided at ramp signals for entrance ramps;
- Expanded traveler information systems with additional traffic monitoring equipment and cameras, and
- Active traffic management.

1.2.3 LPA Construction

Construction of bridges over the Columbia River is the most substantial element of the project, and this element sets the sequencing for other project components. The main river crossing and immediately adjacent highway improvement elements would account for the majority of the construction activity necessary to complete this project.

1.2.3.1 Construction Activities Sequence and Duration

The following table (Exhibit 1-2) displays the expected duration and major details of each element of the project. Due to construction sequencing requirements, the timeline to complete the initial phase of the LPA with highway phasing is the same as the full LPA.

Exhibit 1-2. Construction Activities and Estimated Duration

Element	Estimated Duration	Details
Columbia River bridges	4 years	• Construction is likely to begin with the bridges. • General sequence includes initial preparation, installation of foundation piles, shaft caps, pier columns, superstructure, and deck.
Hayden Island and SR 14 interchanges	1.5 - 4 years for each interchange	• Each interchange must be partially constructed before any traffic can be transferred to the new structure. • Each interchange needs to be completed at the same time.
Marine Drive interchange	3 years	• Construction would need to be coordinated with construction of the southbound lanes coming from Vancouver.

Demolition of the existing bridges	1.5 years	• Demolition of the existing bridges can begin only after traffic is rerouted to the new bridges.
Three interchanges north of SR 14	4 years for all three	• Construction of these interchanges could be independent from each other or from the southern half of the project. • More aggressive and costly staging could shorten this timeframe.
Light rail	4 years	• The river crossing for the light rail would be built with the bridges. • Any bridge structure work would be separate from the actual light rail construction activities and must be completed first.
Total Construction Timeline	6.3 years	• Funding, as well as contractor schedules, regulatory restrictions on in-water work, weather, materials, and equipment, could all influence construction duration. • This is also the same time required to complete the smallest usable segment of roadway – Hayden Island through SR 14 interchanges.

1.2.3.2 Major Staging Sites and Casting Yards

Staging of equipment and materials would occur in many areas along the project corridor throughout construction, generally within existing or newly purchased right-of-way or on nearby vacant parcels. However, at least one large site would be required for construction offices, to stage the larger equipment such as cranes, and to store materials such as rebar and aggregate. Suitable sites must be large and open to provide for heavy machinery and material storage, must have waterfront access for barges (either a slip or a dock capable of handling heavy equipment and material) to convey material to the construction zone, and must have roadway or rail access for landside transportation of materials by truck or train.

Three sites have been identified as possible major staging areas:

1. Port of Vancouver (Parcel 1A) site in Vancouver: This 52-acre site is located along SR 501 and near the Port of Vancouver’s Terminal 3 North facility.
2. Red Lion at the Quay hotel site in Vancouver: This site would be partially acquired for construction of the Columbia River crossing, which would require the demolition of the building on this site, leaving approximately 2.6 acres for possible staging.
3. Vacant Thunderbird hotel site on Hayden Island: This 5.6-acre site is much like the Red Lion hotel site in that a large portion of the parcel is already required for new right-of-way necessary for the LPA.

A casting/staging yard could be required for construction of the over-water bridges if a precast concrete segmental bridge design is used. A casting yard would require access to the river for barges, including either a slip or a dock capable of handling heavy equipment and material; a large area suitable for a concrete batch plant and associated heavy machinery and equipment; and access to a highway and/or railway for delivery of materials.

Two sites have been identified as possible casting/staging yards:

1. Port of Vancouver Alcoa/Evergreen West site: This 95-acre site was previously home to an aluminum factory and is currently undergoing environmental remediation, which should be completed before construction of the CRC project begins (2012). The western portion of this site is best suited for a casting yard.

2. Sundial site: This 50-acre site is located between Fairview and Troutdale, just north of the Troutdale Airport, and has direct access to the Columbia River. There is an existing barge slip at this location that would not have to undergo substantial improvements.

1.2.4 The No-Build Alternative

The No-Build Alternative illustrates how transportation and environmental conditions would likely change by the year 2030 if the CRC project is not built. This alternative makes the same assumptions as the build alternatives regarding population and employment growth through 2030, and also assumes that the same transportation and land use projects in the region would occur as planned. The No-Build Alternative also includes several major land use changes that are planned within the project area, such as the Riverwest development just south of Evergreen Boulevard and west of I-5, the Columbia West Renaissance project along the western waterfront in downtown Vancouver, and redevelopment of the Jantzen Beach shopping center on Hayden Island. All traffic and transit projects within or near the CRC project area that are anticipated to be built by 2030 separately from this project are included in the No-Build and build alternatives. Additionally, the No-Build Alternative assumes bridge repair and continuing maintenance costs to the existing bridge that are not anticipated with the replacement bridge option.

1.3 Long-term Effects

The long-term effects identified in this report include noise impacts from traffic on project roadways.

Currently, there are an estimated 230 noise sensitive land uses that have sound levels that approach or exceed the noise abatement criteria in the main CRC project area. Under the future 2030 No-Build Alternative, sound levels at 270 noise sensitive land uses within the project study area would approach or exceed the noise abatement criteria. 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.

The Full Build of the LPA, which would include noise walls, would reduce noise levels to many areas within 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 110 residual residential equivalent traffic noise impacts to noise sensitive land uses. This represents an overall reduction in traffic noise impacts by 160 from the No-Build Alternative.

There were also noise impacts identified at 16 floating homes on Hayden Island and 15 single-family residences along E 17th Street due to light rail operations. All 16 floating homes are in Portland, near the Jantzen Beach area, and the 15 single-family residences are all along E 17th Street between C and G Streets. If the light rail alignment was along McLoughlin Boulevard instead of SE 17th Street, there would be 19 noise impacts to single-family residences.

Finally, vibration levels are predicted to exceed the FTA criteria at the Smith Tower and 14 houses along E 17th Street. Under the McLoughlin Alternative, the same 19 homes identified with noise impacts along McLoughlin Boulevard would also have vibration impacts.

The LPA has four options as described below:

- LPA Option A: Full Build of LPA with vehicular access between Marine Drive and Hayden Island on an arterial bridge
- LPA Option B: Full Build of LPA with vehicular access between Marine Drive and Hayden Island on collector-distributor lanes
- LPA Option A with highway phasing: LPA with some deferred highway elements and vehicular access between Marine Drive and Hayden Island on an arterial bridge
- LPA Option B with highway phasing: LPA with some deferred highway elements and vehicular access between Marine Drive and Hayden Island on collector-distributor lanes

Unless stated otherwise, the LPA with highway phasing options would have the same traffic noise levels effects as the corresponding LPA full build options. Similarly, whether Option A or Option B is built, the traffic noise level impacts are expected to be the same, except where noted.

The primary difference across the design options occurs at the SR 500 interchange with I-5. The LPA (Option A or B) with highway phasing option would defer various ramp improvements, including improvements at the SR 500 interchange with I-5. By delaying this improvement, 13 traffic noise impacts to homes south of SR 500 would be deferred. Mitigation that is recommended to be constructed along this deferred ramp improvement would be constructed at the time the ramp improvements are built.

1.4 Temporary Effects

The primary construction phases for the 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 could range from 99 to 105 dBA at the nearest residences (50 to 100 feet) during the preparation, construction and demolition phases. 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 Proposed Mitigation for Long-term 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 considered for the LPA Full Build.

Eleven noise walls are proposed to mitigate noise impacts predicted to occur to the residences within the project study area. The recommended noise walls and brief descriptions are as follows:

- **Noise Wall No. 1 - *Fort Vancouver Noise Wall / East of I-5***
  This wall would begin along the north side of SR 14, follows the SR 14 on-ramp to northbound I-5, and extend north to the proposed I-5 Community Connector just south of East Evergreen Boulevard. The wall would provide noise level reductions in the range of 6 to 15 dBA for 33 residential equivalents. In addition, the noise wall would provide a 5- to 7-dBA reduction for 29 more residential equivalents, bringing the total number of residences benefiting from the wall to 62.
- **Noise Wall No. 2 - *Downtown Vancouver / West of I-5***
  This wall would be constructed on the west side of I-5 at East 7th Street and provide a 10-dBA noise level reduction for 3 residences.

- **Noise Wall No. 3 - *East Mill Plain to East Fourth Plain / West of I-5***
  This noise wall would be constructed on the west side of I-5 from East Mill Plain Boulevard to East Fourth Plain Boulevard and provide noise level reductions in the range of 4 to 10 dBA for 27 residential equivalents. In addition, the noise wall would provide a 3- to 6-dBA reduction for 17 more residences bringing the total number of residences benefiting from the wall to 44.
- **Noise Wall No. 4 - *East Fourth Plain to East 29th Street / West of I-5***
  This noise wall would be constructed on the west side of I-5 from East 26th Street at East Fourth Plain along the east shoulder of J Street to East 29th Street. This wall would provide noise level reductions in the range of 4 to 13 dBA for 26 residences.
- **Noise Wall No. 5 - *East 29th to East 33rd Streets / West of I-5***
  This noise wall would be constructed on the west side of I-5 from East 29th Street to East 33rd Street and provide noise level reductions in the range of 5 to 12 dBA for the 13 residences. In addition, the noise wall would provide a 5- to 8-dBA reduction for six more residences, bringing the total number of residences benefiting from the wall to 19.
- **Noise Wall No. 6 - *East 33rd Street to East 39th Street / West of I-5***
  This noise wall would be constructed on the west side of I-5 from East 33rd Street to East 39th Street and provide noise level reductions in the range of 9 to 13 dBA for the 23 residences. In addition, the noise wall would provide a 4- to 7-dBA reduction for 14 more residences, bringing the total number of residences benefiting from the wall to 37.
- **Noise Wall No. 7 - *East Fourth Plain to East 29th Street / East of I-5***
  This noise wall would be constructed on the east side of I-5 from East Fourth Plain to East 29th Street and provide noise level reductions in the range of 3 to 13 dBA for 25 residential equivalents. Two residences would continue to have noise levels exceeding the NAC due to the required opening in the noise wall at East 29th Street.
- **Noise Wall No. 8 - *East 29th Street to East 33rd Street / East of I-5***
  This noise wall would be constructed on the east side of I-5 from East 29th Street to East 33rd Street and provide noise level reductions in the range of 7 to 13 dBA for 19 residences. One additional residence would receive 7-dBA reduction from the noise wall bring the total number of residences benefiting from the wall to 20.
- **Noise Wall No. 9 - *East 33rd Street to NE 15th Avenue / East of I-5***
  This noise wall would be constructed on the east side of I-5 from East 33rd Street and East 37th Street, continue along the north boundary of the residential subdivision and end on the edge of SR 500 near NE 15th Avenue. The wall would provide noise level reductions in the range of 3 to 10 dBA for 30 residences. In addition, the noise wall would provide a 4- to 7-dBA reduction for 13 more residences, bringing the total number of residences benefiting from the wall to 43.
- **Noise Wall No. 10 - *R Street to V Street / South of SR 500***
  This noise wall would be constructed on the south side of SR 500 from R Street to V Street and provide noise level reductions in the range of 8 to 10 dBA for 13 residences.
- **Noise Wall No. 11 - *East 39th Street to East 40th Street / West of SR 500***
  This noise wall would be constructed on the west side of I-5 from East 39th Street to the southern portion of the Discovery Middle School and provide a noise level reduction of 12 dBA for 8 residences.

The light rail noise impacts at the floating homes could be mitigated with a sound wall along the elevated structure. The light rail noise impacts to the single-family homes on 17th or on McLoughlin would be mitigated with sound insulation. Finally, all light rail vibration impacts would be mitigated with rail boots. Sound insulation of private residences for highway traffic is generally not allowed under FHWA guidelines. Therefore, for the purposed of this analysis, residential sound insulation would only be considered for light rail noise impacts.

1.6 Proposed Mitigation for Short-term Construction Noise and Vibration Effects

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

- Require all engine-powered equipment to have mufflers that were 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.
- Where possible, schedule the construction of the residential noise barriers early in the project. In some jurisdictions, this may be a requirement in order to get any noise variances.
- 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.
- Use broadband back-up alarms or restrict the use of back-up beepers during evening and nighttime hours and use spotters. In all areas, Occupational Safety and Health Administration (OSHA) will require back-up warning devices and spotters for haul vehicles.
- Use pile driving noise shroud and/or employ auguring techniques where possible to limit effects of pile driving.

Additional noise mitigation measures might be implemented as more details on the actual construction processes are identified.

2. Methods

2.1 Introduction

The purpose of this Noise and Vibration Analysis is to describe existing and future noise levels and proposed noise mitigation measures for the Interstate 5 Columbia River Crossing LPA Phase I Only Option. The FHWA, FTA, ODOT, and 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 conditions in areas potentially affected by the project alternatives
- Regulations and policies governing evaluation and mitigation of noise impacts
- Methodology used in the analysis
- Impacts of the proposed project alternatives (short-term, long-term, and cumulative)
- Potential mitigation measures.

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, light rail transit and construction noise is an integral part of this FEIS.

Federal, state, and local governments provide guidance on acceptable noise levels to ensure the public's health and wellbeing, 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 also a light rail transit component. Under the preferred alternative, the light rail transit component includes a light rail transit system between Clark College in Vancouver and the existing Interstate MAX line at the Portland Expo Center. Potential noise and vibration related to the light rail transit 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 light rail transit component, the FTA requires that both noise and vibration from the light rail transit 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

This section discusses how noise is evaluated—its definition, transmission characteristics, and measurement. This section also provides some typical noise levels for reference. 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 the library creates a relatively small change in the room air pressure, whereas air pressure changes are much greater in the front row of a rock concert.

In addition to the loudness of sound, 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 or "high-pitched." One common example of a high-frequency noise is a referee's whistle. A sound that has a low number of pressure changes per second is referred to as low frequency or low-pitched noise (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, the frequency, the amount of background noise present, and the nature of the activity taking place that the noise affects. For example, boisterous children playing outside during the day, while there is background traffic noise, is generally less obtrusive than if the children were making the same amount of noise during the nighttime sleeping hours. When sounds are perceived as 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 sound is called a decibel (dB). In simple terms, the dB scale is a logarithmic conversion of air pressure level variations (measured in a unit called a Pascal) to a unit of measure with a more convenient numbering system. A person with normal hearing can detect a wide range of sound pressures, a ratio of over a million to one. A direct application of the Pascal linear scale using sound pressures would require the use of numbers typically ranging from about 10 micro-Pascals to 100,000,000 micro-Pascals. The dB scale simplifies the units of sound measurement to a manageable range of numbers and is also a more accurate representation of how the human ear reacts to variations in air pressure. A range from 0 to 120 dB is the typical range of hearing.

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 used to measure the frequency of sound is called a 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 sound level of 60 dB at 250 Hz would be considerably less noticeable to a person than 60 dB at 1,000 Hz.

Of course, discussing sounds in terms of both loudness and frequency can become tedious and confusing. In order 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 frequencies. The adjusted dB scale, referred to as the A-weighted dB scale, provides an accurate "single number" measure of what the human ear can actually hear. When the A-weighted dB scale is used, the dB levels are designated as dBA. This unit of measurement is used in this report.

For a sense of perspective, 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 sound levels is judged as a doubling of sound level, while a 10-dBA decrease in sound 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.

Because decibels are expressed on a logarithmic scale, they cannot be combined by simple addition. For example, if a single vehicle pass-by produces a sound level of 60 dB at 50 feet from a roadway, two identical vehicle pass-bys would not produce a sound level of 120 dB. They would, in fact, produce a sound level of 63 dB. To combine decibels, they must first be converted to energy, then added or subtracted as appropriate, and converted back to decibels. When two decibel values differ by 10 dB or more, the combined sound level is simply equal to the higher value. That is, the sound level that is lower by more than 10 dB would not increase the sound level. Using the vehicle pass-by example, if two vehicles pass by at the same time, one of which produces 60 dB and another that only produces 50 dB, the sound level would be 60 dB. In this example, the louder vehicle can be considered as masking the quieter vehicle. Another practical example of this would be turning music up more than 10 dBA louder than the neighbor's barking dog so that the dog is no longer heard.

2.3.1.2 Typical Noise Levels

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 wind 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. Noise levels in urban neighborhoods are louder than rural areas. Noise levels during the day in a noisy urban area are frequently as high as 70 to 80 dBA. Nighttime noise levels in urban areas are generally much quieter than daytime noise levels and can range from 40 to 50 dBA.

Long-term, or continuous, exposure to very loud noises can damage the human ear. To protect against hearing loss in the workplace, the Washington State Department of Labor and Industries has established an 8-hour continuous exposure limit of 85 dBA (WAC 296-817-300). Noise levels exceeding 85 dBA over continuous periods can result in permanent hearing loss. Noise levels above 110 dBA become intolerable and then extremely painful.

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

Noise Source or Activity	Sound Level (dBA)	Subjective Impression	Relative Loudness (human judgment of different sound levels)
Jet Aircraft takeoff from carrier (50 feet)	140	Threshold of pain	64 times as loud
50 horsepower siren (100 feet)	130		32 times as loud
Loud rock concert near stage, Jet takeoff (200 feet)	120	Uncomfortably loud	16 times as loud
	110		8 times as loud
Float plane takeoff (100 feet) Jet takeoff (2,000 feet)	100	Very loud	4 times as loud
Heavy truck or motorcycle (25 feet)	90		2 times as loud
Garbage disposal (2 feet)	80	Moderately loud	Reference loudness
Typical at-grade light rail vehicle	70		1/2 as loud
Moderately busy department store, Typical television show (10 feet)	60		1/4 as loud
Typical quiet office environment	50		1/8 as loud
Bedroom or quiet living room	40	Quiet	1/16 as loud
Quiet library, soft whisper (15 feet)	30	Very quiet	1/32 as loud
High quality recording studio	20	Just audible	1/64 as loud
Acoustic Test Chamber	10		1/128 as loud
	0	Threshold of hearing	

Sources: Beranek (1998) 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 level, or L_{eq}. The L_{eq} 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, assume that 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 L_{eq}. The same approach is used to determine the L_{eq} for other time periods such as hourly (L_{eq} [h]) or over a 24-hour period (L_{eq} [24h]).

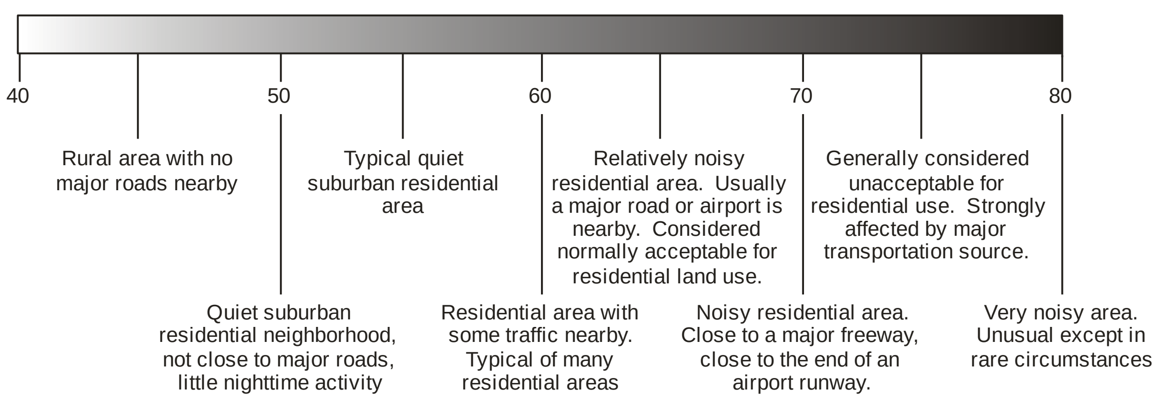
Public response to sound depends greatly upon the range that the sound varies in a given environment. For example, people generally find a moderately high, constant sound level more tolerable than a quiet background level interrupted by high-level noise intrusions. In light of this subjective response, it is often useful to look at a statistical distribution of sound levels over a given time period. Such distributions identify the sound level exceeded and the percentage of time exceeded; therefore, they allow a more complete description of the range of sound levels during the given measurement period.

The State of Washington allows for an exceedance of the noise regulations based on the amount of time the noise source exceeds the criteria. The State of Washington noise regulations are applicable to the construction phases of transportation projects. The sound level descriptor L_{xx} is defined as the sound level exceeded xx percent of the time. To assist with compliance to the noise regulations, the statistical L_{xx} noise descriptor is very useful. For example, during a 1-hour measurement, an L25 of 75 dBA means the sound level was at or above 75 dBA for 15 minutes of that hour (25 percent of the time), which could be used to verify the 15-minute allowable exceedance criterion in the State's code. Similarly, two other statistical descriptors, the L8.3 and L2.5, can be used to verify the 5-minute and the 1.5-minute allowable exceedance criteria in the State's code.

Another noise level descriptor is the Day-Night Equivalent Sound Level, L_{dn}, also abbreviated DNL, which is defined as the 24-hour L_{eq}, 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. It would usually be considered unacceptable for residential land use without special measures taken to enhance outdoor-indoor sound insulation. Residential neighborhoods that are not 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

2.3.1.4 Sound Propagation

Several factors determine how sound levels decrease, or attenuate, over a distance. Two general categories apply to noise sources: 1) a point source (for example, a church bell) and 2) 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 dB at 100 feet and to 54 dB at 200 feet.

Attenuation of point and line sources is 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, dense 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 dBA 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 dBA or less, which is the minimum change in noise levels that the human ear can notice.
- **Topography** includes existing hills, berms, and other ground surface features between the noise source and receiver location. As with structures, topography can 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 toward a sensitive receiver location.
- **Dense foliage** can slightly reduce noise levels. Generally, if the foliage is sufficiently dense that one cannot see over it or through it, then it may provide some additional noise-level reduction from the source to the receiver. For example, the 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.
- **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 traffic 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. There are two types of vibration that 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:

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

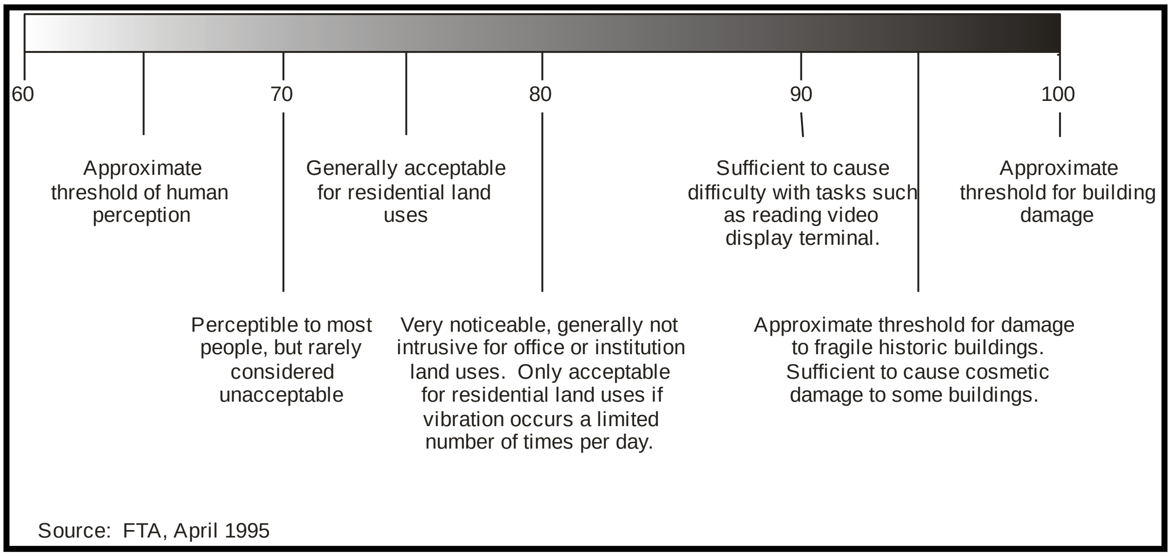
where V is the velocity amplitude in inches/second, Vref is 10^{-6} inches/second, Lv is the velocity level in decibels. The abbreviation VdB is used here for vibration decibels to minimize confusion with sound decibels.

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 USDOT has guidelines for vibration levels from construction related activities, and recommends that the maximum peak-particle-velocity levels 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 feet from a rapid transit or light rail system. Buses and trucks rarely create vibration that exceeds 70 VdB unless there are large bumps or potholes in the road.

Exhibit 2-3. Typical levels of Ground-borne Vibration



2.4 Study Area

The FHWA noise standard, which is documented in 23 CFR 772, requires the identification of all existing activities, developed lands, and undeveloped lands for which development is planned, designed, and programmed that noise from the project might affect. As defined in the WSDOT's Traffic Noise Analysis and Abatement Policy and Procedures (WSDOT 2006a), the noise study area that may be affected by noise from the project includes all lands within 500 feet of the project.

The noise discipline analysts performed a detailed reconnaissance of the project vicinity to identify all noise-sensitive properties within 500 feet of the project. The Full Build of the LPA project study area runs along a 5-mile segment of I-5 that extends approximately from Columbia Boulevard in Oregon to just north of the SR 500 interchange with I-5 in Washington, including the segment of SR 500 from I-5 to V-Street. The study area also includes portions of downtown Vancouver west and east of I-5. The LPA (Option A or B) with highway phasing option would defer various ramp improvements, including improvements at the SR 500 interchange with I-5. Therefore, the project study area for the LPA Options A or B with highway phasing option would not include the segment of SR 500.

2.5 Effects Guidelines

FHWA has published traffic noise criteria that determine when noise mitigation must be considered for a federally funded highway project. The wording of the FHWA criteria leaves some room for interpretation by the state that is conducting the study. The following sections provide details on the FHWA, ODOT, and WSDOT criteria, guiding plans, and policies.

2.5.1 Federal Highway Administration Traffic Noise Impact Criteria

FHWA traffic noise abatement criteria defined in 23 CFR 772 are compared to the study area traffic-noise levels. The abatement criteria applicable for residences, churches, schools, recreational uses, and similar areas are an exterior hourly L_{eq} that approaches or exceeds 67 dBA.

The abatement criteria applicable for other developed lands (such as commercial and industrial uses) are an exterior L_{eq} that approaches or exceeds 72 dBA. FHWA also requires noise abatement to be considered if future noise levels are projected to result in a "substantial increase" over existing noise levels.

Exhibit 2-4 provides the FHWA Traffic Noise Abatement Criteria used for this project.

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 Repor*t May, 2006. The FTA noise criteria would apply to the 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 FTA's use of a sliding scale when assessing noise impacts is what is known as "ambient-based" criteria. The amount that the transit project is allowed to change the overall ambient 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.

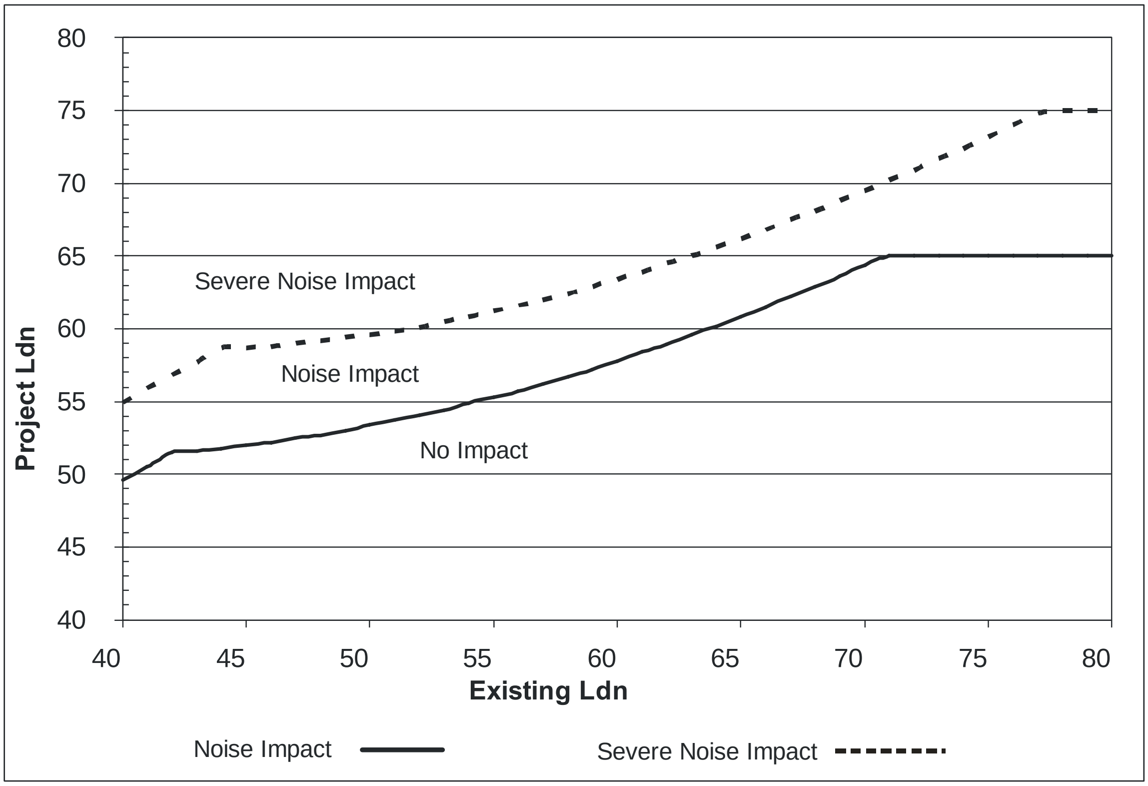
The L_{dn} is used to characterize noise exposure for residential areas (Category 2) and maximum 1-hour L_{eq} during the period that the facility is in use is used for other noise sensitive land uses such as school buildings (Categories 1 and 3).

There are two levels of impact included in the FTA criteria, as shown in Exhibit 2-5. The interpretation of 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 Graphics



The noise impact criteria for fixed guideway transit operations are summarized in Exhibit 2-6. The first column shows the existing noise exposure and the remaining columns show the additional noise exposure caused by the transit project that is necessary for the two levels of impact. The future noise exposure would be the combination of the existing noise exposure and the 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

	Project Noise Exposure Impact Thresholds, L_{dn} or L_{eq}[a] (all noise levels in dBA)			
Existing Noise Exposure	**Category 1 or 2 Sites**		**Category 3 Sites**	
(Leq or Ldn)a	**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

a L_{dn} is used for land uses where nighttime sensitivity is a factor; Daytime L_{eq} 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.

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

Existing Ambient Noise Level (Leq or Ldn)[a]	Allowable Cumulative Noise Level Increases, L_{eq} or L_{dn}[a] (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

a L_{dn} is used for land uses where nighttime sensitivity is a factor; Daytime L_{eq} 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.

2.5.3 Federal Transit Administration Vibration Criteria

The FTA has developed impact criteria for acceptable levels of ground-borne noise and vibration. The FTA vibration criteria would apply to the 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 one-second RMS time constant is assumed. This is in contrast to vibration from blasting and other construction procedures that have the potential of causing building damage. When looking at 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 Guidance Manual (ref. 1) 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 previous standards, criteria, and design goals including ANSI S3.29 and the noise and vibration guidelines of the American Public Transit Association.

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. Exhibits 2-8 and 2-9 gives the FTA criteria for acceptable levels of ground-borne vibration and noise for various types of buildings.

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

	Ground-borne Vibration Impact Levels (VdB re 1 u-inch/sec)		Ground-borne Noise Impact Levels (dB re 20 micro-Pa)	
Land Use Category	Frequent[a] Events	Infrequent[b] Events	Frequent[a] Events	Infrequent[b] Events
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB3	65 VdB[c]	N/A[d]	N/A[d]

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[a] Events	Infrequent[b] Events	Frequent[a] Events	Infrequent[b] Events
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

a “Frequent Events” is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.

b “Infrequent Events” is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.

c 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. Vibration-sensitive equipment is not sensitive to ground-borne noise.

d Vibration-sensitive equipment is generally no sensitive to ground-borne noise.

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 micro-inch/sec)		Ground-borne Noise Impact Levels (dB re 20 micro-Pa)	
	Frequent[a] Events	Infrequent[b] Events	Frequent[a] Events	Infrequent[b] Events
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

a ”Frequent Events” is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.

b “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.

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 State Department of Transportation Criteria

ODOT is responsible for implementing the FHWA regulations in Oregon. Under ODOT policy, a traffic noise impact occurs if predicted noise levels are 2 A-weighted decibels (dBA) below 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 Impact Criteria

Description of Activity	Approach/Exceed 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 Noise Manual.

2.5.4.2 Oregon Department of Environmental Quality (DEQ) Noise Control Regulations

Oregon Administrative Rule (OAR) 340-35 sets 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 (L_{xx}), discrete frequency sounds, and impulsive sounds. L_{xx} 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.

2.5.4.3 Washington State Department of Transportation Criteria

WSDOT's NAC further clarify the FHWA traffic noise criteria. WSDOT clarifies the meaning of "approaches" by requiring noise abatement to be considered when predicted project-related noise levels approach the FHWA criteria level within 1 dBA. Therefore, noise abatement must be considered for residential land use with projected noise levels of 66 dBA L_{eq} or higher, and for commercial land uses with noise levels of 71 dBA L_{eq} or higher.

Exhibit 2-12 provides WSDOT's Noise Abatement Table, which identifies noise levels in L_{eq} that are considered an impact on various land use activity categories. If a noise impact is identified as part of this Type I project, further analysis of potential noise mitigation shall be studied following procedures outlined in WSDOT's Traffic Noise Analysis and Abatement Policy and Procedures (WSDOT 2006a).

Exhibit 2-12. WSDOT Noise Abatement Criteria (NAC)

Activity Category	L_{eq} (h) (dBA)	Description of Activity
A	57 (exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks residences, motels, hotels, schools, churches, libraries, and hospitals.
C	72 (exterior)	Developed lands, properties or activities not included in Categories A or B above
D	–	Undeveloped lands.
E	52 (interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.[a]

Source: USDOT (1982); endnote source WSDOT (2006a).

a Interior noise mitigation will only be considered for public institutions such as schools, hospitals, and libraries and analysis of exterior sound mitigation is determined to be unreasonable or infeasible.

WSDOT also clarifies the meaning of "substantial increase" by considering 10 dBA to be a substantial increase. Noise levels of 80 dBA L_{eq} and higher for outdoor activity areas are defined as "a severe exceedance of the NAC." An NAC exceedance is also considered severe if future design-year noise levels are predicted to increase by 30 dBA or higher over existing noise levels.

There are no criteria for undeveloped lands or construction noise.

2.5.4.4 Washington Administrative Code (WAC)

Daytime construction noise is exempt from regulations in the WAC. Therefore, within the WAC noise ordinance, project construction could be performed during the normal daytime hours of 7:00 a.m. to 10:00 p.m. If construction were to be performed during nighttime hours, the contractor would be required either to meet the noise-level requirements presented in Exhibit 2-13 or to obtain a noise variance from the governing jurisdiction.

Exhibit 2-13. Washington State Noise Control Regulation

Source of Noise	Receiver of Noise (Maximum Allowable Sound Level in dBA[a])		
	Residential	Commercial	Industrial
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

a Between 10:00 p.m. and 7:00 a.m., the levels given above are reduced by 10 dBA for residential receiving property.

In addition to the property-line noise standards listed in Exhibit 2-13, there are exemptions for short-term noise exceedances, including those outlined in Exhibit 2-14, that are based on the minutes per hour that the noise limit is exceeded. This exhibit also provides the corresponding statistical descriptors for each range of exceedances.

Exhibit 2-14. Washington State – Exemptions for Short-term Noise Exceedances

Statistical Descriptor[a]	Minutes Per Hour	Adjustment to Maximum Sound Level
L_{25}	15 (25% of one hour)	+5 dBA
$L_{8.3}$	5 (8.3% of one hour)	+10 dBA
$L_{2.5}$	1.5 (2.5% of one hour)	+15 dBA

a L_{25}, $L_{8.3}$ and $L_{2.5}$ are the noise levels that are exceeded 25 percent, 8.3 percent, and 2.5 percent of the time (one hour, in this case).

2.5.5 Local Noise Ordinances

The City of Portland and the City of Vancouver 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 and to construction from 7:00 pm to 7:00 am and all day on Sundays. The full regulations are given in the City of Portland Municipal Code Title 18, *Noise Control*. Under the City’s noise control ordinance, virtually all major construction projects require a noise variance if work is planned during nighttime hours or on Sundays. Multnomah 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), 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. This code would apply to rail transit stops and stations and to park and ride lots.

2.6 Data Collection Methods

Sound level measurements are recorded only to validate the TNM (2.6.2.1 Noise Model Validation). The sound level measurements are not used to establish the existing sound levels in the study area. Once the model is validated with the sound measurement data, the existing sound levels are established by modeling peak-hour traffic volumes.

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, 6 were long-term (24 to 48 hours) and the other 62 were short-term (15 minutes) monitoring sites. The long-term sites are required for analysis of the light rail transit alternatives, and therefore are primarily located along potential light rail transit routes. The short-term sites are used for primarily for traffic noise, but are also used to support the light rail transit 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.

Traffic counts at 15 minute intervals were made along I-5 from the vantage point of the overpass at W Evergreen Boulevard. Local traffic was also counted near each monitoring location. Because the I-5 counts were made at one location, it is expected that the actual I-5 traffic volumes north and south of the W Evergreen overpass varied from the precise counts made. However, given the relatively consistent traffic flow through the corridor, as well as the consistency in the 24 hour recorded noise levels, the I-5 traffic counts were deemed sufficiently accurate for the model verification process.

2.6.2 Noise Measurement Locations and Levels

On the Portland side, there were two long-term sites on the boat house docks, just west of I-5. Other long-term sites include locations on Broadway Street, Main Street, E McLoughlin Boulevard, and three along K Street for the I-5 light rail transit 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 21 additional short-term 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 and noise levels on aerial photos. The measured L_{eq} is listed for all monitoring locations, however the L_{dn} is only provided for FTA Category 2 land uses along the light rail transit alignment alternatives. Graphs of the long-term data are in Appendix A, Long Term Noise Monitoring Graphs. Appendix A also includes detailed monitoring sheets that include monitoring dates and times of each of the measurements.

Exhibit 2-15. Noise Monitoring Summary

Area	Rec#[a]	Location[b]	Analysis Type[c]	Type[d]	L_{eq}[e]	L_{dn}[f]
Portland	PD-2	1545 N. Jantzen, M. Tworoger 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	E 7th along the side of the hotel	Traffic	Short	68	
	DT-5	316 E 7th Street - Normandy Apartments	Traffic	Short	75	
	DT-6	401 E 13th Street - Shilo Inn Hotel	Traffic	Short	63	
	DT-7	500 E 13th Street - Fort Apartments	Traffic	Short	63	
West side of I-5, north of E 15th	VW-1	514 E 15th Street	Traffic	Short	65	
	VW-3	1601 G Street	Both	Short	65	64
	VW-4	615 E 17th Street	Both	Short	65	64
	VW-6	701 E McLoughlin Boulevard	Both	Short	67	66
	VW-7	704 E McLoughlin Boulevard	Both	Short	66	65
	VW-8	1908 Reserve Street	Traffic	Short	72	
	VW-9	1914 H Street	Traffic	Short	59	
	VW-10	1931 H Street	Traffic	Short	58	
	VW-12	2205 H Street	Traffic	Short	57	
	VW-13	810 I Street	Traffic	Short	63	
	VW-14	2400 H Street	Traffic	Short	58	
	VW-15	904 E 26th Street	Traffic	Short	65	
	VW-16	804 E 26th Street	Traffic	Short	61	
	VW-17	900 E 27th Street	Traffic	Short	60	
	VW-18	815 E 27th Street	Traffic	Short	59	
	VW-19	2714 H Steet	Traffic	Short	57	
	VW-20	901 E 29th Street	Traffic	Short	65	
	VW-21	814 E 30th Street	Traffic	Short	59	
	VW-22	903 E 31st Street	Traffic	Short	69	
	VW-23	615 E 31st Street	Traffic	Short	53	
	VW-24	3114 H Street	Traffic	Short	53	
	VW-25	3200 I Street	Traffic	Short	59	
	VW-26	904 E 33rd Street	Traffic	Short	67	
	VW-27	3306 I Street	Traffic	Short	58	
	VW-28	901 E 34th Street	Traffic	Short	60	
	VW-29	3413 H Street	Traffic	Short	58	
	VW-30	811 E 36th Street	Traffic	Short	57	
	VW-31	3615 H Street	Traffic	Short	53	

Area	Rec#[a]	Location[b]	Analysis Type[c]	Type[d]	L_{eq}[e]	L_{dn}[f]
	VW-32	701 I Street	Traffic	Short	63	
	VW-33	3801 H Street	Traffic	Short	57	
	VW-35	3915 I Street	Traffic	Short	66	
	VW-36	Discovery Middle School: East parking area	Traffic	Short	74	
	VW-39	415 E McLoughlin Boulevard	LRT	Long-term	63	62
	VW-43[g]	2217 E Broadway Street	LRT	Long-term	64	64
	VW-48[g]	3001 Main Street	LRT	Long-term	69	69
	VW-54[g]	Covington Court Apartments	LRT	Long-term	71	71
Fort Vancouver Area	FV-2	Historic Apple 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 Street	Both	Long-term	72	75
	VE-5	2615 K Street	Both	Short	63	65
	VE-6	1111 E 28th Street	Both	Short	57	57
	VE-7	2816 K Street	Both	Short	69	71
	VE-8	2914 K Street	Both	Long-term	69	72
	VE-9	1109 E 30th Street	Both	Short	57	57
	VE-10	3014 K Street	Both	Short	65	66
	VE-11	1104 E 32nd Street	Both	Short	59	59
	VE-12	3200 K Street	Both	Short	65	66
	VE-13	United Pentecostal Church	Both	Short	64	65
	VE-14	3335 K Street	Both	Short	54	53
	VE-15	3503 K Street	Both	Short	61	61
	VE-16	3611 K Street	Both	Long-term	69	70
	VE-17	3608 L Street	Both	Short	61	64
	VE-18	3708 L Street	Both	Short	65	66
	VE-35	Leverich Park near outdoor play structure	Traffic	Short	63	
	VE-38	1006-8 Leverich Park Way	Traffic	Short	68	
	VE-40	4515-2 Leverich Park Way	Traffic	Short	67	

Notes

a Noise modeling number.

b Noise monitoring locations shown on Exhibits 2-16, 2-17, and 2-18.

c Measurements for traffic, light rail or both.

d Long-term (24+ hours) or short-term (15-20 minutes) measurement period.

e Peak traffic hour L_{eq} noise levels.

f 24-hour L_{dn} noise level.

g These receivers are no longer needed because the preferred alignment do not use this area.

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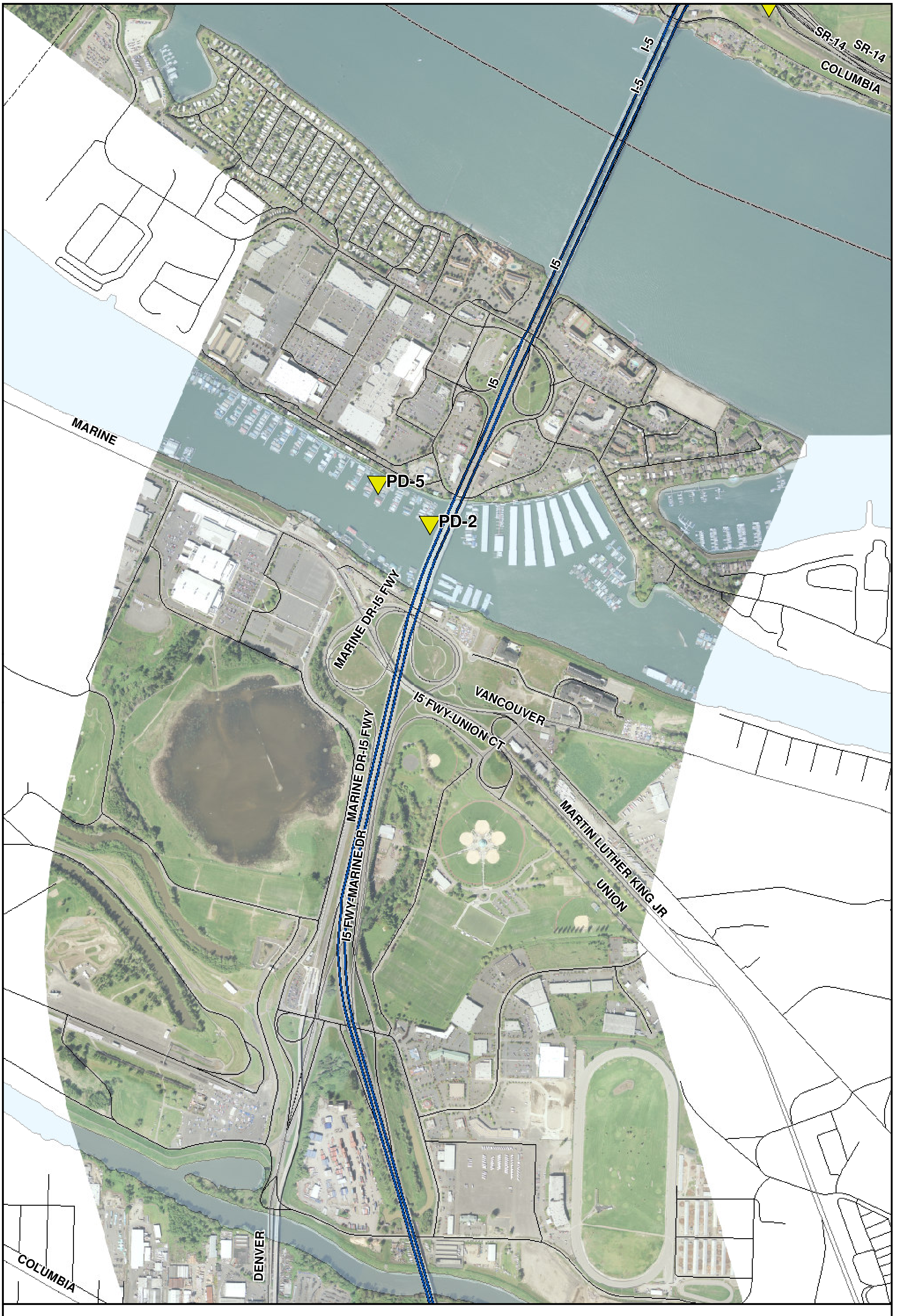

N W E S

0 390 780
Feet

Noise Monitoring Stations

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

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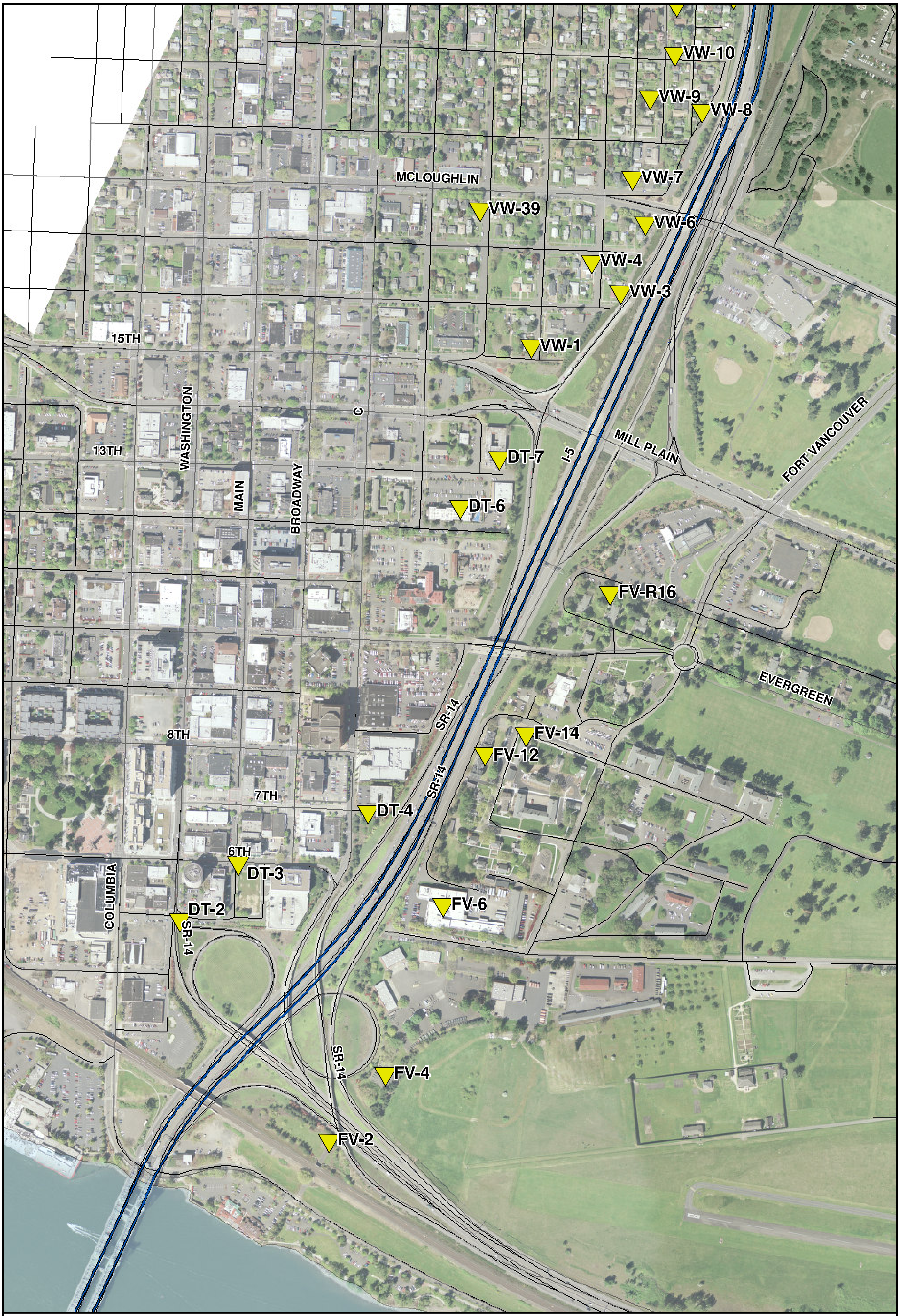

N W E S

0 210 420
Feet

Noise Monitoring Stations

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

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N
W E
S
0 320 640
Feet

Noise Monitoring Stations

Exhibit 2-18. Noise Monitoring Locations - North Vancouver

Columbia River CROSSING

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Noise levels in the project corridor ranged from 53 to 75 dBA L_{eq}, 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 L_{eq}, 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 74 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. A full listing of the traffic data collected during the noise monitoring is provided in Appendix B.

Exhibit 2-19. Traffic Counts for I-5

	Date: June 6, 13, 2007		Northbound I-5			Hourly Equivalent Counts[a]		
#	Start Time	End Time	Cars[b]	MT[c]	HT[d]	Cars[b]	MT[c]	HT[d]
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
	Date: June 6, 13, 2007		**Southbound I-5**			**Hourly Equivalent Counts[a]**		
#	**Start Time**	**End Time**	**Cars[b]**	**MT[c]**	**HT[d]**	**Cars[b]**	**MT[c]**	**HT[d]**
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

a Traffic counts normalized to a 1-hour count.

b Cars = normal passenger vehicles, van, and small trucks.

c MT= Medium trucks, such as delivery vans for UPS and Federal Express.

d HT= Heavy trucks and buses, such as dump trucks and long haul tractor trailers.

After careful review of the noise monitoring field notes, it was determined that 48 of the 71 noise monitoring locations had noise levels that were dominated by I-5 traffic 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 #[a]	Modeled[b]	Measured[c]	Modeled – Measured[d]
PD-5	62	63	-1
PD-2	67	67	0
DT-2	65	66	-1
DT-4	68	68	0
DT-5	73	75	-2
DT-6	65	63	2
VW-1	65	65	0
VW-3	65	65	0
VW-6	66	67	-1
VW-7	64	66	-2
VW-10	60	58	2
VW-12	58	57	1
VW-13	61	63	-2
VW-14	56	58	-2
VW-15	67	65	2
VW-16	62	61	1
VW-17	62	60	2
VW-18	60	59	1
VW-19	57	57	0
VW-21	61	59	2
VW-22	67	69	-2
VW-25	60	59	1
VW-26	66	67	-1
VW-29	58	58	0
VW-32	65	63	2
VW-35	68	66	2
VW-36	73	74	-1
FV-4	64	66	-2
FV-12	69	67	2
FV-14	71	69	2
VE-1	61	61	0
VE-2	57	58	-1
VE-3	69	69	0
VE-4	73	72	1
VE-6	58	57	1
VE-8	67	69	-2
VE-9	55	57	-2
VE-10	64	65	-1

Receiver #[a]	Modeled[b]	Measured[c]	Modeled – Measured[d]
VE-11	57	59	-2
VE-12	64	65	-1
VE-13	63	64	-1
VE-14	56	54	2
VE-15	61	61	0
VE-17	62	61	1
VE-18	65	65	0
VE-35	65	63	2
VE-38	67	68	1
VE-40	67	67	0

a Receivers shown on Exhibits 2-16, 2-17, and 2-18.
b Modeled noise levels from TNM.
c Measured noise levels.
d Difference, modeled minus measured.

The modeled and measured noise results agree within 2 dBA. Because a 2 dBA change in noise levels is barely perceptible to a person with normal hearing, an agreement of +/- 2 dBA or less is considered acceptable for modeled and measured noise level deviations.

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 can be a significant noise source. For this assessment, it has been assumed that audible warning signals would not be used before every street/rail at-grade crossing, as is the practice on some light rail systems. The 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 significant noise source at specific frequencies. Because the noise originates close to the ground, substantial noise mitigation can be achieved with relatively low sound walls. For example, on elevated structures, where sound walls can be located within a few feet of the transit vehicles, walls that are only 3.5 to 4 feet 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. The L_{max} reference noise level for the light rail was provided by TriMet and is the level used in the contract specifications for light rail acquisition. Because TriMet typically runs two car trains, the correction factor of +3.01 dB is included, resulting in a reference level of 78 dBA for a two car train.
3. A model of the noise levels that would be generated by light rail trains was developed and used for this project. The model is based on equations provided in 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 noise levels generated by light rail vehicles used on the Portland TriMet system.

Exhibit 2-21. Light Rail Vehicle Noise Reference Levels

Conditions	
Speed:	50 mph
Length:	two (2) vehicles
Distance from Track Centerline:	50 feet
Track Type:	tie and Ballast

4. 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.
5. Noise exposure projections were developed for each receptor cluster. The projections incorporate the train speed, expected number and length of trains during the daytime (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 train schedules used for the noise projections assumes:

   Peak hour headways of 7.5 minutes, off-peak headways of 15 minutes. Total summary of light rail operation is as follows:

Exhibit 2-22. Light Rail Operation Summary

Time	Headways	Total 2-car Trains
4:00 am to 7:00 am	15 minute	12
7:00 am to 7:00 pm	8 minute	104
7:00 pm to 10:00 pm	15 minute	8
10:00 pm to 2:00 am	15 minute	16

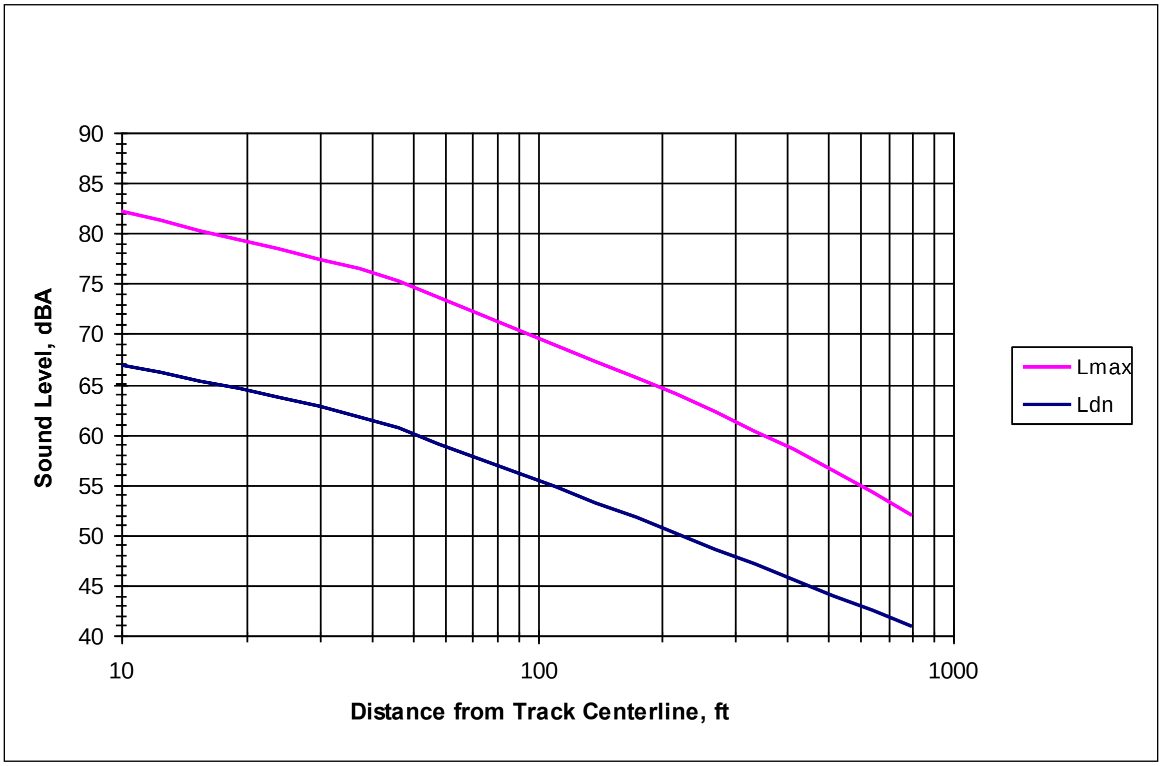
6. The projections also include adjustments based on the track type as summarized in Exhibit 2-22. These adjustments are added to the predicted reference noise levels used to predict potential noise impacts.
7. Graphical representations of projected L_{dn} and L_{max} vs. distance assuming a train speed of 50 mph are shown in Exhibit 2-23.

Exhibit 2-23. Track Type Adjustments for Noise Level Projections

Track Type	Adjustment in dB
At-grade Ballast and Tie Track, Ballast Exposed	0
Elevated Structure	+4
Embedded Track	+3
Retained Cut	-6
At-Grade Station	0
Cross Over	+10

Source: FTA 2006.

Exhibit 2-24. Predicted Noise Levels for a Single Car Light Rail Vehicle at 50 mph



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 2-24, 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 2-24 shows that:

1. If the existing L_{dn} is 65 dBA, there is no impact as long as the project L_{dn} is less than 61 dBA.
2. With a 65 dBA L_{dn}, there is moderate impact if the project L_{dn} will be between 61 and 66 dBA. 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.
3. With a 65 dBA L_{dn}, there is 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 National Environmental Protection Act (NEPA). Noise impacts in the severe range represent the most compelling need for mitigation.

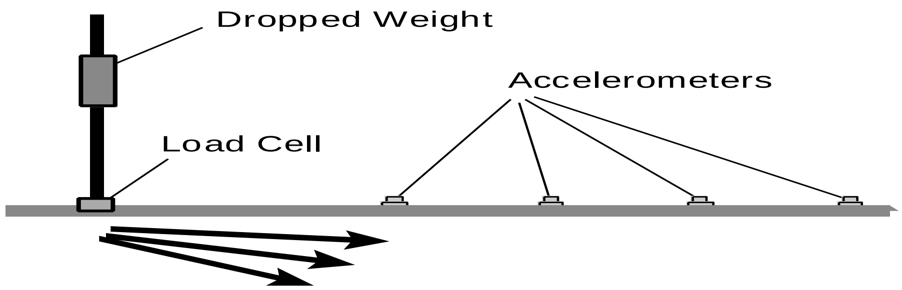
Noise mitigation options were evaluated for all locations where the projected levels of noise exposure exceed either of the FTA noise impact thresholds. The noise mitigation measures for the various alternatives are discussed in Section 6.

Noise levels for the No-Build alternative were derived from the No-Build traffic sections. In general, it was assumed the noise levels would increase an incremental amount as traffic volumes in and around the project corridors also increases. The data in Section 4 shows increases of 1 to 2 dBA throughout most of the project study area.

2.6.4 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



2.6.4.1 Vibration Measurement Locations

Vibration propagation testing was performed at four locations in Vancouver near the proposed light rail transit 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. Because the preferred alternative light rail alignment will access Clark College along E 17th Street, and there are no plans in this project to have light rail access north of E McLoughlin Boulevard, sites 2 through 4 are no longer used in this analysis.

Finally, because the alignment in the Portland area is either elevated or at great distances from any vibration sensitive properties, no propagation testing was performed. The four measurement sites are shown in Exhibit 2-26.

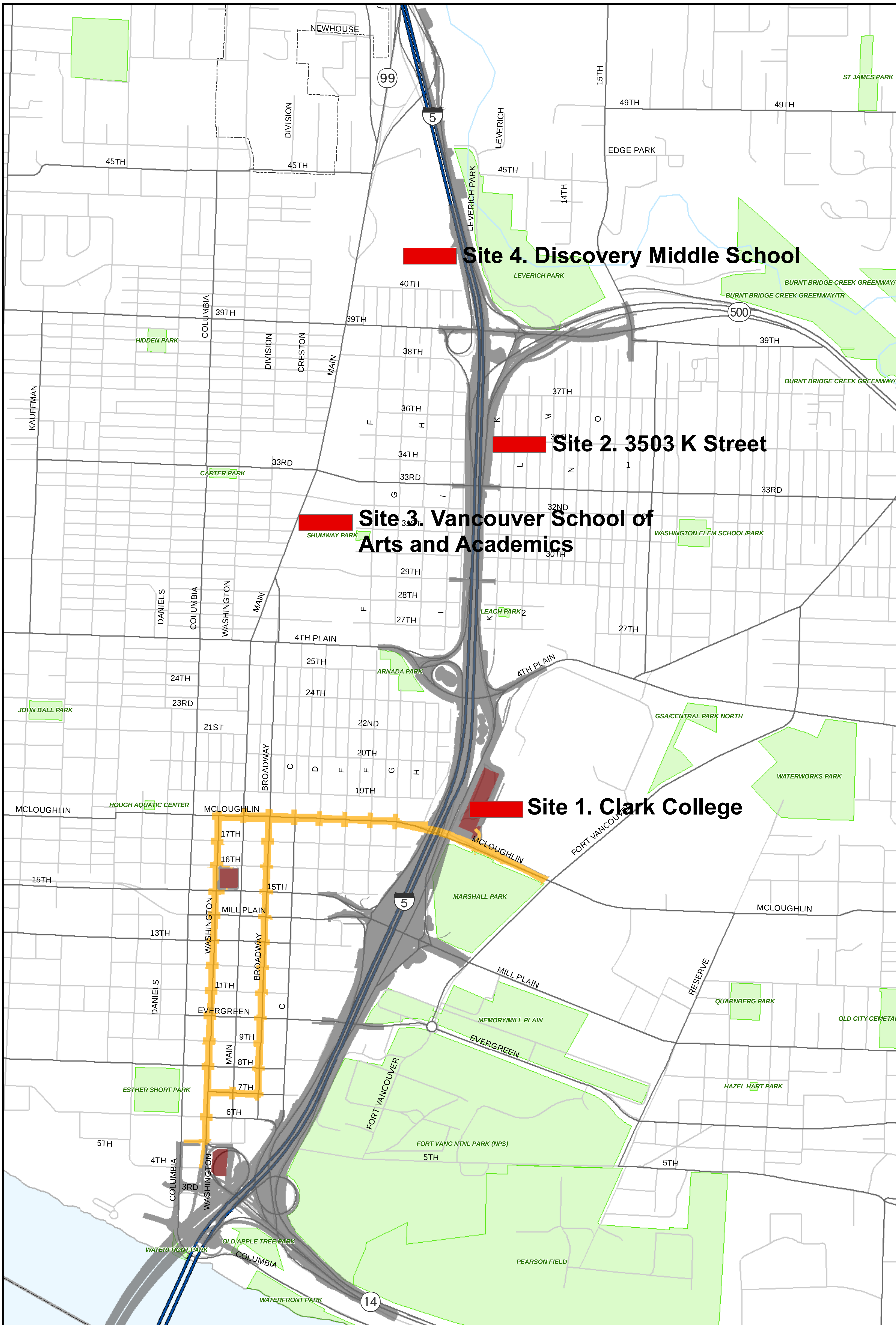


Exhibit 2-26. Vibration Propagation Test Sites

- Vibration Propagation Test Sites
- Park and Ride
- Project Footprint
- Transit Alignment

0 490 980 Feet

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

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The vibration propagation experiments were conducted at the edge of Clark College by the I-5 highway. Three accelerometers and three geophones were placed 25ft, 50ft, 75ft, 100ft, 150ft, and 200ft 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 15ft apart. The measurements were conducted the morning of July 11, 2007. The propagation tests taken at the Clark College site were used for the vibration analysis between the northern landing and the Clark College Terminus.

2.7 Analysis Methods

This chapter summarizes the analysis methods for the noise and vibration analysis within the project study area. Exhibit 2-27 provides a tabulated summary of the noise and vibration sources and the appropriate criteria used in this analysis.

Exhibit 2-27. Summary of Applicable Regulations and Information Sources

Regulation	Citation	Trigger(s)	Information Sources Used
National Environmental Policy Act (NEPA)	National Environmental Policy Act of 1969, as amended.	All federally funded major actions must be analyzed for all physical environmental impacts including noise pollution.	The National Environmental Policy Act (NEPA) of 1969 provides broad authority and responsibility for evaluating and mitigating adverse environmental effects, including highway traffic noise. NEPA directs the federal government to use all practical means and measures to promote the general welfare and foster a healthy environment.
Procedures for Abatement of Highway Traffic Noise and Construction Noise	23 CFR 772 1) WSDOT Traffic Noise Analysis and Abatement Policy and Procedures (WSDOT 2006a). 2) Oregon Department of Transportation Noise Manual, Updated March 2009.	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. Design drawings for the preferred 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	FTA-VA-90-1003-06	Evaluate potential noise and vibration impacts related to the operation of the light rail.	Hourly and daily light rail headways, number of cars per train, speeds, total number of trains during daytime and nighttime hours. Design drawings for the preferred alternative including existing and future ground elevations for nearby noise receivers and areas between alternative alignment and receivers. Measured existing noise levels. Direct measurement of light rail noise levels.

Regulation	Citation	Trigger(s)	Information Sources Used
Washington Administrative Code	WAC 173.60	Evaluate and discuss construction noise impacts in Washington State.	The City of Vancouver uses the WAC for construction noise. Under this ordinance construction noise is exempt during weekdays and Saturdays between 7:00 am and 10:00 pm. Construction outside those hours would likely require a noise variance from the City of Vancouver.
City of Portland Noise Control Ordinance	City of Portland Code and Charter, Title 18 Noise Control.	Evaluate and discuss construction noise impacts in Oregon.	The City of Portland noise control ordinance exempts construction noise during weekdays and Saturdays between 7:00 am and 7:00 pm. Construction outside those hours would likely require a noise variance from the City of Portland.

2.7.1 Traffic Noise Criteria

The traffic noise abatement criteria (NAC), against which the project traffic noise levels are evaluated, are taken from Title 23 of the Code of Federal Regulations (CFR) Part 772, Procedures for Abatement of Highway Traffic Noise and Construction Noise. The criterion applicable for residences, churches, schools, recreational uses, and similar areas is an exterior hourly equivalent sound level (L_{eq}) that approaches or exceeds 67 dBA. The criterion applicable for other developed lands, such as commercial and industrial uses, is an exterior L_{eq} that approaches or exceeds 72 dBA. There are no criteria for underdeveloped lands or construction noise.

In Oregon, a noise impact occurs if the noise levels during the design-year peak noise hour meet the approach/exceed 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 approach, within 1 dBA, the noise impact criteria listed in Exhibit 2-12 (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 Long-term Operational Impacts Approach

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 level for each location was compared to the ODOT and WSDOT 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.

2.8 Coordination

The noise and vibration discipline team worked directly with federal, state, and local agencies and community groups. The team coordinated with FHWA, ODOT, WSDOT, FTA, David Evans & Associates, Parametrix, and the US Forest Service. 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.

Our team of 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. We worked with project team members, and the general public to identify all noise-sensitive land uses and to determine an acceptable method of analyzing the many noise sensitive receivers within the project corridor to ensure that any required noise mitigation would be considered.

We also coordinated with project team leads to obtain 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 office space. The 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.
- Contacted schools along the corridor to discuss the 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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3. Affected Environment

3.1 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.

3.2 Land Use

The noise impact criterion levels for noise studies are dependent 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 will evaluate 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.

The following section provides a summary of the land uses based on FHWA and FTA criteria. Exhibits 3-1, 3-2, and 3-3 provide an aerial view with sensitive land uses identified. Text describing the land use is provided in the following three sections.

3.2.1 Portland Land Use

Land use in Portland (Delta Park to the I-5 bridges) includes residential and commercial. Most of the land uses near the highway or light rail transit 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, Residence Inn Hotel, Fairfield Inn & Suites, and the Courtyard by Marriott. There is also a large group of single and multifamily 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. Delta Park is located along the east side of I-5 between N Marine Drive and N Victory Boulevard. South of Delta Park, there are several commercial establishments along N Whitaker Road.

3.2.2 Downtown Vancouver Land Use

Land use in Downtown Vancouver 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 several existing and some relativity new condominiums and apartments along Washington and Columbia Streets, and the Smith Tower at the intersection of Washington Street and W 6th Street. There are also hotels and apartments along the western side of I-5 between E 6th Street and E 15th Street. The Academy Chapel which is used for weddings, is located in the northwest corner of E Evergreen Boulevard and I-5.

3.2.3 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 E 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 light rail transit routes along Main Street include residential, school, hotels, and commercial and retail use. Most residential land uses are located between 27th and 35th Streets.

3.3 Noise Modeling Locations

For the traffic noise analysis, noise levels were modeled at 136 locations representing approximately 805 noise sensitive land uses within the project area. For the light rail transit analysis, noise levels were modeled at 38 locations representing 179 noise sensitive land uses. Some of the modeling locations used for the traffic noise analysis were also used for the transit analysis.

Each traffic and light rail transit modeling location was 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. The noise modeling locations are shown on Exhibits 3-4, 3-5, and 3-6.

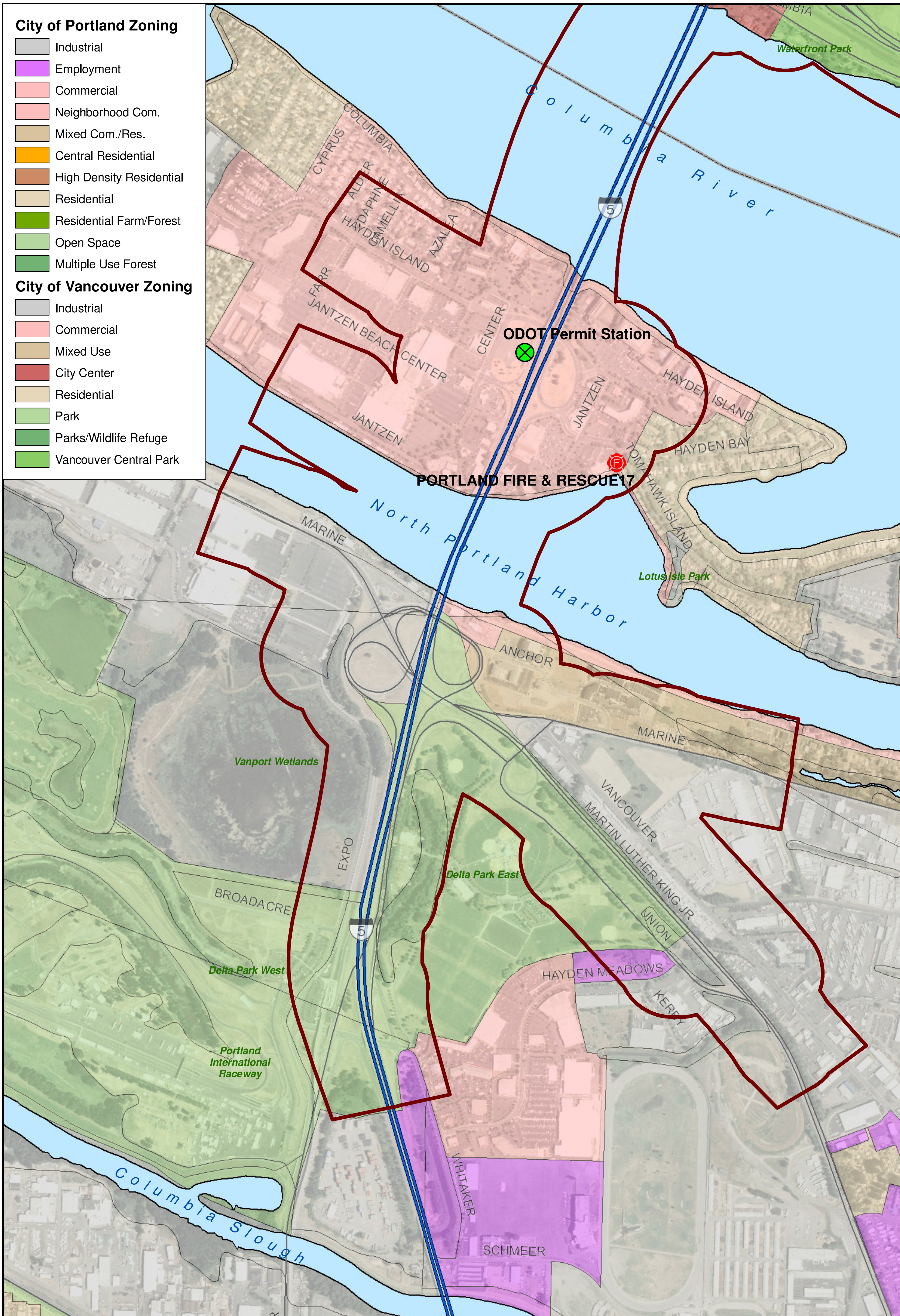
There are several hotels in the study area and those rooms that are projected to have interior noise levels influenced by traffic on I-5 are included in this analysis. There are two hospitals of concern within the project corridor. The VA Medical center is located just south of E Fourth Plain Boulevard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

3.4 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, churches, schools and the cemetery were calculated based on information from the appropriate authority and site inspections.

3.5 Regional Traffic Noise Conditions

Traffic noise modeling was performed for 136 modeling locations representing 805 residences and residential equivalents. The modeling locations are shown on Exhibits 3-4, 3-5, and 3-6. 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 230 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, 96 are located on the Portland side, and 134 are located in Vancouver.



Police Station
Post Office
Hospital
Solid Waste
School
Fire Station
Public Service
Primary API

0 350 700
Feet

Exhibit 3-1. Land Use - Portland Area

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Apr. 14, 2010; File Name: LNU_MM133.mxd

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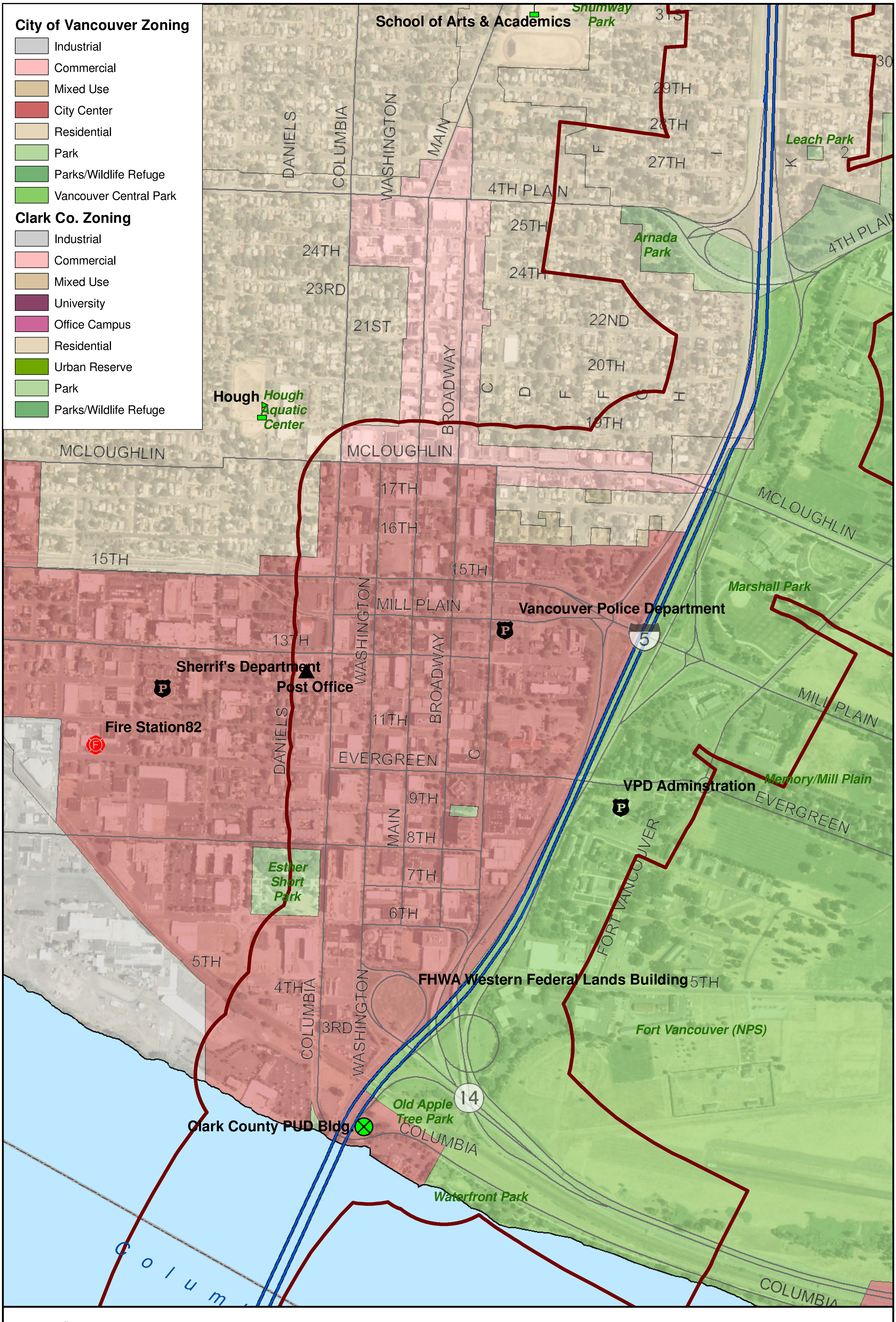

Exhibit 3-2. Land Use - Downtown Vancouver and Fort Vancouver Areas

Analysis by J. Koloszar; Analysis Date: Apr. 14, 2010; File Name: LNU_MM133.mxd

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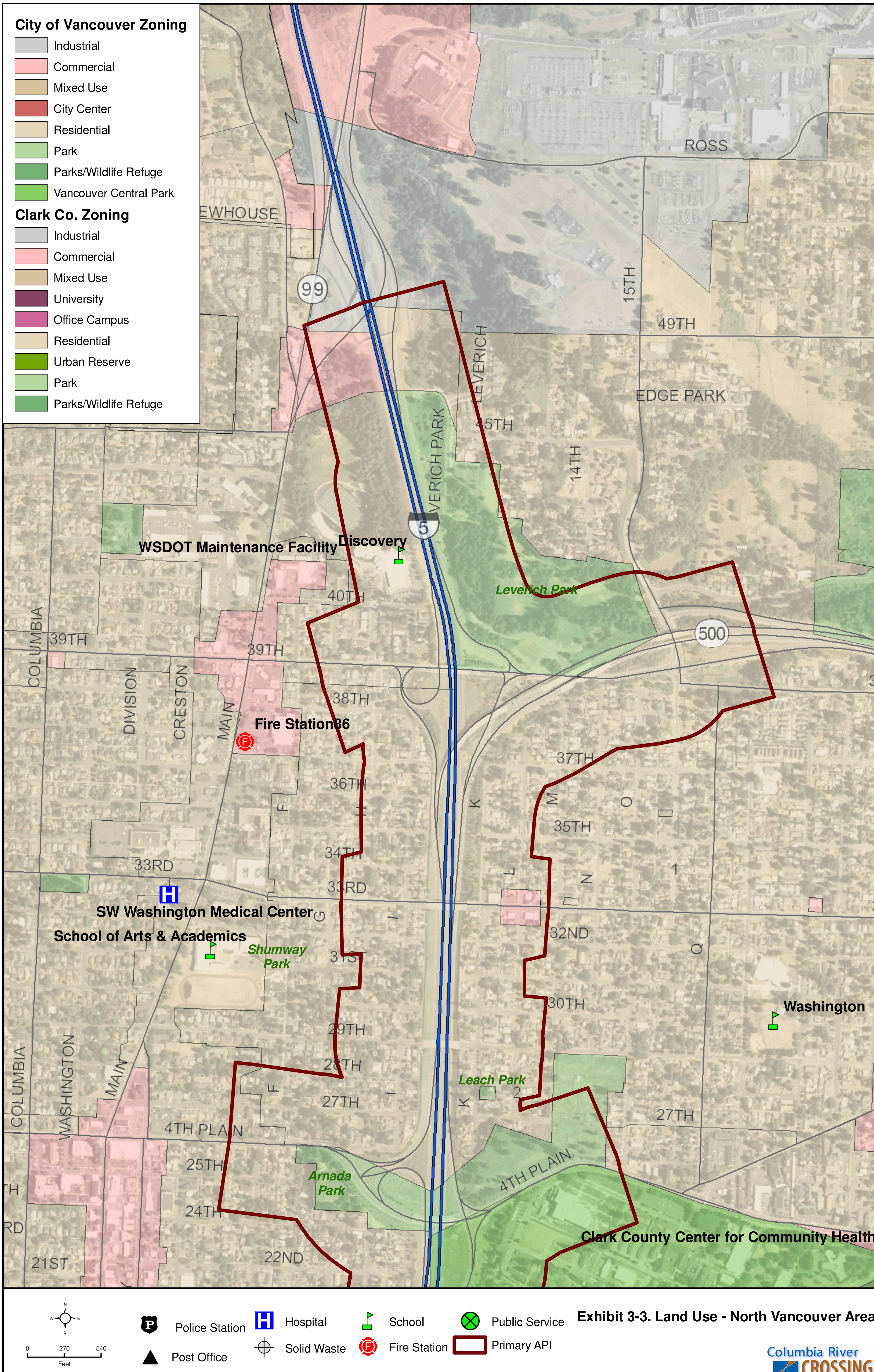

Exhibit 3-3. Land Use - North Vancouver Area

Analysis by J. Koloszar; Analysis Date: Apr. 14, 2010; File Name: LNU_MM133.mxd

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Noise Modeling Stations

Exhibit 3-4. Noise Modeling Locations - Portland Area

N W E S

0 325 650
Feet

Columbia River CROSSING

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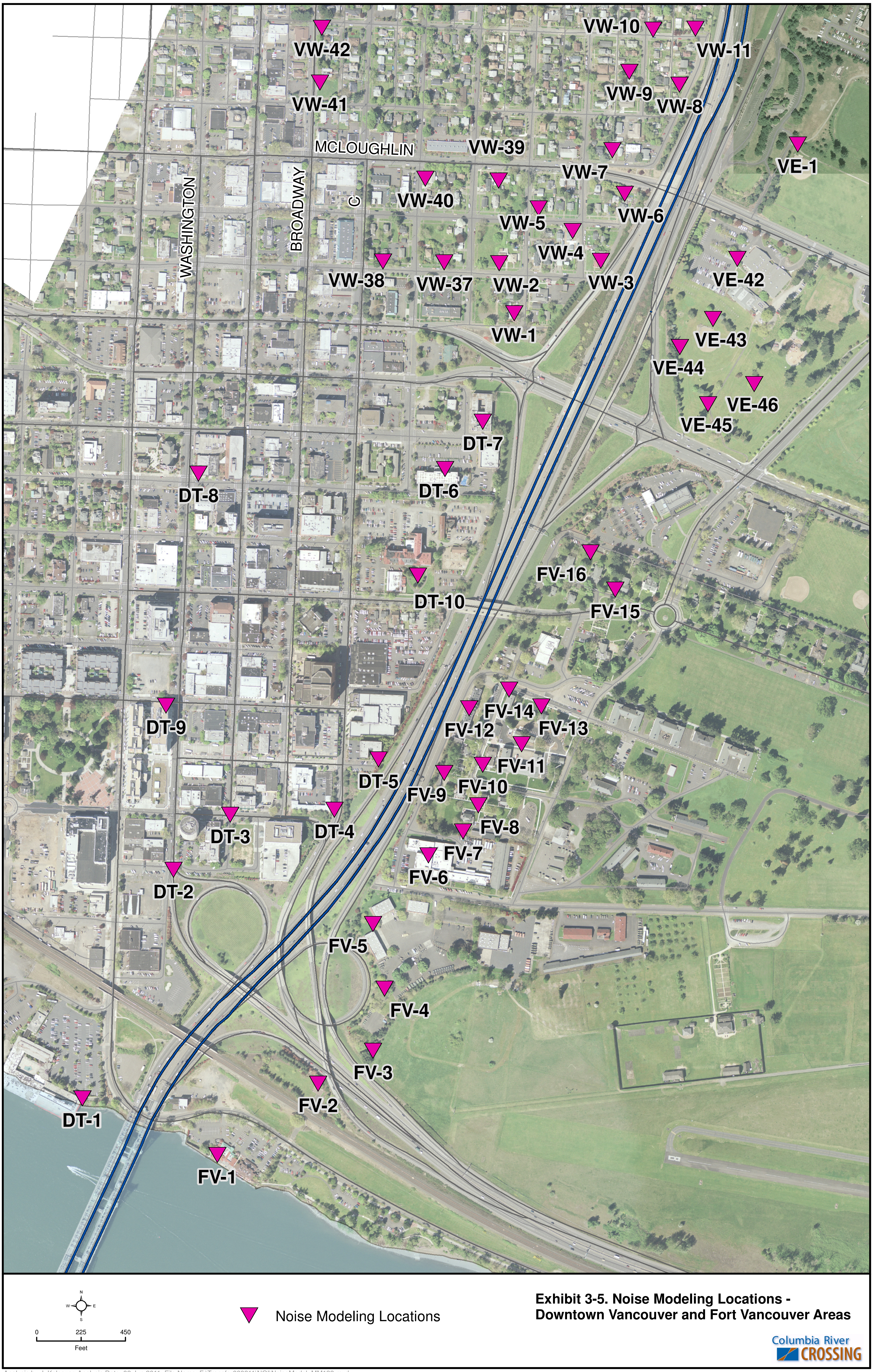

Exhibit 3-5. Noise Modeling Locations - Downtown Vancouver and Fort Vancouver Areas

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 09 Jun 2011; File Name: F:\Transfer060811\NOI\NoiseModel_MM133.mxd

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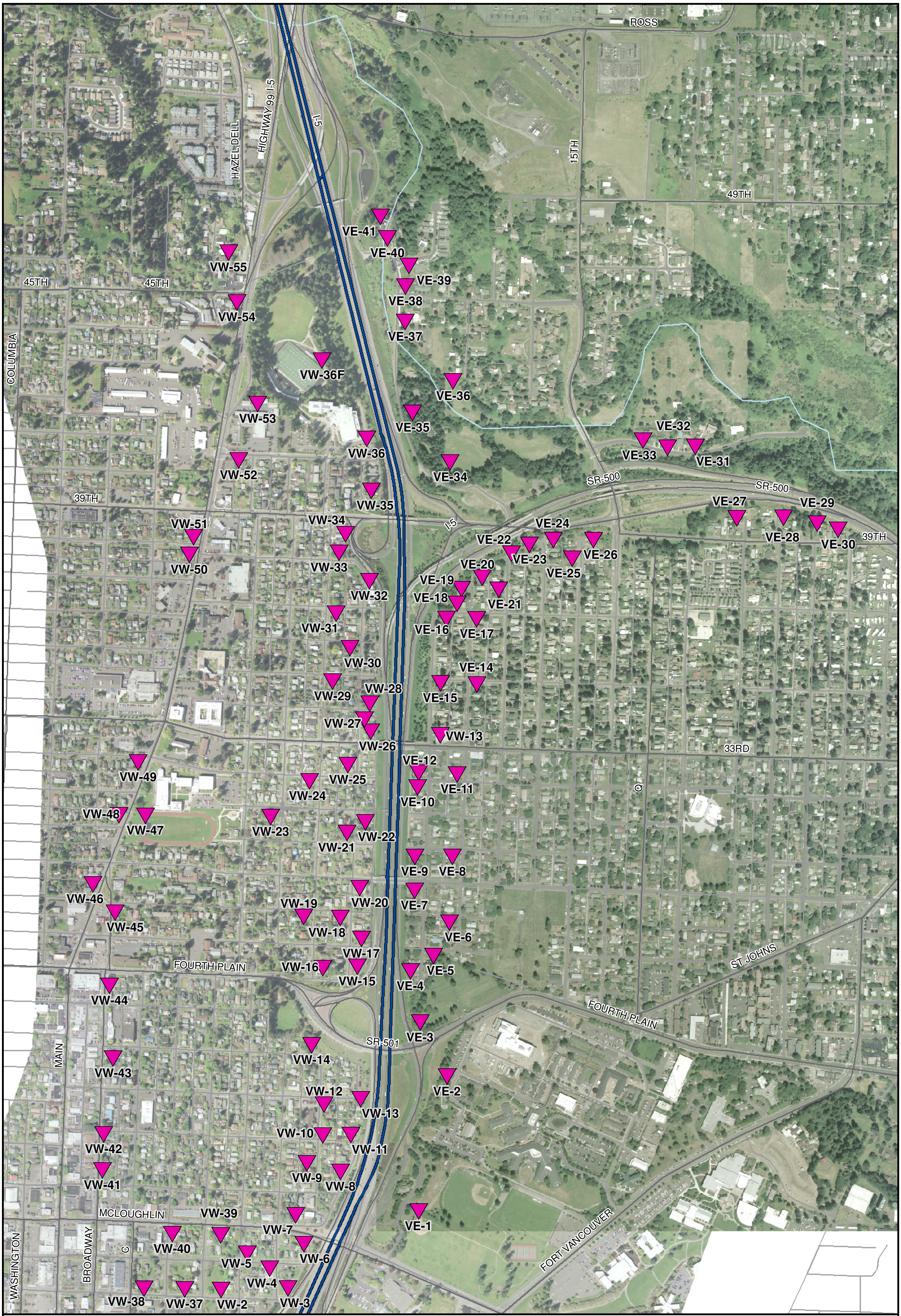

Noise Modeling Locations

Exhibit 3-6. Noise Modeling Locations - North Vancouver

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 09 Jun 2011; File Name: F:\Transfer060811\NOI\NoiseModel_MM133.mxd

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3.6 Delta Park to Mill Plain District

The following sections provide a summary of 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.

3.6.1 Portland Existing Modeled Traffic Noise Levels

Current noise levels are projected to exceed the ODOT traffic noise criteria at 96 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}. Existing noise levels also exceed the criteria within the south portion of Delta Park (PD-27) and 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 3-7 provides a summary of the modeled noise levels and corresponding number of noise impacts.

Exhibit 3-7. Existing Conditions Traffic Noise for Portland

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
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[g]	0	Hotel[g]	–	64	
PD-12[g]	0	Hotel[g]	–	67	0
PD-13[g]	0	Hotel[g]	–	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	
PD-21	24	Res	65	56	
PD-22	12	Res	65	55	
PD-23	6	Hotel	65	54	
PD-24	6	Hotel	65	62	
PD-25	4	Park	65	63	

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
PD-26	4	Park	65	59	
PD-27	4	Park	65	65	4
PD-28	0	Comm	70	67	
Totals Units:	**277**			**Total Impacts:**	**96**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences, hotel rooms, or residential equivalence.

c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

d Traffic noise impacts criteria.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria.

g This receiver represents a hotel that is vacant and not in use.

3.6.2 Downtown Vancouver

There are nine traffic noise modeling locations in Downtown Vancouver that represent 79 noise sensitive properties. Land uses in this section include multi-family residences, hotels, motels, and the Academy Chapel (a church used for weddings). The University of Phoenix located in the West Coast Bank building was considered for a noise sensitive noise modeling location but due to the fact that the two classrooms on the third floor face west (away from I-5) it was not included in the analysis. Currently, an estimated 41 of the 79 identified noise sensitive land uses meet or exceed the WSDOT traffic noise criteria due primarily to traffic noise from I-5.

This analysis is concerned only with I-5, SR 14 and ramps on and off these two highways. Additional noise from traffic operating on local surface streets such as Washington Street and 6th Street cause the noise levels at the Smith Towers to exceed the criteria. However, noise levels generated exclusively from I-5 do not exceed the criteria at this location, and therefore, noise impacts at the Smith Tower are not included in the totals. Due to shielding from other buildings and the distance from the highway, projected noise levels at the tower from I-5, SR 14 and ramps are expected to be 61 dBA $L_{eq.}$ However, the mid-day measured noise level on the sidewalk in front of the building was 69 dBA L_{eq}. Exhibit 3-8 is a summary of the modeled noise levels.

Exhibit 3-8. Downtown Vancouver Traffic Noise Levels

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
DT-1	2	Hotel	66	67	2
DT-2	0	Undeveloped	–	68	
DT-3	24	Res	66	61[g]	
DT-4	12	Hotel	66	70	12
DT-5	6	Res	66	74	6
DT-6	6	Hotel	66	66	6
DT-7	12	Res	66	68	12
DT-10	11	Church	66	64	
DT-11	24	Res	66	64	
Totals Units:	**79**			**Total Impacts:**	**38**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences, hotel rooms, or residential equivalence.

c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

d Traffic noise impacts criteria.

e Existing modeled noise levels from TNM version 2.5 with impacts in bold red type.

f Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria.

g Noise levels at the Smith Tower only from I-5, SR 14 and ramps. Actual noise levels at this location measured 69 dBA L_{eq} due to local traffic.

3.6.3 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 38 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 3-9.

Exhibit 3-9. Fort Vancouver Area Traffic Noise Levels

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
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	

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
FV-14	0	Undeveloped	–	72	
FV-15	4	Comm	66	61	
FV-16	2	Comm	66	68	
Totals Units:	**99**			**Total Impacts:**	**11**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences, hotel rooms, or residential equivalence.

c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

d Traffic noise impacts criteria.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria.

3.7 Mill Plain District to North Vancouver

This 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.

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

There are 46 noise modeling locations for the area between Mill Plain and north of SR 500. The 46 locations represent 183 residences and residential equivalents, a church, school, hospital, two parks and a cemetery. Existing noise levels at the modeling locations ranged from 55 to 74 dBA L_{eq}. Currently there are 36 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 3-10 is a summary of the existing noise levels and location of noise impacts.

Exhibit 3-10. Traffic Noise Levels East of I-5, North of Mill Plain

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
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	
VE-15	10	Res	66	60	

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
VE-16	5	Res	66	64	
VE-17	5	Res	66	61	
VE-18	4	Res	66	61	
VE-19	3	Res	66	62	
VE-20	2	Res	66	64	
VE-21	3	Res	66	64	
VE-22	4	Res	66	62	
VE-23	1	Res	66	65	
VE-24	2	Res	66	67	2
VE-25	2	Res	66	64	
VE-26	1	Res	66	65	
VE-27	4	Res	66	64	
VE-28	3	Res	66	62	
VE-29	3	Res	66	67	3
VE-30	3	Res	66	61	
VE-31	2	Res	66	57	
VE-32	2	Res	66	57	
VE-33	3	Res	66	56	
VE-34	6	Park	66	62	
VE-35	6	Park	66	64	
VE-36	4	Res	66	61	
VE-37	2	Res	66	66	2
VE-38	2	Res	66	67	2
VE-39	1	Res	66	66	1
VE-40	3	Res	66	67	3
VE-41	4	Res	66	67	4
VE-42	3	Park	66	64	
VE-43	3	Park	66	65	
VE-44	3	Park	66	69	3
VE-45	3	Park	66	64	
VE-46	22	Park	66	61	
Totals Units:	**183**			**Total Impacts:**	**36**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences, hotel rooms, or residential equivalence.

c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

d Traffic noise impacts criteria.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria.

3.7.2 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 56 to 73 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, 50 residences and the Discovery School Parking area meet or exceed the abatement 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. As a result, the school parking lot is not considered a noise sensitive land use. The noise levels for the parking lot are carried through this analysis for information purposes only. Exhibit 3-11 is a summary of the existing noise levels and location of noise impacts.

Exhibit 3-11. Traffic Noise Levels West of I-5, North of Mill Plain

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
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	
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	

Rec[a]	Units[b]	Land Use[c]	Criteria[d]	Existing[e]	Impacts[f]
VW-34	4	Res	66	68	4
VW-35	8	Res	66	68	8
VW-36	0	School Parking	71	73	0
VW-36F	22	School	66	65	
Totals Units:	**167**			**Total Impacts:**	**50**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.
b Number of residences, hotel rooms, or residential equivalence.
c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.
d Traffic noise impacts criteria.
e Existing modeled noise levels from TNM version 2.5.
f Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria.

3.8 Existing Noise Levels for Light Rail Transit Analysis

Noise level reporting for the light rail 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 light rail analysis is taken from on-site measurements and derived using methods described in the FTA Transit Noise and Vibration Manual. Several of the locations used for the traffic noise analysis are also used for the light rail alternative, if they are in the transit corridor.

There are several methods described in the FTA manual for determining the existing noise environment. For those locations were monitoring was not performed, the existing environment as derived using one of the FTA methods, or by extrapolating the noise levels using standard acoustical formulas. Exhibit 3-12 summarizes the locations for light rail analysis and the projected noise levels in L_{eq} and L_{dn}.

Exhibit 3-12. Existing L_{eq} and L_{dn} for Light Rail Transit Noise Analysis

Rec#[a]	Land Use[b]	Location[c]	L_{eq}[d]	L_{dn}[e]
PD-1	Res	Portland	67	69
PD-2	Res	Portland	67	69
PD-3	Res	Portland	64	67
PD-4	Res	Portland	63	63
PD-5	Res	Portland	63	63
PD-6	Res	Portland	61	61
PD-8	Res	Portland	66	69
PD-11	Res	Portland	64	65
DT-1	Res	Waterfront	64	66
DT-3	Res	Washington Street	69	71
DT-4	Res	Broadway Street	65	67
DT-9	Res	Washington Street	67	69
DT-8	Res	Washington Street	66	67
VW-2	Res	16th Street	61	60
VW-3	Res	16th Street	65	66
VW-37	Res	16th Street	61	60

Rec#[a]	Land Use[b]	Location[c]	L_{eq}[d]	L_{dn}[e]
VW-38	Res	16th Street	60	60
VW-6	Res	McLoughlin Blvd	67	68
VW-7	Res	McLoughlin Blvd	66	67
VW-39	Res	McLoughlin Blvd	63	62
VW-40	Res	McLoughlin Blvd	63	62
VW-41[F]	Res	Broadway	64	64
VW-42[8]	Res	Broadway	64	64
VW-43[8]	Res	Broadway	64	64
VW-44[8]	Res	Broadway	64	64
VW-45[8]	Res	Broadway	65	65
VW-46[8]	Res	Main Street	69	69
VW-47[8]	School	Main Street	69	69
VW-48[8]	Res	Main Street	69	69
VW-49[8]	Res	Main Street	69	69
VW-50[8]	Medical Center	Main Street	69	69
VW-51[8]	Res	Main Street	69	69
VW-52[8]	Res	Main Street	69	69
VW-53[8]	Fire	Main Street	69	69
VW-54[8]	Res	Main Street	69	69
VW-55[8]	Res	Main Street	69	69
VW-56[8]	Res	Main Street	69	69
VE-1	Park	McLoughlin Blvd	61	60
VE-2	Hospital	VA Medical Center	58	58
VE-3	Res	I-5	69	70
VE-13	Church	I-5	64	65
VE-15	Res	I-5	66	67
VE-16	Res	I-5	69	70
VE-18	Res	I-5	69	70

a Receivers shown on Exhibits 2-16, 2-17 and 2-18.

b Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

c General location of receiver.

d Peak-hour L_{eq} for institutional land uses.

e 24-hour L_{dn} for residential analysis.

f Receivers VW-41 through VW-56 were used for an analysis of a light rail along Main Street, which is not being considered as part of this analysis and the noise levels are presented for reference only.

4. Long-term Effects

4.1 Introduction

This chapter describes the potential noise effects from the No-Build Alternative and the LPA Full Build option within the project area. The long-term traffic noise effects presented here would be essentially the same with the LPA Design Option A and B. The LPA with highway phasing option would defer various ramp improvements, including improvements at the SR 500 interchange with I-5. By delaying these ramp improvements, long-term traffic noise effects to homes south of SR 500 would be deferred. Mitigation that is recommended to be constructed along this deferred ramp improvement would be constructed at the time the ramp improvements are built.

The following sections are organized by the subareas.

4.2 Portland Area Traffic Noise

This section describes the potential noise effects from the No-Build Alternative and the LPA Full Build within the Portland, Oregon area.

4.2.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for Portland area receivers (PD) as shown in Exhibit 4-1. No-Build Alternative noise levels are projected to exceed the ODOT traffic noise criteria at the same 96 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 66 to 73 dBA L_{eq}. With the No-Build Alternative these levels would increase by 1 to 2 dBA over the existing noise levels, an increase typically not discernable by a person with normal hearing. All other traffic noise levels above the traffic noise abatement criteria are within the south east portion of Delta Park and at the Red Lion Columbia Center hotel, which include all rooms facing toward I-5 with noise levels ranging from 68 to 72 dBA L_{eq}. Exhibit 4-1 provides a summary of the modeled noise levels associated with the No-Build Alternative.

Exhibit 4-1. Portland Area No-Build Alternative Traffic Noise Levels

Rec[a]	Residents[b]	Land Use[c]	Existing[e]	No-Build[f]	Change[g]
PD-1	3	Res	71	72	1
PD-2	17	Res	71	72	1
PD-3	16	Res	66	67	1
PD-4	14	Res	58	59	1
PD-5	7	Res	60	61	1
PD-6	15	Res	50	51	1
PD-7	24	Res	47	48	1
PD-8	14	Res	**73**	**74**	1
PD-9	15	Res	56	58	2
PD-10	5	Res	57	58	1

Rec[a]	Residents[b]	Land Use[c]	Existing[e]	No-Build[f]	Change[g]
PD-11[g]	0	Hotel[g]	64	65	1
PD-12[g]	0	Hotel[g]	67	68	1
PD-13[g]	0	Hotel[g]	70	71	1
PD-14	2	Hotel	**67**	**68**	1
PD-15	40	Hotel	**71**	**72**	1
PD-16	2	Hotel	62	63	1
PD-17	12	Res	62	63	1
PD-18	6	Res	59	60	1
PD-19	14	Res	55	56	1
PD-20	11	Res	56	58	2
PD-21	24	Res	56	58	2
PD-22	12	Res	55	56	1
PD-23	6	Hotel	54	55	1
PD-24	6	Hotel	62	63	1
PD-25	4	Park	63	64	1
PD-26	4	Park	59	60	1
PD-27	4	Park	**65**	**66**	1
PD-28	0	Comm	67	68	1

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences, hotel rooms, or residential equivalence.

c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

d Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

e No-Build modeled noise levels.

f Change in noise, No-Build minus Existing.

g This receiver represents a hotel that is vacant and not in use.

4.2.2 LPA Full Build Traffic Noise

Traffic noise levels were predicted for the LPA Full Build. Exhibit 4-2 shows the results of the LPA Full Build analysis along with a comparison to the existing noise levels to assess whether substantial increase impacts would occur. Both LPA Design Options A and B were modeled and the results indicate that the noise levels vary by 0- to 3-dBA between the two design options. The differences are considered slight and there are no differences in the number of traffic related impacts between the two design options. No traffic noise impacts are expected with the LPA Full Build with Option A or B. In addition, there are no substantial increase impacts estimated at any of the Portland area receivers.

Thirty-two floating homes would be displaced by the proposed alignment. These homes are represented by PD-1, PD-2, and PD-8. In addition, PD-11, PD-12 and PD-13 representing the Red Lion Hotel would be displaced. The displacement of the Red Lion Hotel does not change the overall number of traffic impacts as this vacant hotel is not considered a noise sensitive property for the purposes of this analysis. The LPA with Design Options A and Be include the addition of 3.5 foot safety barriers along all both sides of all elevated roadway structures. The combined effect of displacing noise sensitive properties nearest the project roadways and the addition of the safety barriers would result in no traffic-related impacts in the Portland area.

Exhibit 4-2. Portland Area LPA Full Build Traffic Noise Levels

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
PD-1	3	Res	65	**71**	**72**	–[l]	–[l]	–[l]	–[l]	
PD-2	17	Res	65	**71**	**72**	**–l**	**–l**	**–l**	**–l**	
PD-3	16	Res	65	**66**	**67**	64	62	-2	-4	
PD-4	14	Res	65	58	59	63	62	5	4	
PD-5	7	Res	65	60	61	63	62	3	2	
PD-6	15	Res	65	50	51	59	Same as Option A	9	Same as Option A	
PD-7	24	Res	65	47	48	56	57	9	1	
PD-8	14	Res	65	**73**	**74**	**–l**	**–l**	**–l**	**–l**	
PD-9	15	Res	65	56	58	61	Same as Option A	5	Same as Option A	
PD-10	5	Res	65	57	58	61	Same as Option A	4	Same as Option A	
PD-11	0	Hotel	65	64	65	**–l**	–[l]	–[l]	–[l]	
PD-12	0	Hotel	65	67	68	**–l**	–[l]	–[l]	–[l]	
PD-13	0	Hotel	65	70	71	**–l**	**–l**	**–l**	**–l**	
PD-14	2	Hotel	65	**67**	**68**	63	64	-4	-3	
PD-15	40	Hotel	65	**71**	**72**	63	64	-8	-7	
PD-16	2	Hotel	65	62	63	61	Same as Option A	-1	Same as Option A	
PD-17	12	Res	65	62	63	52	53	-10	-9	
PD-18	6	Res	65	55	56	56	59	-3	0	
PD-19	14	Res	65	55	56	59	61	4	6	
PD-20	11	Res	65	56	58	60	61	4	5	
PD-21	24	Res	65	56	58	61	Same as Option A	5	Same as Option A	
PD-22	12	Res	65	55	56	59	Same as Option A	4	Same as Option A	
PD-23	6	Hotel	65	54	55	57	58	3	4	
PD-24	6	Hotel	65	62	63	60	62	-2	0	
PD-25	4	Park	65	63	64	61	Same as Option A	-2	Same as Option A	

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
PD-26	4	Park	65	59	60	58	Same as Option A	-1	Same as Option A	
PD-27	4	Park	65	**65**	**66**	63	Same as Option A	-2	Same as Option A	
PD-28	0	Comm	70	67	68	65	Same as Option A	-2	Same as Option A	
									Total Traffic Noise Impacts:	**0**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences or residential equivalents.

c Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail; Church, school, cemetery, hospital and medical centers.

d Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.

g Future LPA Full Build Option A noise levels.

h Future LPA Full Build Option B noise levels.

i Change in noise levels, LPA Full Build Option A compared to Existing.

j Change in noise levels, Full Build Option B compared to Existing.

k Number of impacts under the LPA Full Build Options A and B.

l Displaced by proposed alignment in LPA Full Build Options A and B.

4.3 Downtown Vancouver Subarea Traffic Noise

This section describes the potential noise effects from the No-Build and Full Build within the Downtown Vancouver area.

4.3.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for Downtown Vancouver area receivers (DT) as shown on Exhibit 4-3. No-Build Alternative traffic noise levels are projected to exceed the WSDOT traffic noise criteria at the same 38 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.

Exhibit 4-3 is a summary of the modeled noise levels and number of impacts within the Downtown Vancouver area

Exhibit 4-3. Traffic Noise Levels West of I-5, Downtown Vancouver

Rec[a]	Residents[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	Change[g]	Impacts[h]
DT-1	2	Hotel	66	67	68	1	2
DT-2	0	Undeveloped	–	68	69	1	0
DT-3	3	Res	66	61[i]	63	2	
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
DT-10	11	Church	66	64	65	1	
DT-11	24	Res	66	64	65	1	

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.
b Number of residences, hotel rooms, or residential equivalence.
c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.
d Traffic noise impacts criteria.
e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.
f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.
g Change in noise, No-Build minus Existing.
h Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria under the No-Build Alternative.
i Noise levels at the Smith Tower only from I-5, SR 14 and ramps. Actual noise at this location measured 69 dBA L_{eq} due to local traffic.

4.3.2 LPA Full Build Traffic Noise

Traffic noise levels were projected for the LPA Full Build with Design Options A and B. Exhibit 4-4 shows the future Full Build traffic noise levels along with the No-Build noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts under the LPA Full Build Option A and B. Throughout the Vancouver area, the predicted traffic noise levels are the same for Design Options A and B.

36 of the same noise-sensitive land uses that exceed the WSDOT traffic noise criteria under the existing and No-Build conditions would also exceed the criteria under the LPA Full Build. Under the LPA, the noise impacts associated with DT-1 (Hotel) would no longer occur, as the existing hotel would be displaced by the project alignment. Noise level increases at DT-10 (church) and DT-11 (apartments) would raise the total number of traffic noise impacts to 71 under the Full Build.

Exhibit 4-4. Downtown Vancouver Area LPA Full Build Traffic Noise Levels

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
DT-1	2	Hotel	66	67	68	–[l]	–[l]	–[l]	–[l]	
DT-2	0	Roadway	n/a	68	69	n/a	n/a	n/a	n/a	
DT-3	3	Hotel	66	61	63	65	Same as Option A	4	Same as Option A	
DT-4	12	Hotel	66	70	70	**69**	Same as Option A	-1	Same as Option A	12
DT-5	6	Res	66	74	75	**76**	Same as Option A	2	Same as Option A	6
DT-6	6	Hotel	66	66	67	**71**	Same as Option A	5	Same as Option A	6
DT-7	12	Res	66	70	70	**72**	Same as Option A	2	Same as Option A	12
DT-10	11	Church	66	64	65	**68**	Same as Option A	4	Same as Option A	11
DT-11	24	Res	66	64	65	**67**	Same as Option A	3	Same as Option A	24
									Total Traffic Noise Impacts:	**71**

Notes:

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences or residential equivalents

c Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail; Church, school, cemetery, hospital and medical centers.

d Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.

g Future LPA Full Build Option A noise levels.

h Future LPA Full Build Option B noise levels.

i Change in noise levels, LPA Full Build Option A compared to Existing.

j Change in noise levels, Full Build Option B compared to Existing.

k Number of impacts under the LPA Full Build Options A and B.

l Displaced by proposed alignment in LPA Full Build Options A and B.

n/a This receiver was used for model verification only - does not represent noise sensitive land use.

4.4 Fort Vancouver Subarea Traffic Noise

This section describes the potential noise effects from the No-Build and Full Build within the Fort Vancouver area.

4.4.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for Fort Vancouver area receivers (FV) as shown on Exhibit 4-5. 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 predicted to increase by 1 dBA over existing conditions throughout the Fort. Currently there are an estimated 10 residences and residential equivalents along with one commercial land use that exceed the WSDOT traffic criteria. Under the No-Build Alternative the number of residential noise impacts would increase to 16 with six new impacts near Officers Row. An additional commercial impact would also occur raising the number of commercial impacts to 2. The modeled results for the No-Build Alternative within the Fort Vancouver area are given in Exhibit 4-5.

Exhibit 4-5. Fort Vancouver Area No-Build Traffic Noise Levels

Rec[a]	Residents[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	Change[g]	Impacts[h]
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	–	72	73	1	
FV-15	4	Comm	66	61	62	1	
FV-16	2	Comm	66	68	69	1	

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences, hotel rooms, or residential equivalence.

c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

d Traffic noise impacts criteria.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.

g Change in noise, No-Build minus Existing.

h Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria under the No-Build Alternative.

4.4.2 LPA Full Build Traffic Noise

Traffic noise levels were projected for the LPA Full Build with Design Options A and B. Exhibit 4-6 shows the future LPA Full Build traffic noise levels along with the No-Build noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts under the LPA Full Build. Throughout the Vancouver area, the predicted traffic noise levels are the same for Design Options A and B.

The overall number of potential traffic noise impacts to residences and residential equivalents within the Fort Vancouver area would be 37 for the LPA Full Build. In addition, two commercial noise impacts would occur to land uses that recently converted from residential to commercial (see FV-16). Traffic noise levels are expected to increase throughout the Fort Vancouver area by up to 7 dBA at the two residences represented by FV-12 and from 0 to 6 dBA at most other locations. At the office buildings represented by FV-5 and FV-6 traffic noise levels would be lowered by 5 to 6 dBA. The proposed Community Connector just south of E Evergreen Boulevard would reduce traffic noise levels in areas nearest the connector by 2 to 5 dBA.

Exhibit 4-6. Fort Vancouver Area LPA Full Build Traffic Noise Levels

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
FV-1	16	Comm	71	65	66	68	Same as Option A	3	Same as Option A	
FV-2	4	Park	66	62	63	64	Same as Option A	5	Same as Option A	
FV-3	17	Park	66	62	63	67	Same as Option A	5	Same as Option A	17
FV-4	11	Comm	71	64	65	66	Same as Option A	2	Same as Option A	
FV-5	1	Comm	71	70	71	65	Same as Option A	-5	Same as Option A	
FV-6	1	Comm	71	73	74	67	Same as Option A	-6	Same as Option A	
FV-7	6	Res	66	65	66	65	Same as Option A	0	Same as Option A	
FV-8	6	Res	66	64	65	66	Same as Option A	2	Same as Option A	6
FV-9	8	Res	66	71	72	74	Same as Option A	3	Same as Option A	8
FV-10	10	Comm	71	65	66	67	Same as Option A	2	Same as Option A	
FV-11	10	Comm	66	62	63	64	Same as Option A	2	Same as Option A	
FV-12	2	Res	66	70	71	77	Same as Option A	7	Same as Option A	2
FV-13	1	Park	66	63	64	65	Same as Option A	2	Same as Option A	
FV-14	0	Undeveloped	n/a	72	73	72	Same as Option A	0	Same as Option A	
FV-15	4	Comm	66	61	62	67	Same as Option A	6	Same as Option A	
FV-16	2	Comm	66	68	69	73	Same as Option A	5	Same as Option A	
									Total Traffic Noise Impacts:	**33**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.
b Number of residences or residential equivalents.
c Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail; Church, school, cemetery, hospital and medical centers.
d Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington.
e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.
f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.
g Future LPA Full Build Option A noise levels.
h Future LPA Full Build Option B noise levels.
i Change in noise levels, LPA Full Build Option A compared to Existing.
j Change in noise levels, Full Build Option B compared to Existing.
k Number of impacts under the LPA Full Build Options A and B.

4.5 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 LPA Full Build option and the No-Build Alternative within this area east of I-5.

4.5.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for "VE" designated receivers as shown on Exhibit 4-6. Future No-Build Alternative noise levels at the modeling locations in this area ranged from 57 to 76 dBA L_{eq}, an increase of 1 to 2 dBA over the existing noise levels. Currently there are 36 locations that meet or exceed the WSDOT traffic noise abatement criteria. Under the No-Build Alternative, there would be 45 locations that meet or exceed the WSDOT traffic noise abatement 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 areas within the cemetery near I-5. Exhibit 4-7 is a summary of the projected No-Build noise levels and location of noise impacts.

Exhibit 4-7. East of I-5/North of Mill Plain No-Build Traffic Noise Levels

Rec[a]	Residents[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	Change[g]	Impacts[h]
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	
VE-18	4	Res	66	61	63	2	
VE-19	3	Res	66	62	64	2	
VE-20	2	Res	66	64	66	2	2
VE-21	3	Res	66	64	65	1	
VE-22	4	Res	66	62	63	1	
VE-23	1	Res	66	65	67	2	1
VE-24	2	Res	66	67	69	2	2
VE-25	2	Res	66	64	66	2	2
VE-26	1	Res	66	65	67	2	1
VE-27	4	Res	66	64	65	1	
VE-28	3	Res	66	62	63	1	

Rec[a]	Residents[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	Change[g]	Impacts[h]
VE-29	3	Res	66	67	68	1	3
VE-30	3	Res	66	61	63	2	
VE-31	2	Res	66	57	59	2	
VE-32	2	Res	66	57	58	1	
VE-33	3	Res	66	56	58	2	
VE-34	6	Park	66	62	63	1	
VE-35	6	Park	66	64	65	1	
VE-36	4	Res	66	61	62	1	
VE-37	2	Res	66	66	67	1	2
VE-38	2	Res	66	67	68	1	2
VE-39	1	Res	66	66	67	1	1
VE-40	3	Res	66	67	68	1	3
VE-41	4	Res	66	67	67	0	4
VE-42	3	Park	66	64	65	1	
VE-43	3	Park	66	65	66	1	3
VE-44	3	Park	66	69	70	1	3
VE-45	3	Park	66	64	65	1	
VE-46	22	Park	66	61	62	1	

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences, hotel rooms, or residential equivalence.

c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.

d Traffic noise impacts criteria.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.

g Change in noise, No-Build minus Existing.

h Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria under the No-Build Alternative.

4.5.2 LPA Full Build Traffic Noise

Traffic noise levels were modeled for the LPA Full Build. The overall number of potential traffic noise impacts would be 102 with the LPA Full Build. The increase in the number of impacts, including several substantial increase impacts, are predicted in this area primarily due to the fact that the existing noise walls were not included in the future Full Build TNM analysis. In the Vancouver area, there are existing noise walls along both sides of I-5. At this stage in the project design, it is expected that the existing noise walls would be removed as part of the construction of the proposed retaining walls and project roadways. While these noise walls were included in the existing and No-Build TNM model, they were not included in the LPA Full Build TNM model which results in higher noise levels and a greater number of traffic noise impacts than if the walls were included.

Exhibit 4-8 shows the future Full Build traffic noise levels along with the No-Build noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts.

Exhibit 4-8. East of I-5/North of Mill Plain LPA Full Build Traffic Noise Levels

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
VE-1	6	School	66	63	64	56	Same as Option A	-7	Same as Option A	
VE-2	1	Hospital	66	58	60	59	Same as Option A	1	Same as Option A	
VE-3	2	Cemetery	66	70	71	68	Same as Option A	-2	Same as Option A	2
VE-4	10	Res	66	74	76	77	Same as Option A	3	Same as Option A	10
VE-5	8	Res	66	61	62	71[l]	Same as Option A	10[l]	Same as Option A	8
VE-6	3	Res	66	58	60	68[l]	Same as Option A	10[l]	Same as Option A	3
VE-7	2	Res	66	67	68	75	Same as Option A	8	Same as Option A	2
VE-8	2	Res	66	67	68	77[l]	Same as Option A	10[l]	Same as Option A	2
VE-9	1	Res	66	56	57	64	Same as Option A	8	Same as Option A	
VE-10	8	Res	66	64	65	73	Same as Option A	9	Same as Option A	8
VE-11	4	Res	66	57	58	67[l]	Same as Option A	10[l]	Same as Option A	4
VE-12	5	Res	66	64	65	76[l]	Same as Option A	12[l]	Same as Option A	5
VE-13	3	Church	66	62	63	71	Same as Option A	9	Same as Option A	3
VE-14	4	Res	66	55	57	63	Same as Option A	8	Same as Option A	
VE-15	10	Res	66	60	61	71[l]	Same as Option A	11[l]	Same as Option A	10
VE-16	5	Res	66	64	65	70	Same as Option A	6	Same as Option A	5
VE-17	5	Res	66	61	62	59	Same as Option A	-2	Same as Option A	
VE-18	4	Res	66	61	63	66	Same as Option A	5	Same as Option A	4
VE-19	3	Res	66	62	64	66	Same as Option A	4	Same as Option A	3
VE-20	2	Res	66	64	66	67	Same as Option A	3	Same as Option A	2
VE-21	3	Res	66	64	65	64	Same as Option A	0	Same as Option A	
VE-22	4	Res	66	62	63	65	Same as Option A	3	Same as Option A	
VE-23	1	Res	66	65	67	66	Same as Option A	1	Same as Option A	1
VE-24	2	Res	66	67	69	68	Same as Option A	1	Same as Option A	2
VE-25	2	Res	66	64	66	65	Same as Option A	1	Same as Option A	
VE-26	1	Res	66	65	67	64	Same as Option A	-1	Same as Option A	
VE-27	4	Res	66	64	65	66	Same as Option A	2	Same as Option A	4

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
VE-28	3	Res	66	62	63	67	Same as Option A	5	Same as Option A	3
VE-29	3	Res	66	67	68	67	Same as Option A	0	Same as Option A	3
VE-30	3	Res	66	61	63	68	Same as Option A	7	Same as Option A	3
VE-31	2	Res	66	57	59	56	Same as Option A	-1	Same as Option A	
VE-32	2	Res	66	57	58	56	Same as Option A	-1	Same as Option A	
VE-33	3	Res	66	56	58	55	Same as Option A	-1	Same as Option A	
VE-34	6	Park	66	62	63	60	Same as Option A	-2	Same as Option A	
VE-35	6	Park	66	64	65	65	Same as Option A	1	Same as Option A	
VE-36	4	Res	66	61	62	62	Same as Option A	1	Same as Option A	
VE-37	2	Res	66	66	67	67	Same as Option A	1	Same as Option A	2
VE-38	2	Res	66	67	68	68	Same as Option A	1	Same as Option A	2
VE-39	1	Res	66	66	67	67	Same as Option A	1	Same as Option A	1
VE-40	3	Res	66	67	68	68	Same as Option A	1	Same as Option A	3
VE-41	4	Res	66	67	67	68	Same as Option A	1	Same as Option A	4
VE-42	3	Park	66	64	65	63	Same as Option A	-1	Same as Option A	
VE-43	3	Park	66	65	66	64	Same as Option A	-1	Same as Option A	
VE-44	3	Park	66	69	70	67	Same as Option A	-2	Same as Option A	3
VE-45	3	Park	66	64	65	65	Same as Option A	1	Same as Option A	
VE-46	22	Park	66	61	62	63	Same as Option A	2	Same as Option A	
									Total Traffic Noise Impacts:	**102**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.
b Number of residences or residential equivalents.
c Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail; Church, school, cemetery, hospital and medical centers.
d Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington.
e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.
f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.
g Future LPA Full Build Option A noise levels.
h Future LPA Full Build Option B noise levels.
i Change in noise levels, LPA Full Build Option A compared to Existing.
j Change in noise levels, Full Build Option B compared to Existing.
k Number of impacts under the LPA Full Build Options A and B.
l Substantial increase of 10 dBA or higher above existing noise levels.

4.6 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 LPA Full Build option and No-Build Alternative within this area west of I-5.

4.6.1 No-Build Alternative Traffic Noise

No-Build traffic noise levels were projected for "VW" designated receivers as shown on Exhibit 4-9. 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, the number of residences with noise levels that would approach or exceed the traffic abatement criteria are predicted to increase to 75 from the currently estimated 50 locations. An area of the Discovery School including the eastern edge of the football field north (VW-36F, Kiggins Bowl) of the school would have noise levels meeting the abatement criteria under the No-Build Alternative.

Exhibit 4-9 provides the predicted No-Build noise levels and location of noise impacts.

Exhibit 4-9. West of I-5/North of Mill Plain No-Build Traffic Noise Levels

Rec[a]	Residents[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	Change[f]	Impacts[g]
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	
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
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	

Rec[a]	Residents[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	Change[f]	Impacts[g]
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	0	School Parking	71	73	74	1	
VW-36F	22	School	66	65	**66**	1	22

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.
b Number of residences, hotel rooms, or residential equivalence.
c Land use: Res-residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands; Undeveloped are lands that are not considered noise sensitive.
d Traffic noise impacts criteria.
e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.
f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.
g Change in noise, No-Build minus Existing.
h Number of residences, hotel rooms, or residential equivalence expected to exceed the traffic noise criteria under the No-Build Alternative.

4.6.2 LPA Full Build Traffic Noise

Traffic noise levels were modeled for the LPA Full Build. The overall number of potential traffic noise impacts would be 119 for the LPA Full Build. This would be an increase of 44 residential impacts above what is predicted with the No-Build Alternative. The increase in the number of impacts, including several substantial increase impacts, are predicted in this area primarily due to the fact that the existing noise walls were not included in the future Full Build TNM analysis. In the Vancouver area, there are existing noise walls along both sides of I-5. At this stage in the project design, it is expected that the existing noise walls would be removed as part of the construction of the proposed retaining walls and project roadways. While these noise walls were included in the existing and No-Build TNM model, they were not included in the LPA Full Build TNM model which results in higher noise levels and a greater number of traffic noise impacts than if the walls were included.

Exhibit 4-10 shows the future LPA Full Build traffic noise levels along with No-Build noise levels, number of residences or residential equivalents, impact criteria, and expected number of impacts with the LPA Full Build.

Exhibit 4-10. Future Traffic Noise Levels for the LPA Full Build: North of Mill Plain West of I-5

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
VW-1	2	Res	66	67	**68**	**68**	Same as Option A	1	Same as Option A	2
VW-2	4	Res	66	61	62	64	Same as Option A	3	Same as Option A	
VW-3	2	Res	66	68	**69**	**71**	Same as Option A	3	Same as Option A	2
VW-4	4	Res	66	63	64	**67**	Same as Option A	4	Same as Option A	4
VW-5	3	Res	66	61	62	64	Same as Option A	3	Same as Option A	
VW-6	4	Res	66	66	**67**	**70**	Same as Option A	4	Same as Option A	4
VW-7	3	Res	66	64	65	**67**	Same as Option A	3	Same as Option A	3
VW-8	8	Res	66	71	**72**	**72**	Same as Option A	1	Same as Option A	8
VW-9	7	Res	66	63	64	65	Same as Option A	2	Same as Option A	
VW-10	3	Res	66	61	63	63	Same as Option A	2	Same as Option A	
VW-11	4	Res	66	67	**68**	**69**	Same as Option A	2	Same as Option A	4
VW-12	4	Res	66	60	61	62	Same as Option A	2	Same as Option A	
VW-13	5	Res	66	63	64	64	Same as Option A	1	Same as Option A	
VW-14	2	Res	66	59	60	60	Same as Option A	1	Same as Option A	
VW-15	3	Res	66	68	**70**	**74**	Same as Option A	6	Same as Option A	3
VW-16	3	Res	66	64	65	**69**	Same as Option A	5	Same as Option A	3
VW-17	4	Res	66	63	64	**74**[l]	Same as Option A	11[l]	Same as Option A	4
VW-18	6	Res	66	61	62	**72**[l]	Same as Option A	11[l]	Same as Option A	6
VW-19	4	Res	66	58	59	**66**	Same as Option A	8	Same as Option A	4
VW-20	6	Res	66	69	**70**	**77**	Same as Option A	8	Same as Option A	6
VW-21	4	Res	66	61	62	**73**[l]	Same as Option A	12[l]	Same as Option A	4
VW-22	5	Res	66	67	**68**	**76**	Same as Option A	9	Same as Option A	5
VW-23	4	Res	66	56	57	64	Same as Option A	8	Same as Option A	
VW-24	2	Res	66	56	57	61	Same as Option A	5	Same as Option A	
VW-25	4	Res	66	60	61	**66**	Same as Option A	6	Same as Option A	4
VW-26	4	Res	66	66	**67**	**76**[l]	Same as Option A	10[l]	Same as Option A	4
VW-27	4	Res	66	60	62	**72**[l]	Same as Option A	12[l]	Same as Option A	4
VW-28	8	Res	66	62	63	**74**[l]	Same as Option A	12[l]	Same as Option A	8

Rec[a]	Res[b]	Land Use[c]	Criteria[d]	Existing[e]	No-Build[f]	LPA Full Build Option A[g]	LPA Full Build Option B[h]	LPA Option A vs. Existing[i]	LPA Option B vs. Existing[j]	Impacts[k]
VW-29	4	Res	66	57	59	64	Same as Option A	7	Same as Option A	
VW-30	4	Res	66	59	61	65	Same as Option A	6	Same as Option A	
VW-31	4	Res	66	56	58	59	Same as Option A	3	Same as Option A	
VW-32	3	Res	66	65	**69**	**66**	Same as Option A	1	Same as Option A	3
VW-33	2	Res	66	60	63	62	Same as Option A	2	Same as Option A	
VW-34	4	Res	66	68	**72**	**69**	Same as Option A	1	Same as Option A	4
VW-35	8	Res	66	68	**70**	**73**	Same as Option A	5	Same as Option A	8
VW-36	0	School Parking	66	73	74	76	Same as Option A	3	Same as Option A	
VW-36F	22	School	66	65	**66**	**66**	Same as Option A	1	Same as Option A	22
									Total Traffic Noise Impacts	**119**

a Receivers shown on Exhibits 3-4, 3-5, and 3-6.

b Number of residences or residential equivalents.

c Land use: res = residential; Hotel = hotel/motel; park = parklands; Comm = commercial and retail; Church, school, cemetery, hospital and medical centers.

d Traffic noise impact criteria; 65 dBA L_{eq} in Oregon and 66 dBA L_{eq} in Washington.

e Existing modeled noise levels from TNM version 2.5 with impacts in **bold red** type.

f No-Build modeled noise levels from FHWA TNM using future 2030 traffic volumes and speeds.

g Future LPA Full Build Option A noise levels.

h Future LPA Full Build Option B noise levels.

i Change in noise levels, LPA Full Build Option A compared to Existing.

j Change in noise levels, Full Build Option B compared to Existing.

k Number of impacts under the LPA Full Build Options A and B.

l Substantial increase of 10 dBA or higher above existing noise levels.

4.7 Light Rail Noise and Vibration Effects

The noise and vibration analyses results for the light rail alternative are provided in following sections. First, the potential noise levels that would occur with the No-Build Alternative are explained, followed by the effects that would occur under the proposed light rail alignment alternative. Finally, a light rail vibration impacts analysis is provided. To simplify the exhibits, a set of aerial photos with the analysis locations for noise and vibration along with identification of all noise and vibration impacts are at the end of this section.

4.7.1 No-Build Noise Levels along the Light Rail Corridor

Noise levels along the light rail 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 4-11 provides a summary of future No-Build noise levels along the proposed light rail corridors.

Exhibit 4-11. Projected Future No-Build L_{eq} and L_{dn} for Transit Corridors

			Existing Noise Levels[c]		No-Build Noise Levels[d]		Change from Existing[e]	
Rec#	Land Use[a]	Residences[b]	L_{eq}	L_{dn}	L_{eq}	L_{dn}	L_{eq}	L_{dn}
PD-1	Res	3	66	69	69	70	3	1
PD-2	Res	17	66	69	69	70	3	1
PD-3	Res	16	64	67	67	69	3	2
PD-4	Res	14	63	63	65	65	2	2
PD-5	Res	7	63	63	65	65	2	2
PD-6	Res	15	61	61	63	63	2	2
PD-8	Res	14	66	69	68	70	2	1
PD-11	Res	0	64	65	64	65	0	0
DT-1	Res	2	64	66	65	67	1	1
DT-3	Res	24	69	71	70	71	1	0
DT-9	Res	3	67	69	68	69	1	0
DT-8	Res	40	66	67	67	68	1	1
VW-2	Res	4	61	60	62	61	1	1
VW-3	Res	2	65	66	69	70	4	4
VW-37	Res	4	61	60	62	61	1	1
VW-38	Res	4	60	60	61	61	1	1
VW-6	Res	4	67	68	68	69	1	1
VW-7	Res	3	66	67	67	68	1	1
VW-39	Res	4	63	62	64	63	1	1

Rec#	Land Use[a]	Residences[b]	Existing Noise Levels[c] L_{eq}	Existing Noise Levels[c] L_{dn}	No-Build Noise Levels[d] L_{eq}	No-Build Noise Levels[d] L_{dn}	Change from Existing[e] L_{eq}	Change from Existing[e] L_{dn}
VW-40	Res	4	63	62	64	63	1	1
VE-1	Park	6	61	60	64	63	3	3

a Land use: Res = residential; Comm = commercial; Hotel = Hotel/Motel; Park = park lands.
b Number of representative residences or equivalents.
c Existing Peak-hour L_{eq} for institutional land uses and 24-hour L_{dn} for residential analysis.
d No-Build alternative Peak-hour L_{eq} for institutional land uses and 24-hour L_{dn} for residential analysis.
e Change in noise from existing to No-Build.

4.7.2 Portland Area Light Rail Noise

The only noise sensitive land use between the Expo Center connection and the new bridge are several rows of floating homes along the North Portland Harbor. The first three rows of homes and one home on the third dock would be relocated due to project construction, and therefore those homes were not analyzed for noise impacts. For analysis purposes, the nearest remaining homes were grouped into five groups based on the distance between the tracks and the homes. In all, 36 homes on the west side of the proposed multimodal bridge were evaluated for noise. The existing L_{dn} for the homes was extrapolated from measured data and on-site inspections.

The analysis identified 16 floating homes where noise levels are predicted to meet or exceed the moderate FTA noise impact criteria. The impacts occur at the two rows of homes nearest the tracks. For the row of homes adjacent to the tracks, the light rail is predicted to produce an L_{dn} of 63 dBA L_{dn}, while the second row has light rail related noise levels of 61 dBA L_{dn}. The FTA criteria for noise impacts at residential properties with an existing 63 dBA L_{dn} is 60 dBA $L_{dn.}$ The third row from the bridge was below the criteria with predicted noise levels of 58 dBA L_{dn}.

Light rail noise levels at the other floating homes in the area are predicted at 57 to 59 dBA L_{dn}, and no additional noise impacts were identified. Exhibit 4-12 provides a full summary of the existing and future noise levels related to transits operations and identifies the locations with noise impacts. Exhibit 4-14, at the end of this section, provides an aerial view of the areas and identifies the grouping of the homes and location of the proposed light rail alignment.

Noise from the light rail is well below the traffic noise levels at all other noise sensitive properties in the Portland area, including the manufactured home residential area along the Columbia River.

4.7.3 Downtown Vancouver Subarea Light Rail Noise

Between the southern bridge landing and W 6th Street no noise impacts were identified. Project noise levels at the Smith Tower are predicted to range from 58 to 60 dBA L_{dn} with the higher level at lower floors. The criteria for impacts at the Smith Tower ranged from 61 to 66 dBA L_{dn} and no noise impacts were identified.

The only noise sensitive land uses identified along Washington Street are the multi-family units at 700 Washington and the St. James Church at 218 West 12th Street. The multi-family units at 700 Washington Street are in two separate buildings. The southern building is over 150 feet from the light rail alignment and the project L_{dn} of 57 dBA is below the FTA criteria. The northern building, while much closer at approximately 40 feet, is near where the northbound trains traverse along 7th Street from Broadway, and only the southbound trains travel directly in front of the building. As a result the future light rail noise levels of 61 dBA L_{dn} remain below the FTA criteria of 63 dBA L_{dn}. Noise levels at the St James Church, at 218 West 12th Street, are predicted at 58 dBA $L_{eq,}$ which is below the category 3 criteria of 67 dBA L_{eq}.

The only noise sensitive property along Broadway is the EconoLodge Hotel, which is located over 200 feet from the northbound alignment. The light rail noise levels at the hotel of 54 dBA L_{dn} are well below the FTA criteria of 63 dBA. Exhibit 4-12 provides a summary of the noise analysis and the modeling sites are shown on Exhibit 4-15, at the end of this section.

4.7.3.1 E 17th Street Alignment

The proposed light rail alignment also travels along 17th Street heading east, from the Broadway-Washington light rail couplet to the connection to McLoughlin Boulevard. This area contains a mixture of commercial and residential structures. The structures along this section of the alignment were combined in to 10 receiver groups. The homes each the group are same distance from the alignment and are predicted to have the same existing noise level. Project noise levels are predicted to meet, or exceed the FTA criteria at 15 single family residences along 17th Street between C Street and G Street. East of G Street the existing ambient noise levels are sufficiently high enough that there are no noise impacts due to light rail operations.

Noise levels at the Marshall Community Center and park are predicted to be below the FTA category 3 criteria at distances greater than 40 to 50 feet from the alignment, and no noise impacts were identified. Exhibit 4-12 provides a full summary of the existing and future noise levels related to transits operations and identifies the locations with noise impacts. Exhibit 4-16 is an aerial view of the areas and identifies the grouping of the homes, location of the proposed light rail alignment and locations that meet or exceed the FTA criteria.

4.7.3.2 McLoughlin Boulevard Alignment

Along McLoughlin Boulevard there were 19 homes identified with light rail noise impacts. Light rail noise levels ranged from 0 to 2 dBA over the FTA criteria, with future light rail noise levels ranging from 57 to 63 dBA L_{dn}. The majority of noise impacts are to the residences between D and G Streets. No other noise impacts were identified in this segment of the corridor. Exhibit 4-12 provides a full summary of the existing and future noise levels related to transits operations and identifies the locations with noise impacts. Exhibit 4-16 is an aerial view of the areas and identifies the grouping of the homes, location of the proposed light rail alignment and locations that meet or exceed the FTA criteria.

4.7.4 East of I-5 Marshall Community Area Light Rail Noise

The light rail terminus is located east of I-5, in the center of McLoughlin Boulevard. There is a double crossover located near I-5, directly across from the Marshall Community Center parking lot, over 180 feet from the Community Center building. A second single crossover located at the terminus with access to a trailing track so the trains can switch directions. Noise levels are not predicted to meet the FTA criteria for a Category 3 use inside the park areas that are more that 30 to 40 feet from the station. No noise impacts are predicted in this segment of the corridor. Exhibit 4-12 provides a full summary of the existing and future noise levels related to transits operations. Modeling locations are shown on Exhibit 4-16.

Exhibit 4-12. Projected Future Build L_{eq} and L_{dn} for Transit Corridors

Rec.#[a]	Area Description[b]	Land Use[c]	Number of Units[d]	Existing Noise[e]	Light Rail Noise Contribution[f]	Total Noise[g]	Criteria[h]		Impacts[i]	
							Moderate	Severe	Moderate	Severe
Portland										
FH3	Second Row of Homes (Second set of homes from the tracks)	SF	8	63	**61**	65	60	65	8	–
FH4	Third Row of Homes	SF	8	63	58	64	60	65	–	–
FH5	Forth Row of Homes	SF	8	62	56	63	59	64	–	–
FH6	Fifth Row of Homes	SF	7	61	56	62	59	64	–	–
Downtown Vancouver (Washington and Broadway Streets)										
WA-1	Red Lion at the Quay	Hotel	1	66	61	67	62	67	–	–
WA-2	Smith Towers 3rd floor	SF	7	71	58	71	66	70	–	–
WA-2A	Smith Towers 4th floor	SF	7	71	57	69	64	69	–	–
WA-2B	Smith Towers 5th – 6th floors	SF	7	71	57	67	63	67	–	–
WA-2C	Smith Towers above floor 6	SF	7	71	58	66	61	66	–	–
WA-3	700 Washington, lower floors, south building	MF	6	69	57	69	64	69	–	–
WA-3B	700 Washington, middle floors, south building	MF	12	68	57	68	63	68	–	–
WA-3C	700 Washington, upper floors, south building	MF	12	67	57	67	63	67	–	–
WA-4D	700 Washington, lower floors, north building	MF	12	68	61	69	63	68	–	–
WA-4E	700 Washington, upper floors, north building	MF	12	67	61	68	63	67	–	–
WA-5	St James Church	Church	1	66	58	67	67	67	–	–
B-1	EconoLodge 601 Broadway Street	Hotel	1	67	54	67	63	67	–	–
E 17th Street: Washington Street to I-5										
17-0	17th Ave Alignment (Broad – C)	Comm	–	–	–	–	–	–	–	–
17-1	17th Ave Alignment (C-D north)	SR	1	62	**61**	65	59	64	1	–
17-2	17th Ave Alignment (C-D south)	SF	2	62	**61**	65	59	64	2	–
17-3	17th Ave Alignment (D-E north)	SF	2	62	**61**	65	59	64	2	–

Rec.#[a]	Area Description[b]	Land Use[c]	Number of Units[d]	Existing Noise[e]	Light Rail Noise Contribution[f]	Total Noise[g]	Criteria[h] Moderate	Criteria[h] Severe	Impacts[i] Moderate	Impacts[i] Severe
17-4	17th Ave Alignment (D-E south)	SF	1	62	**62**	65	59	64	1	–
17-5	17th Ave Alignment (E-F north)	SF	1	64	**62**	66	61	65	1	–
17-6	17th Ave Alignment (E-F south)	SF	1	64	**61**	66	61	65	1	–
17-7	17th Ave Alignment (F-G north)	SF	4	65	**63**	67	61	66	4	–
17-8	17th Ave Alignment (F-G south)	SF	3	65	**62**	67	61	66	3	–
17-9	17th Ave Alignment (G-I-5)	SF	1	68	60	69	63	68	–	–
17-10	17th Ave Alignment (G-I-5)	SF	2	67	59	68	63	67	–	–
McLoughlin Boulevard: Washington Street to I-5										
MC-1	Res D to E South	SF	4	64	**63**	67	61	65	4	–
MC-2	Res E to F North	SF	2	64	**62**	66	61	65	2	–
MC-3	Res E to F South	SF	4	64	**63**	67	61	65	4	–
MC-4	Res F to G North	SF	2	66	**62**	67	62	67	2	–
MC-5	Res F to G South	SF	4	66	**63**	68	62	67	4	–
MC-6	Res G to I-5 North	SF	4	67	59	68	63	67	–	–
MC-7	Res G to I-5 South	SF	3	68	**63**	69	63	68	3	–
MC-8	Res at I-5 North	MF	8	68	57	68	63	68	–	–
MC-8B	Res at I-5 North	MF	2	68	58	68	63	68	–	–
Marshall Community Center, Parks and Playfields										
MC-9	Park Areas @ 25 feet from near track	Park	–	68	69	72	67	73	–	–
MC-10	Park Areas @ 50 feet from near track	Park	–	68	66	70	67	73	–	–
MC-11	Park Areas @ 50 feet from near track	Park	–	68	65	70	67	73	–	–
MC-12	Marshall Community Center	–	1	68	63	69	67	73	–	–

a Receivers shown on Exhibits 4-12 and 4-13
b General description of the area of analysis.
c Land Use: SF = single-family; MF = multi-family.
d Number of individual apartments or homes affected.
e Existing noise levels in L_{dn} for category 2 land use, or L_{eq} for category 1 or 3 land uses.
f Noise from operation of the light rail only. This is the noise level used to determine impacts with the FTA criteria. Levels in **bold red** type exceed FTA criteria.
g Total noise, which includes the light rail and existing ambient noise.
h FTA impact criteria.
I Number of units impacted by project noise.

4.7.5 Portland Area Light Rail Vibration

There are no vibration impacts predicted in the Portland area. The light rail is on structure in most areas and is not near any vibration sensitive buildings. The vibration level for the floating homes nearest the light rail structure is provided in Exhibit 4-13 for reference.

4.7.6 Downtown Vancouver Subarea Light Rail Vibration

Vibration levels at the Smith Tower are predicted to exceed the FTA criteria due to the close proximity to the building. Maximum vibration levels at the tower could reach 76 VdB. Vibration levels at the northern most multi-family units at 700 Washington Street were predicted at 71 Vdb using the most current design drawings, and no vibration impact was identified.

The vibration levels for non-residential uses along Washington Street and Broadway Street are predicted to remain below the FTA criteria of 75 VdB. No other vibration impacts were identified. Exhibit 4-13 provides a summary of the vibration levels and the receiver locations are shown on Exhibit 4-15.

4.7.7 E 17th Street Light Rail Vibration

There are 14 single-family residents along E 17th Street that are predicted to meet or exceed the FTA impact criteria. Vibration levels are predicted to range from 66 to 76 VdB at residences along E 17th Street. All of the 14 structures predicted to exceed the criteria are also identified with noise impacts. Structures with impacts have vibration level ranging from 72 to 76 VdB. Exhibit 4-13 provides a summary of the vibration levels and the receiver locations were shown on Exhibit 4-16.

4.7.8 McLoughlin Boulevard Light Rail Vibration

There are up to 19 single-family residents that are predicted to meet or exceed the FTA impact criteria. Vibration levels are predicted to range from 66 to 77 VdB at residences along McLoughlin Boulevard. The 19 structures predicted to exceed the criteria are the same structures identified with noise impacts. Structures with impacts have vibration level ranging from 73 to 77 VdB. Exhibit 4-13 provides a summary of the vibration levels and the receiver locations were shown on Exhibit 4-16.

4.7.9 East of I-5 Marshall Community Area Light Rail Vibration

Even with the switches, the vibration level at the park and the Marshall Community Building are predicted to remain below the FTA criteria. No vibration impacts were identified in this segment.

Exhibit 4-13. Projected Vibration Levels

Rec#[a]	Area Description[b]	Land Use[c]	Vibration Criteria[d]	Vibration Level[e]	Meets Criteria[f]	Number of Impacts[g]
Portland						
FH-1	Floating Homes	SF	72	46 - 60	N	–
Downtown Vancouver						
WA-1	Smith Towers	MF	72	76	Y	1
WA-2	700 Washington	MF	72	71	N	0

Rec#[a]	Area Description[b]	Land Use[c]	Vibration Criteria[d]	Vibration Level[e]	Meets Criteria[f]	Number of Impacts[g]
–	Commercial Uses on Washington and Broadway	CO	75	70 – 74	N	–
E 17th Street						
17-0	Broadway to C	Comm	75	72	N	–
17-1	C to D northside	SF/Comm	72/75	72	Y	1 (res
17-2	C to D southside	SF/Comm	72/75	72	Y	2 (res)
17-3	D to E northside	SF/Comm	72/75	72	Y	2 (res)
17-4	D to E southside	SF/Comm	72/75	73	Y	1 (res)
17-5	E to F northside	SF/Comm	72/75	73	Y	1 (res)
17-6	E to F southside	SF/Comm	72/75	70	N	
17-7	F to G northside	SF	72	76	72	4
17-8	F to G southside	SF	72	74	72	3
17-9	McLoughlin Blvd northside	SF	72	68	N	
17-10	East of G southside	SF	72	66	N	
McLoughlin Boulevard						
MC-1	Res D to E South	SF	72	76	Y	4
MC-2	Res E to F North	SF	72	73	Y	2
MC-3	Res E to F South	SF	72	76	Y	4
MC-4	Res F to G North	SF	72	73	Y	2
MC-5	Res F to G South	SF	72	77	Y	4
MC-6	Res G to I-5 North	SF	72	64	N	–
MC-7	Res G to I-5 South	SF	72	76	Y	3
MC-8	Res at I-5 North	MF	72	60	N	–
MC-8B	Res at I-5 North	MF	72	62	Y	–

a Receivers shown on Exhibits 4-13 and 4-16.
b General description of the area of analysis.
c Land Use: SF = single-family; MF = multi-family; CO = commercial.
d FTA vibration impact criteria.
e Predicted vibration level.
f Amount the predicted level exceeds the criteria.
g Number of individual structures affected.

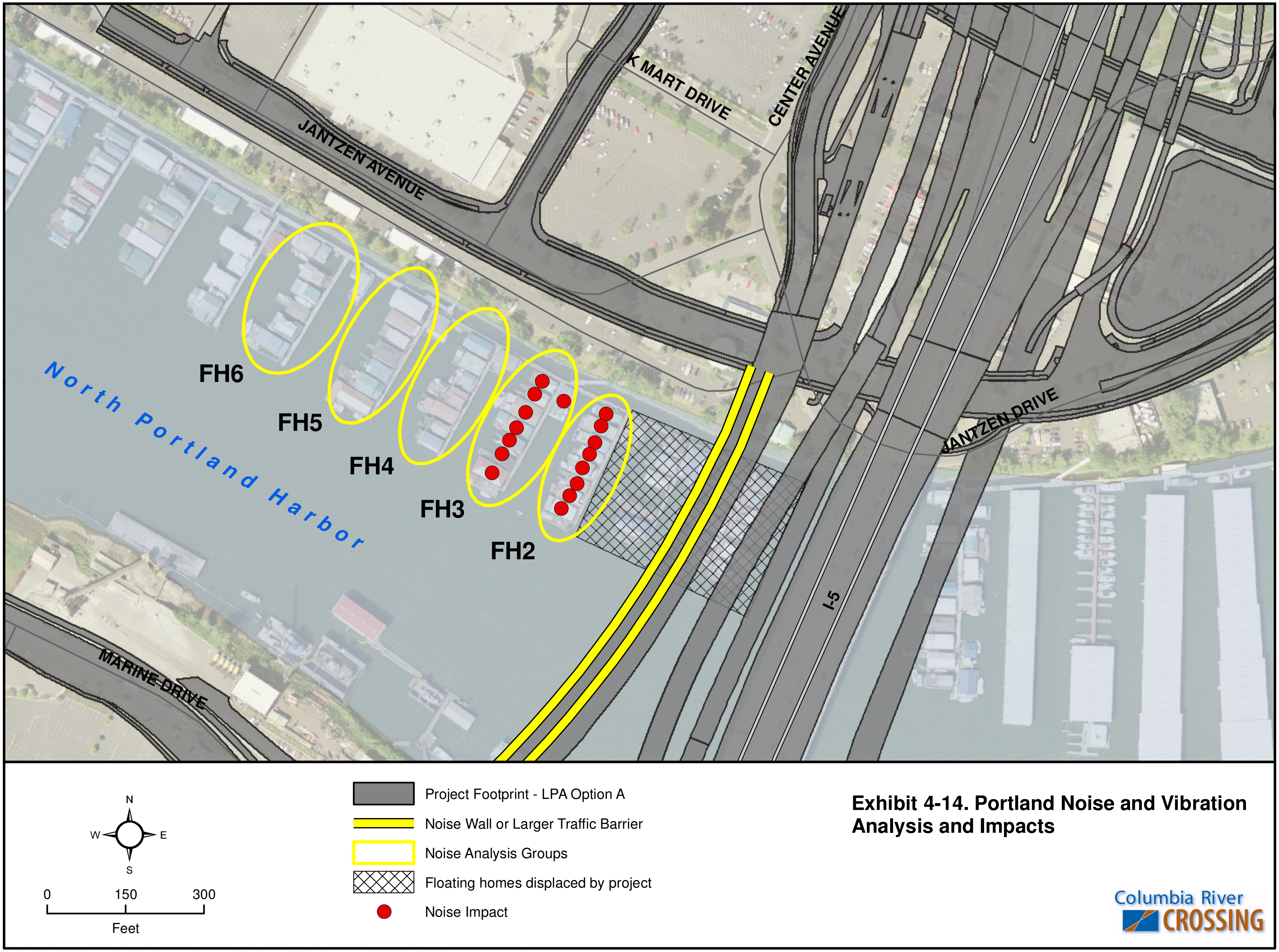

Exhibit 4-14. Portland Noise and Vibration Analysis and Impacts

Analysis by J. Koloszar; Analysis Date: 11 Aug 2011; File Name: F:\Transfer060811\NOI\NoiseExhibits_4-14_6-13.mxd

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Exhibit 4-15. Downtown Vancouver Noise and Vibration Analysis and Impacts

Analysis by J. Koloszar; Analysis Date: 09 Jun 2011; File Name: F:\Transfer060811\NOI\NoiseExhibits_4_15.mxd

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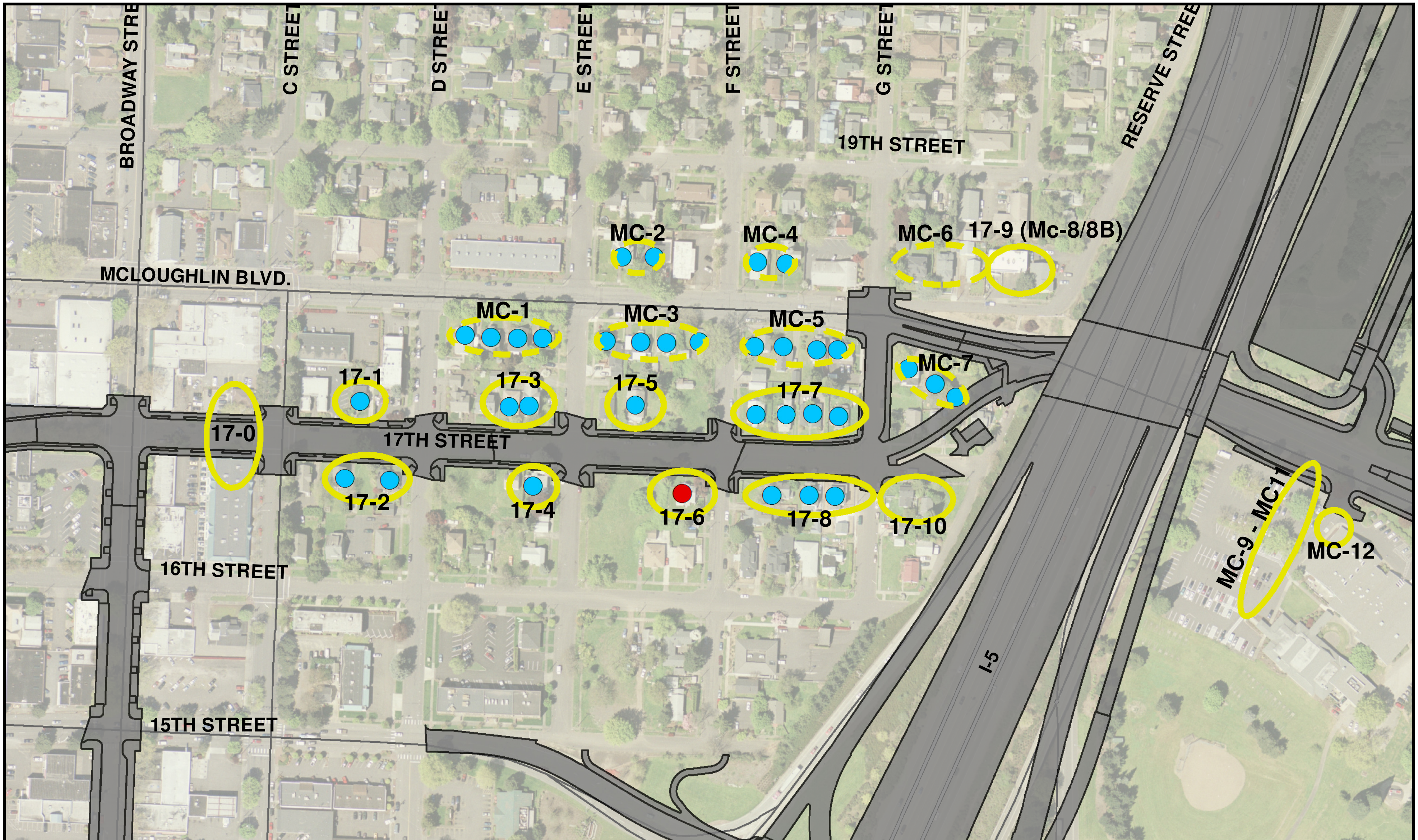

N
W E
S

0 170 340
Feet

Project Footprint
Analysis Groups (17th Ave. Alignment)
Analysis Groups (McLoughlin Alternative)
Noise Impacts Only
Noise and Vibration Impacts

Exhibit 4-16. E 17th St., McLoughlin and Marshall Park Noise and Vibration Analysis and Impacts

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 09 Jun 2011; File Name: F:\Transfer060811\NOI\NoiseExhibits_2.mxd

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5. Temporary Effects

5.1 Introduction

The analysts considered temporary noise effects that construction could cause in the study area; effects that would end when project construction was completed.

5.2 Construction Activities

Equipment required to complete the project includes normal construction equipment that is used for many roadway and structural activities. Exhibit 5-1 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 5-1. Construction Equipment List, Use, and Reference Maximum Noise Level

Equipment	Typical Expected Project Use[a]	L_{max}[b]	Source[c]
Air Compressors	Used for pneumatic tools and general maintenance - all phases	70 - 76	a, b, c
Backhoe	General construction and yard work	78 - 82	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

a Typical maximum noise level under normal operation as measured at 50 feet from the noise source.

b Maximum noise level as measured at a distance of 50 feet under normal operation.

c Sources of noise levels presented:

Portland, Oregon Area Projects: Light rail, I-5 Preservation and Hawthorn Bridge construction projects and other measured date from Portland area projects.

USDOT construction noise documentation and other construction noise sources.

5.2.1 Construction Noise

Four general construction phases would be required to complete the project. Typical construction phases for the project would include the following:

- Preparing for construction of new structures
- Constructing new structures and paving roadways
- Conducting miscellaneous activities, including striping, lighting, and erecting signs
- Demolishing existing structures.

5.2.1.1 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.

5.2.1.2 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.

5.2.1.3 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.

5.2.1.4 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 5-2 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 5-2 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 5-2. Noise Levels for Typical Construction Phases at 50 Feet from Work Site

Scenario[a]	Equipment[b]	L_{max}[c] (dBA)	L_{eq}[d] (dBA)
Preparing for construction of new structures	Air compressor, backhoe, concrete pump, crane, excavator, forklift, haul truck, loader, water pump, power plant, service truck, tractor trailer, utility truck, and vibratory equipment.	94	87
Constructing new structures and paving roadways	Air compressor, backhoe, cement mixer, concrete pump, crane, forklift, haul truck, loader, paver, pump, power plant, service truck, tractor trailer, utility truck, vibratory equipment, and welder.	94	88
Conducting miscellaneous activities, including striping, lighting, and providing signs	Air compressor, backhoe, crane, forklift, haul truck, loader, pump, service truck, tractor trailer, utility truck, and welder.	91	83
Demolishing existing structures	Air compressor, backhoe, concrete saw, crane, excavator, forklift, haul truck, jackhammer, loader, power plant, pneumatic tools, water pump, service truck, and utility truck.	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.

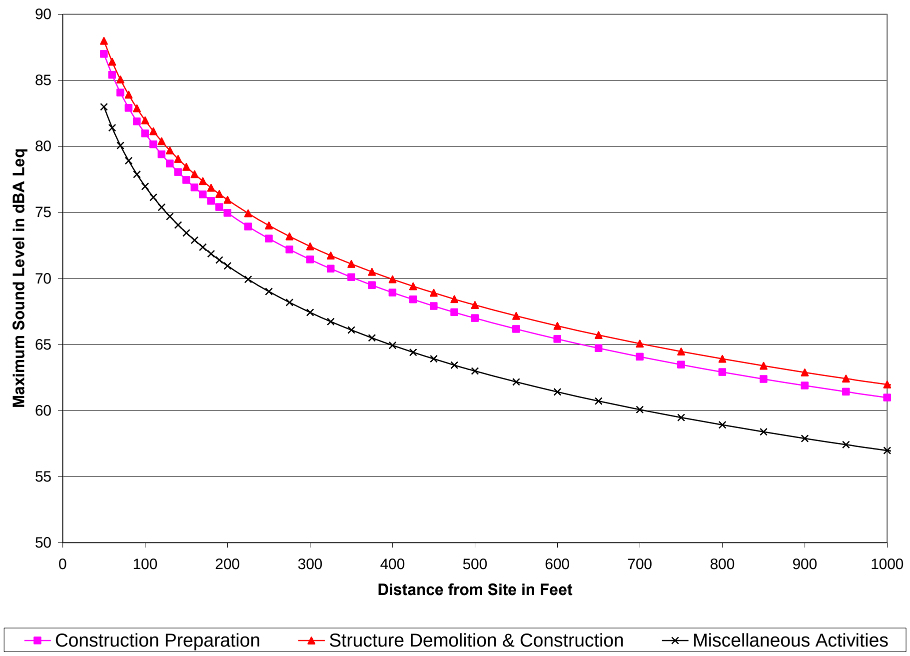
c L_{max} (dBA) is an average maximum noise emission for the construction equipment under the given scenario.

d L_{eq} (dBA) is an energy average noise emission level for construction equipment operating under the given scenario. For this type of equipment, the L_{eq} is approximately equal to the L50 (that is, noise levels that are exceeded 50 percent of the time).

To provide the public with a general understanding of how loud construction might be, the analysts performed a study that assumed worst-case noise levels based on the four expected construction phases. The noise levels presented in this report are for periods of maximum construction activity. The actual noise levels experienced during construction would generally be lower than those described in this report.

The information given in Exhibit 5-2 was used to predict construction noise levels for several distances from the project work area. Exhibit 5-3 is a graph of the construction noise level versus distance for the phases of project construction listed in Exhibit 5-2.

Exhibit 5-3. Noise Level versus Distance for Typical Construction Phases



5.2.2 Construction Vibration

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 sensitive receivers. It is unlikely that vibration levels would exceed 0.5 inch per second at distances greater than 100 feet from the construction sites.

6. Proposed Mitigation for Adverse Effects

6.1 Introduction

When project-related noise effects are identified, traffic noise mitigation measures must be considered. Mitigation measures that meet ODOT's and WSDOT's 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 is a cost benefit analysis based on predicted future noise levels.

Several different traffic noise abatement measures are evaluated whenever noise effects are expected. Under ODOT and WSDOT policies, the following abatement measures must be considered:

1. Traffic management measures (for example, 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. Highway design measures (for example, alteration of horizontal/vertical alignments).
3. Acquisition of property rights (either in fee or lesser interest) for construction of noise barriers.
4. 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.
5. Sound insulation of public use or nonprofit institutional structures.
6. Construction of sound barriers (including landscaping for aesthetic purposes) whether within or outside the highway right-of-way. Interstate construction funds may not participate in landscaping.

6.1.1 Traffic Management Measures

Management measures include modifying speed limits, restricting or prohibiting truck traffic, or closing roadways or access ramps during times when noise could have an adverse effect.

Speed reduction can reduce noise levels from vehicles. However, this method is not seen as a potential mitigation or design option for this project as it would interfere with the project objectives. Furthermore, the slight noise reduction that would be achieved would not significantly reduce noise levels or noise effects.

Restricting truck use or closing access ramps on the project would reduce noise levels at nearby receivers since trucks are louder than cars. The I-5 corridor serves as an important regional and local truck route. Restricting truck traffic on I-5 or its access ramps would displace trucks onto local side streets causing noise levels to increase in those areas that currently have lower truck traffic volumes (for example, residential side streets). Therefore, this mitigation method is not considered a feasible or reasonable form of mitigation for this project.

6.1.2 Highway Design Measures

Highway design measures include altering the roadway alignment and depressing roadway cut sections. Alternating roadway alignment could decrease noise levels by moving the noise source farther from the affected receivers. The project involves adding on and off ramps to already established highways which does not allow for substantial shifts in the alignment or elevation of the ramps.

Another noise mitigation measure often discussed is the use of plants for sound reduction. While dense foliage can slightly reduce noise levels, the amount of land required to create an effective sound barrier is substantial and is not available within the study area. The Federal 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.

6.1.3 Acquisition of Property Rights for Construction of Noise Barriers

Once the need for noise barriers are evaluated and found warranted by meeting ODOT's or WSDOT's feasibility and reasonableness criteria then every effort is made to construct those noise barriers within the ODOT or WSDOT right-of-way. 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 ODOT and WSDOT policies, noise barriers are normally evaluated and constructed within the state'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.

6.1.4 Acquisition of Real Property to Serve as a Buffer Zone

In some instances, real property can be acquired to serve as a buffer zone to preempt development that would be adversely affected by traffic noise; FHWA limits this noise abatement measure to Type I projects such as this project. Buffer zones are undeveloped, open spaces which border a highway. Buffer zones are created when a highway agency purchases land or development rights, in addition to the normal right-of-way, so that future dwellings cannot be constructed close to the highway. This prevents the possibility of constructing dwellings that would otherwise experience an excessive noise level from nearby highway traffic. An additional benefit of buffer zones is improvement of the roadside appearance. However, because of the tremendous amount of land that must be purchased and because in many cases dwellings already border existing roads, creating buffer zones is often not possible. While federal-aid highway funds may be used on a highway project to create buffer zones, this measure has not been used very often. As with acquisition of real property for noise barrier construction, any additional cost to acquire access, acquire property, provide alternative access, or provide additional infrastructure to accommodate access must be added to the cost calculation and compared to the normal reasonableness cost allowance of the abatement to determine whether the proposed abatement is reasonable.

Within this study area, the majority of the undeveloped, open spaces that border the proposed alignment have been designated park lands are contained within the Leverich Park boundary. These park lands have been identified as a noise-sensitive land use for this project and are restricted from residential development. No other open spaces within the study area that could be construed as possible buffers zones exist at this time.

6.1.5 Noise Insulation (Public Use or Nonprofit Institutional Structures)

Architectural treatment for noise mitigation may be used for public or nonprofit 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 to less than the NAC are described below.

6.1.5.1 Ventilation Systems

In public buildings where windows are used for ventilation, noise effects may occur. Closing the windows is often sufficient to reduce interior noise levels to less than the NAC. 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.

6.1.5.2 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.

6.1.5.3 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 nonprofit institution can add air conditioning at a later date.

6.1.6 Noise Barriers

Noise barriers may be constructed between the roadways and the affected receivers to 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. Earthen berms would not be a feasible form of noise abatement due to the limited amount of right-of-way available for noise barrier construction. Noise barriers should be high enough to break the line-of-sight between the highway and the receiver. They must also be long enough to prevent significant flanking of noise around the ends of the walls.

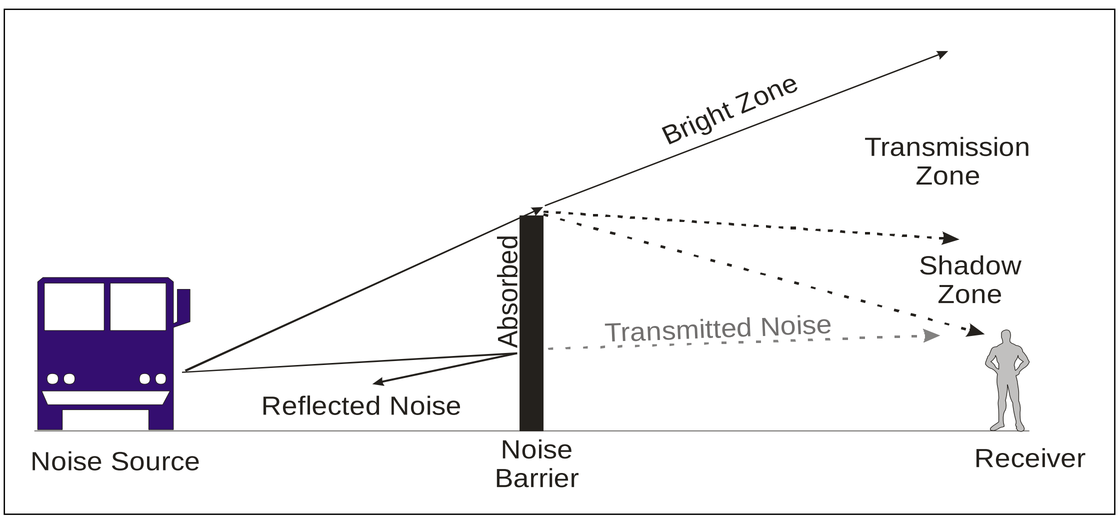
Openings in noise walls (for example, at driveways, bridges, and side streets) allow noise to pass through the openings, usually limiting the achievable noise- level reduction to less than 3 dBA for receivers near the openings.

Other design considerations that can affect the overall effectiveness of noise walls include horizontal placement, the general topography between the receivers and the roadway, and the elevation relationship (for example, relative height differences) between the receiver, noise wall, and roadway. In general, noise walls are most effective if they are placed as close as possible to either the noise source or the receiver locations. In addition, if sensitive receivers are located above the roadway grade, the overall effectiveness of the noise wall can be considerably reduced unless it is placed at the same elevation as the receiver. Noise walls have the greatest noise-reducing effect for receivers located close to the roadway.

As shown in Exhibit 6-1, noise walls reduce traffic noise either by directly absorbing it, reflecting it back across the highway, or dispersing or diffracting it upward. Reflected noise is the noise that moves back toward the traffic after hitting the noise wall. Some noise would be diffracted over the wall, while a small amount of noise would either be transmitted through, or absorbed by, the wall.

There are three zones that can reduce the effectiveness of a noise wall. The bright zone is the area above the wall with a direct line of sight to the noise source. The bright zone contains noise directly transmitted from the noise source. The other two zones are the transmission zone and the shadow zone. The transmission zone contains some noise that is directly transmitted by the noise source, along with some noise that is diffracted over the wall. The shadow zone is primarily all diffracted noise.

Exhibit 6-1. Noise Wall Absorption, Transmission, Reflection, and Diffraction



Source: Adapted from Noise Barrier Design Handbook (USDOT 2000a).

Two factors to consider when determining the height of a noise wall are design feasibility and construction costs. There is a point of diminishing returns, where the additional height of a noise wall is prohibitively more expensive to construct while providing very little additional noise reduction.

Other factors, such as construction considerations and safety and potential noise wall reflections, are also considered when determining if a noise wall is feasible. If a noise wall is safe, feasible, and meets the WSDOT or ODOT cost-effectiveness criteria (explained below), it is typically recommended for construction with the project.

6.1.6.1 WSDOT Noise Wall Feasibility and Reasonableness (Cost) Criteria

WSDOT requires that every reasonable effort be made to attain a 10-dBA (or greater) noise reduction at the first row of receivers (for example, front-line receivers). For a noise wall to be considered a feasible form of mitigation by WSDOT, the following feasibility criteria must be met:

1. The proposed mitigation must be physically constructible,
2. A majority of the first row ground floor receivers must achieve a 5-dBA noise reduction as a result of mitigation, assuring the every reasonable effort would be made to assess ground floor exterior use areas as appropriate, and
3. At least one receiver must have at least a 7-dBA noise reduction.

For most projects, noise wall construction is considered feasible if a 7-dBA noise reduction can be achieved for ground floor residences. Mitigation from noise walls is not considered for upper floors, such as second floors of single-family residences.

WSDOT has established cost-effectiveness criteria to ensure that if a noise wall is recommended, its cost is consistent with the level of reduction and is not excessive. When a noise wall has been determined feasible, WSDOT then determines whether its construction is reasonable by thoroughly considering the following factors:

1. The noise mitigation cost per residence (or residential equivalent) does not exceed the amounts indicated in Exhibit 6-2. This amount is determined by counting all residences (including owner occupied, rental units, mobile homes, and residential equivalents as defined by WSDOT) that receive at least a 3-dBA noise reduction from the noise wall, and then dividing that number into the total cost of the noise abatement measure. Each benefited unit in a multifamily building is counted as a separate residence. In addition, areas such as parks and schools are counted based on the WSDOT residential equivalent calculations. The criteria used for the residential equivalency for this analysis were determined using the method provided by WSDOT. See the "Potential Effects of the Project" section for more details on residential equivalents. Exhibit 6-2 shows that as the predicted future noise level increases, it is considered reasonable to implement more costly measures, as necessary, to mitigate traffic noise.
2. Consideration of aesthetic barrier treatments, artwork, re-vegetation, and any increased cost of alternative barrier construction materials with transmission losses lower than 20 dB per frequency range shall not be included in the noise mitigation reasonableness cost calculations for long-term noise mitigation. Decisions on aesthetic treatments, re-vegetation and barrier material choice is based on applicable department practices and funding availability.

Noise walls would be constructed only if WSDOT determines that they are feasible and reasonable. This decision is normally the responsibility of WSDOT and FHWA, with concurrence from the roadway design personnel. WSDOT policy also provides for local jurisdiction and community input to the process of assessing mitigation measures.

Exhibit 6-2. Cost Allowance for Effects Caused by Total Traffic Noise Levels

Design Year Traffic Noise Level	Noise Level Increase as a Result of the Project[a]	Allowed Cost per Qualified Residence or Residential Equivalent[b]	Allowed Wall Surface Area per Qualified Residence or Residential Equivalent
66 dBA		$37,380	700 sq ft (65.0 sq m)
67 dBA		$41,110	770 sq ft (71.5 sq m)
68 dBA		$44,640	836 sq ft (77.7 sq m)
69 dBA		$48,270	904 sq ft (84.0 sq m)
70 dBA		$51,900	972 sq ft (90.3 sq m)
71 dBA	10 (substantial, tier 1)[c]	$55,530	1,040 sq ft (96.6 sq m)
72 dBA	11 (substantial, tier 1)	$59,160	1,108 sq ft (103.0 sq m)
73 dBA	12 (substantial, tier 1)	$62,790	1,176 sq ft (109.2 sq m)
74 dBA	13 (substantial, tier 1)	$66,420	1,244 sq ft (115.6 sq m)
75 dBA	14 (substantial, tier 1)	$70,060	1,312 sq ft (121.9 sq m)
76 dBA[d]	15 (substantial, tier 2)[e]	$73,690	1,380 sq ft (128.2 sq m)

a If noise level increase as the result of the project is 10 dBA or more, follow the allowed wall surface area and cost for the level of increase in lieu of the total design year traffic noise level. For total highway-related noise levels at 76 dBA or more or project results in an increase of 15 or more decibels, continue increasing the allowance at the rate provided in the exhibit unless circumstances determined on a case-by-case basis require an alternative methodology for determining allowance.

b Costs shown are for 2006 and are re-evaluated each year using current construction costs. Based on $53.43 per square foot construction cost.

c Tier 1 is when the noise levels are 10 to 14 dBA over existing traffic noise as a result of the transportation project.

d If the traffic-related noise level is 80 dBA or more or there is an increase of traffic-related noise of 30 dBA or more over existing traffic noise levels as a result of a proposed transportation project, then the effects are considered severe. Additional consideration for mitigation may be considered under these circumstances.

e Tier 2 is when the noise levels are 15 dBA or more over existing traffic noise as a result of the transportation project (or total highway-related noise levels are between 76 and 79 decibels). Additional consideration for mitigation may be considered under these circumstances.

sq.ft. = square feet

sq m = square meters

6.1.6.2 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. In addition, the noise analysis must also identify 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 noise abatement measures to obtain substantial noise reduction of at least 5 dBA to be considered feasible. 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 wall
- Strong public support for mitigation
- A noise increase of 10 dBA or more
- High noise levels, L_{eq} 70 dBA or higher
- The residence was constructed prior to 1976.

6.1.6.3 Determining Noise Wall Locations and Heights

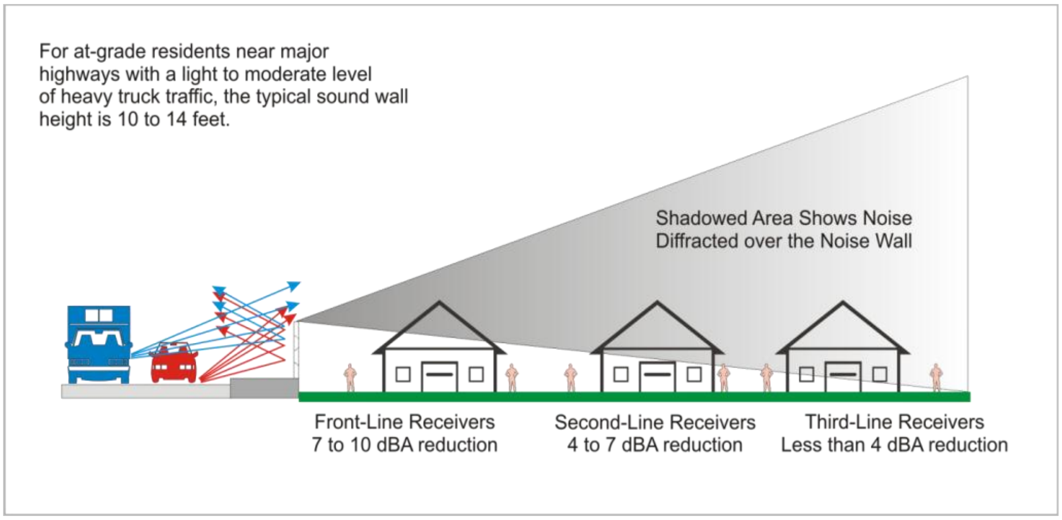
The noise discipline analysts determined the height and location of the noise walls by modeling noise walls at various locations and heights. The following section provides the details on the proposed noise walls, including graphic illustrations of typical situations for receivers located at-grade, below-grade, and above-grade, and how the noise walls' overall noise-reduction characteristics are affected by area topography.

6.1.6.4 Noise Walls with At-Grade Receivers

Noise walls can be a very effective mitigation method for receivers located at a similar grade to I-5 or SR 500. Noise wall heights for locations such as these are generally 10 to 14 feet high. Noise walls of this height are normal for major highways with light to moderate levels of heavy truck traffic (such as SR 500) where receivers are at approximately the same grade as the roadway.

Exhibit 6-3 shows a typical schematic of noise wall placement and relative effectiveness for receivers located at grade for different distances from the project roadway. The data shown in Exhibits 6-3, 6-4, and 6-5 is for a typical neighborhood where the front-line receivers are 40 to 60 feet from the highway, second-line receivers are approximately 100 feet, and the third-line receivers are over 150 feet from the highway. The noise-level projections are for 5 feet above the ground in typical outdoor uses at the residence.

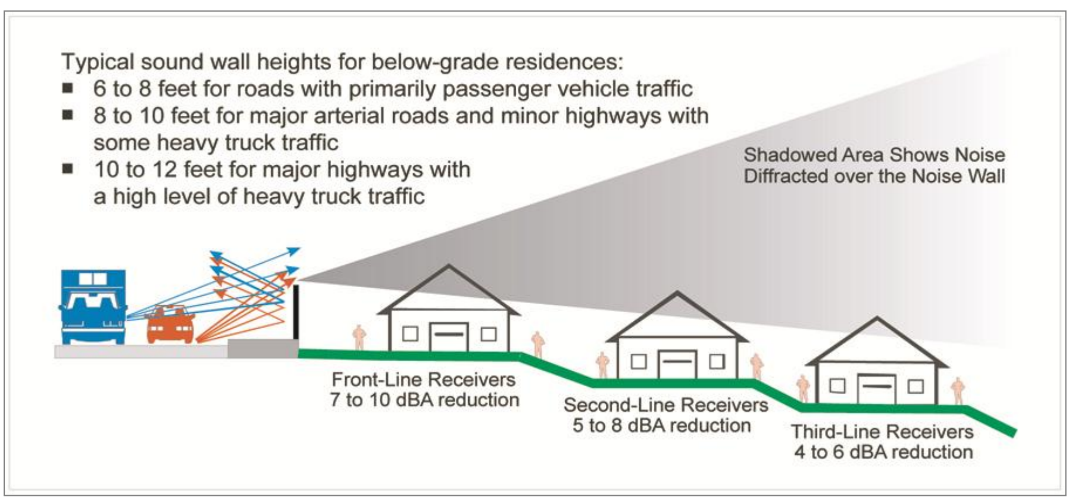
Exhibit 6-3. Typical Noise Wall Effectiveness with At-grade Receiver



6.1.6.5 Noise Walls with Below-Grade Receivers

The overall effectiveness of a noise wall is normally increased for locations where receivers are located below the highway elevation. Because the receivers are located below the elevation of the highway, less of the noise diffracted over the top of the noise wall reaches the receivers. In most cases, the noise wall height could be lower and still provide the same level of noise reduction, as shown for receivers located at the same level as the roadway. Typical noise wall heights for below-grade receivers are 2 to 4 feet less than for at-grade receivers. The actual height of the noise wall would again depend on wall placement, distance to the receiver, and vehicle mix. Exhibit 6-4 provides a typical schematic of noise wall heights and relative effectiveness for receivers located below the road grade.

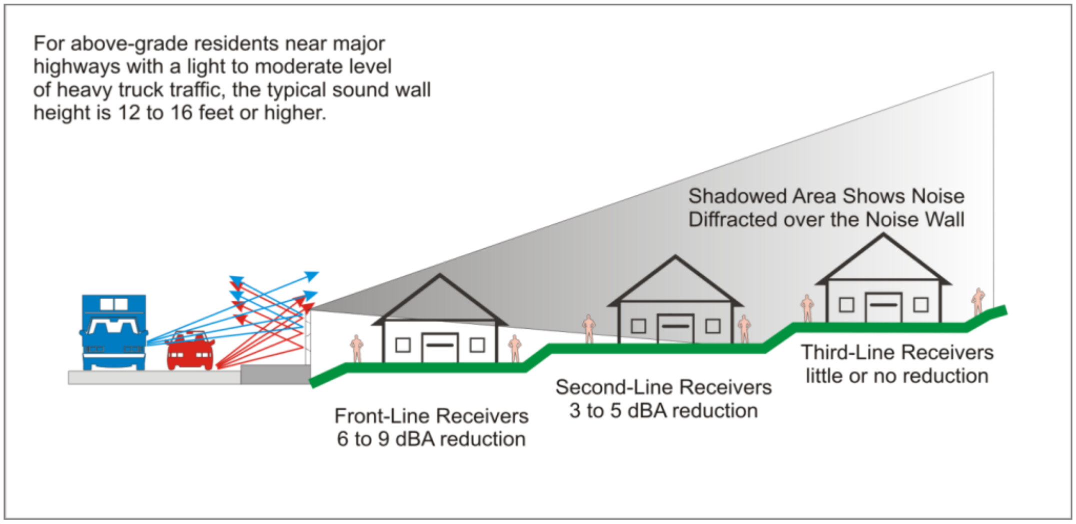
Exhibit 6-4. Typical Noise Wall Effectiveness with Below-grade Receiver



6.1.6.6 Noise Walls with Above-Grade Receivers

Noise walls are normally less effective at reducing transportation noise at locations where receivers are elevated above the roadway because the receivers are closer to noise that is diffracted over the top of the noise wall. Increasing the height of the noise wall can, in some circumstances, result in noise reductions of the same magnitude that would be achieved for at-grade receivers. The overall effectiveness would depend on the level of elevation over the roadway, vehicle mixture, noise wall placement, and other geometric considerations. Exhibit 6-5 shows a typical schematic of noise wall heights and relative effectiveness for receivers located above the road grade.

Exhibit 6-5. Typical Noise Wall Effectiveness with Above-grade Receiver



6.2 Proposed Mitigation for Long-term Adverse Effects

After reviewing the locations of the predicted noise impacts, it was determined that noise walls were the only feasible form of noise mitigation. Noise walls were evaluated for all areas within the project where traffic noise levels are expected to approach or exceed the NAC. The noise wall mitigation discussion is organized by evaluating the two primary requirements established by WSDOT that must be met before any noise wall can be recommended for the project. Whether each evaluated noise wall meets the WSDOT feasibility requirement is discussed followed by a detailed analysis of whether the wall meets the WSDOT cost-effective requirement.

Sixteen potential noise walls were evaluated for areas within the main project area where traffic noise levels are expected to approach or exceed the FHWA noise abatement criteria. The eleven noise walls evaluated for this project that meet both the feasibility and reasonableness criteria are shown on Exhibits 6-6 through 6-8. The noise walls are designated using number designations (for example Noise Wall No.1) which are used to identify the walls for the remainder of this discussion. Noise Walls No. 1 through No. 11 are located in the Vancouver area. Proposed Noise Wall No. 10 would be constructed for the LPA Full Build but would be deferred for the LPA with highway phasing option.

The five noise walls that were evaluated but not recommended are addressed in the following sections. No noise walls were evaluated in the Portland area because no project related traffic noise impacts were predicted.

In the Vancouver area, some neighborhoods that were evaluated for noise wall mitigation currently have noise walls but impacts are expected due to the ineffectiveness of the existing wall designs to maintain future noise levels to below the NAC. Therefore, the existing noise walls would be removed to allow for the construction of new noise walls of appropriate height. In certain situations, the existing noise walls would be removed prior to constructing the proposed retaining walls. In all cases, the existing noise walls were not included in the TNM model when determining future noise levels without mitigation. Using this approach, ensures that any proposed noise wall heights are appropriately established by "crediting" the new walls with the total amount of noise reduction each wall would ultimately provide. Otherwise, if the baseline future LPA Full Build noise levels included the effect of existing noise walls, higher noise wall heights than necessary could be erroneously proposed in an effort to achieve the minimum noise level reductions required by WSDOT's feasibility requirement.

The final decision and recommendation to include noise wall mitigation will be made during the final design process. As the project is advanced through final design, factors that affect the feasibility and cost-effectiveness of sound walls can change. In addition, should the noise-impacted residents be in opposition to the recommended noise mitigation, the recommended abatement for that particular area may not be incorporated into the project.

6.2.1 Feasibility Analysis of Evaluated Noise Walls

6.2.1.1 Fort Vancouver Noise Wall/East of I-5

One noise wall was evaluated to mitigate traffic noise impacts to the 33 residences and residential equivalents within VNHR east of I-5 and north of SR 14 that would have future peak-hour noise levels that meet or exceed the NAC. This wall is designated as Noise Wall No. 1 on Exhibit 6-6. To mitigate traffic noise impacts in the Fort Vancouver area, a noise wall was evaluated that begins along the north side of SR 14, follows the SR 14 on-ramp to northbound I-5, and extends north to the proposed I-5 Community Connector just south of E Evergreen Boulevard. This wall would provide noise level reductions in the range of 6 to 15 dBA for the 33 residential equivalents that would have future noise levels that meet or exceed the NAC. In addition, the noise wall would provide a 5- to 7-dBA reduction for 29 more residential equivalents, bringing the total number of residences benefiting from the wall to 62. The proposed wall would satisfy WSDOT's feasibility requirement.

6.2.1.2 Downtown Vancouver Noise Walls

A noise wall was evaluated for the 24 apartments located in the northwest corner of W 5th Street and Main Street. The apartments begin on the second story of a 5 story building. There are no outdoor use areas (decks/balconies) at the apartments. A wall with a height of up to 28 feet was analyzed that extends along the SR 14 westbound to I-5 southbound ramp and north along the SR 14 to City Center off ramp. The wall would not provide any noise reductions to the elevated apartment homes and therefore would not meet WSDOT's feasibility criteria. This wall is not recommended for the LPA or LPA with highway phasing option.

A second noise wall was evaluated for the traffic noise impacts predicted at the EconoLodge motel. A wall with heights up to 16 feet was evaluated for 12 residential equivalents but would provide less than the required noise level reduction to meet WSDOT's feasible criteria. There are no outdoor use areas at this motel. This wall is not recommended for the LPA or LPA with highway phasing option.

A third wall in the downtown Vancouver area was evaluated for the6 traffic noise impacts at the Normandy Apartments located at the corner of C Street and East 7th Street. A noise wall with heights ranging from 10 to 12 feet would reduce noise levels by 10 dBA for the first floor apartments. The wall is designated as Noise Wall No. 2 on Exhibit 6-7. Although the three lower level apartments would be partially mitigated with the proposed wall, all six apartment units would continue to have noise levels exceeding the NAC. This wall would meet WSDOT's feasibility criteria.

A fourth wall in the downtown Vancouver area was evaluated for the collective 29 traffic noise impacts at the outdoor pool area at the Comfort Inn & Suites, the apartments at E Street and East 13th Street, and the Academy Chapel (church used for weddings). The apartment homes are all on the second floor with parking on the first floor. At a height of 20 feet, the noise wall would reduce noise levels at the apartment homes by only 1-dBA, the outdoor motel pool area by 6-dBA and at the wedding chapel by 4-dBA. Because a minimum acceptable increase is 5-dBA at front line receivers with at least one receiver achieving a 7-dBA reduction, a 20 foot noise wall is not feasible by WSDOT criteria. Increasing the wall height above 20 feet was not considered because it would exceed cost-effectiveness criteria and would therefore not meet WSDOT's reasonableness requirement. This noise wall is not recommended for the LPA or LPA with highway phasing option.

6.2.1.3 E Mill Plain to E Fourth Plain Noise Wall/West of I-5

One noise wall was evaluated to mitigate the future Full Build traffic noise levels that would approach or exceed the NAC at 27 residences west of I-5, between East Mill Plain and East Fourth Plain.

To mitigate traffic noise impacts in this area west of I-5 (represented by VW-1 through VW-14) a noise wall was evaluated that extends from East Mill Plain to East Fourth Plain. This wall is designated as Noise Wall No. 3 on Exhibit 6-7. This wall would provide noise level reductions in the range of 4 to 10 dBA for 27 residential equivalents that would have future noise levels that meet or exceed the NAC. In addition, the noise wall would provide a 3- to 6-dBA reduction for 17 more residences bringing the total number of residences benefiting from the wall to 44. This wall would satisfy WSDOT's feasibility requirement.

6.2.1.4 E Fourth Plain to E 39th Street Noise Wall/West of I-5

Three separate noise walls were evaluated to mitigate the future Full Build traffic noise levels that would approach or exceed the NAC at 62 residences west of I-5 between East Fourth Plain to East 39th Street. The three noise walls would be separated by East 29th Street and East 33rd Street. To reduce the amount of I-5 traffic noise transmission through these openings in the wall, the wall ends would wrap along East 29th Street and East 33rd Street. The wall wraps are subject to final design review and may not be constructed if sight distance is unacceptably impaired.

To mitigate traffic noise impacts in the area west of I-5 between East Fourth Plain and East 29th Street (represented by VW-15 through VW-20) a noise wall was evaluated that extends from East 26th Street at East Fourth Plain along the east shoulder of J Street to E 29th Street. This wall is designated as Noise Wall No. 4 on Exhibit 6-8. This wall would provide noise level reductions in the range of 4 to 13 dBA for the 26 residences that would have future noise levels that meet or exceed the NAC. No other residences would receive a minimum 3-dBA reduction from the noise wall. This wall would satisfy WSDOT's feasibility requirement. During final design, the existing 8 foot noise wall that extends from E 29th Street to just past E 27th Street should be evaluated to determine whether the existing wall can remain during construction. If so, an additional noise analysis should be conducted to determine whether extending the existing wall on either end to match the termini of Noise Wall No. 4, similar noise reductions can be achieved that would meet the WSDOT feasibility criteria.

A noise wall was also evaluated to mitigate traffic noise impacts in the area west of I-5 between East 29th Street and E 33rd Street (represented by VW-21, VW-22 and VW-25) that extends between the East 29th and East 33rd Streets. This wall is designated as Noise Wall No. 5 on Exhibit 6-8. This wall would provide noise level reductions in the range of 5 to 12 dBA for the 13 residences that would have future noise levels that meet or exceed the NAC. In addition, the noise wall would provide a 5- to 8-dBA reduction for six more residences bringing the total number of residences benefiting from the wall to 19. This wall would satisfy WSDOT's feasibility requirement.

Another noise wall was evaluated to mitigate traffic noise impacts in the area west of I-5 between East 33rd Street and East 39th Street (represented by VW-26 through VW-34) that extends between the East 33rd and East 39th Streets. This wall is designated as Noise Wall No. 6 on Exhibit 6-8. This wall would provide noise level reductions in the range of 9 to 13 dBA for the 23 residences that would have future noise levels that meet or exceed the NAC. In addition, the noise wall would provide a 4- to 7-dBA reduction for 14 more residences bringing the total number of residences benefiting from the wall to 37. This wall would satisfy WSDOT's feasibility requirement.

6.2.1.5 E Mill Plain to E McLoughlin Boulevard Noise Wall/East of I-5

A noise wall evaluated to mitigate the traffic noise impact at the Marshall Park perimeter trail nearest I-5 (represented by VE-44). The wall was evaluated at two different locations: along the east side of I-5 along the East Mill Plain to north bound I-5 on-ramp. At either location, the noise wall would provide a maximum noise level reduction of 4-dBA and therefore, would not satisfy WSDOT's feasibility requirement. This noise wall is not recommended for the LPA or LPA with highway phasing option.

6.2.1.6 E Fourth Plain to SR 500 Noise Wall/East of I-5

Four separate noise walls were evaluated to mitigate the future Full Build traffic noise levels that would approach or exceed the NAC at 87 residences and residential equivalents east of I-5 from East Fourth Plain and SR 500. The first three noise walls would be separated by East 29th Street and East 33rd Street. The fourth wall would be located near the east end of the project along the south edge of SR 500.

A noise wall evaluated to mitigate traffic noise impacts in the area east of I-5 between East Fourth Plain and East 29th Street (represented by VE-2 through VE-7) that extends from East Fourth Plain to East 29th Street. This wall is designated as Noise Wall No. 7 on Exhibit 6-8. This wall would provide noise level reductions in the range of 3 to 13 dBA for the 25 residential equivalents that would have future noise levels that meet or exceed the NAC. Two residences, although benefiting from the wall, would continue to have noise levels exceeding the NAC due to the required opening in the noise wall at East 29th Street. No other residences would receive a minimum 3-dBA reduction from the noise wall. This wall would satisfy WSDOT's feasibility requirement.

To mitigate traffic noise impacts in the area east of I-5 between East 29th Street and East 33rd Street (represented by VE-8 through VE-12) a noise wall was evaluated that extends between the East 29th and East 33rd Streets. This wall is designated as Noise Wall No. 8 on Exhibit 6-8. This wall would provide noise level reductions in the range of 7 to 13 dBA for the 19 residences that would have future noise levels that meet or exceed the NAC. One additional residence would receive 7-dBA reduction from the noise wall. This wall would satisfy WSDOT's feasibility requirement.

A noise wall was also evaluated to mitigate traffic noise impacts in the area east of I-5 between East 33rd Street and East 39th Street (represented by VE-13 through VE-26) a noise wall was evaluated that extends between the East 33rd and East 39th Streets. This wall is designated as Noise Wall No. 9 on Exhibit 6-8. This wall would provide noise level reductions in the range of 3 to 10 dBA for 30 residences that would have future noise levels that meet or exceed the NAC. In addition, the noise wall would provide a 4- to 7-dBA reduction for 13 more residences bringing the total number of residences benefiting from the wall to 43. This wall would satisfy WSDOT's feasibility requirement.

To mitigate traffic noise impacts south of SR 500, a noise wall was evaluated that extends along the south side of SR 500 between R Street and V Street. This wall is designated as Noise Wall No. 10 on Exhibit 6-8. This wall would provide noise level reductions in the range of 8 to 10 dBA for 13 homes that would approach or exceed the noise abatement criteria. This wall would satisfy WSDOT's feasibility requirement.

6.2.1.7 North of SR 500/East of I-5

A noise wall was evaluated along the eastside of I-5 northbound to mitigate traffic noise impacts that would occur to 12 homes north of SR 500. This wall would provide noise level reductions in the range of 4 to 7 dBA for the 12 homes. No additional homes would receive a noise-reduction benefit from the noise wall. This wall would satisfy WSDOT's feasibility requirement. However, as discussed later in this report, this wall would not meet WSDOT cost criteria, with the cost exceeding the benefit by $329,684. This wall is not recommended for the LPA or LPA with highway phasing option.

6.2.1.8 North of E 39th Street/West of I-5

To mitigate traffic noise impacts to the eight residences (VW-35) and the 22 residential equivalents for Kiggins Bowl (represented by VW-36F) a noise wall was evaluated that begins along north side of E 39th Street and wraps north along the western side of I-5 southbound.

The noise wall evaluated for this area is designated as Noise Wall No. 11 on Exhibit 6-8. This wall would provide noise level reductions in the range of 3 to 11 dBA for the collective 30 residences/residential equivalents. No additional homes would receive a noise-reduction benefit from the noise wall. This wall would satisfy WSDOT's feasibility requirement. However, as discussed later in this report, this wall would not meet WSDOT cost criteria due to the length required to mitigate Kiggins Bowl. A separate wall design of shorter length was considered for the eight residences. The WSDOT cost criteria would be met for the shorter length wall and would meet WSDOT's feasibility requirement by providing a 12-dBA noise level reduction at the eight residences. This wall is recommended for the LPA or LPA with highway phasing option.

6.2.1.9 Summary of Feasibility Analysis for Evaluated Noise Walls

Noise Wall No.'s 1 through 11 and the noise wall north of SR 500 and east of I-5 evaluated in Vancouver area meet the WSDOT feasibility requirements. The following discussion addresses whether the noise walls meet the WSDOT reasonableness requirements.

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Project Footprint
Community Connector (Noise wall in this section to be integrated with design)
The Village and Pearson Field Trail Facilities
Land Bridge

Sound Walls*
Wall Height (ft.)
12

*Sound wall symbols are not to scale

N W E S
0 120 240
Feet

Exhibit 6-6. Traffic Noise Mitigation - VNHR

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11 Aug 2011; File Name: F:\Transfer060811\NOI\NoiseimpactsWalls_MM133_2.mxd

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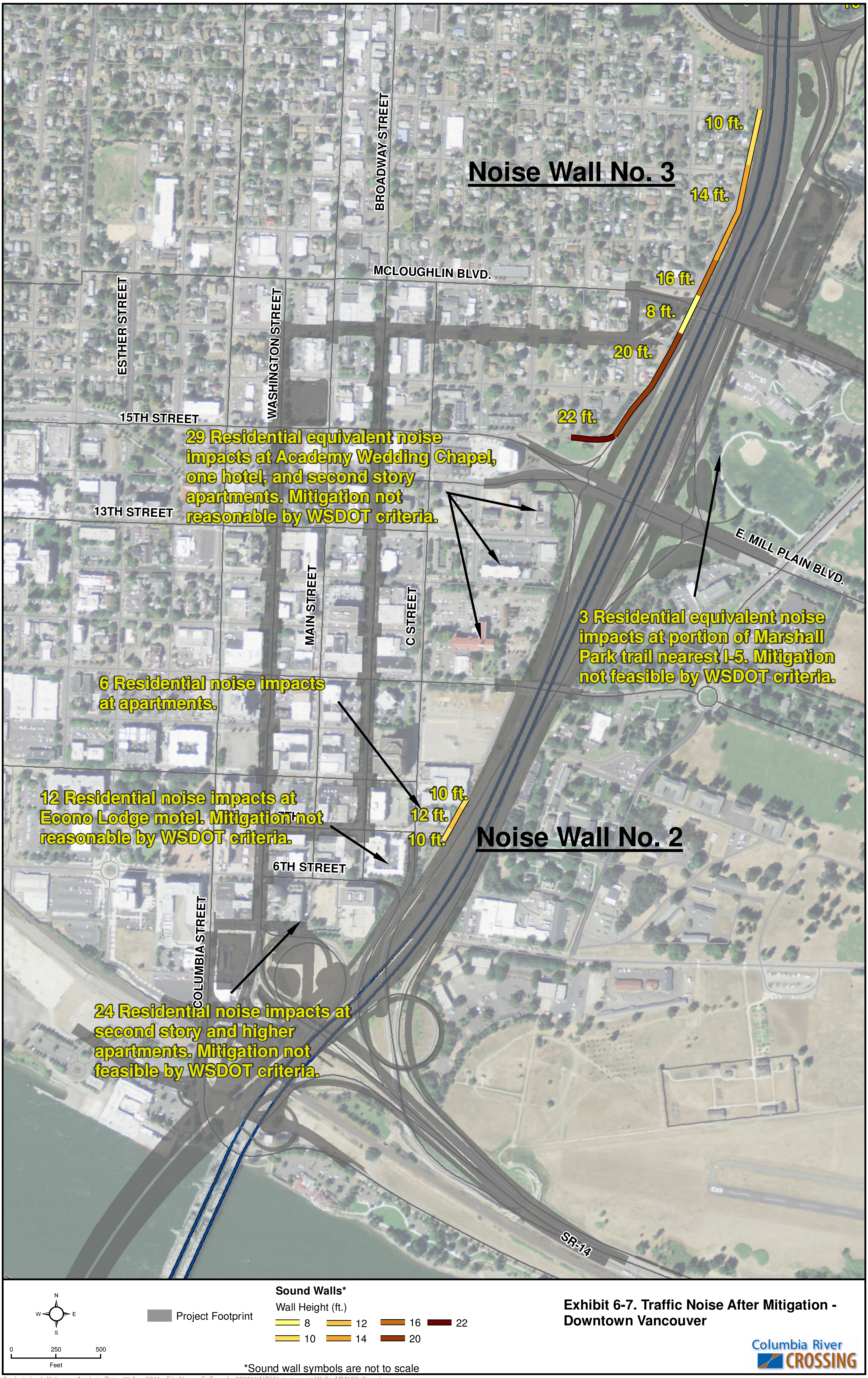

Exhibit 6-7. Traffic Noise After Mitigation - Downtown Vancouver

Analysis by J. Koloszar; Analysis Date: 11 Aug 2011; File Name: F:\Transfer060811\NOI\NoiseimpactsWalls_MM133_3.mxd

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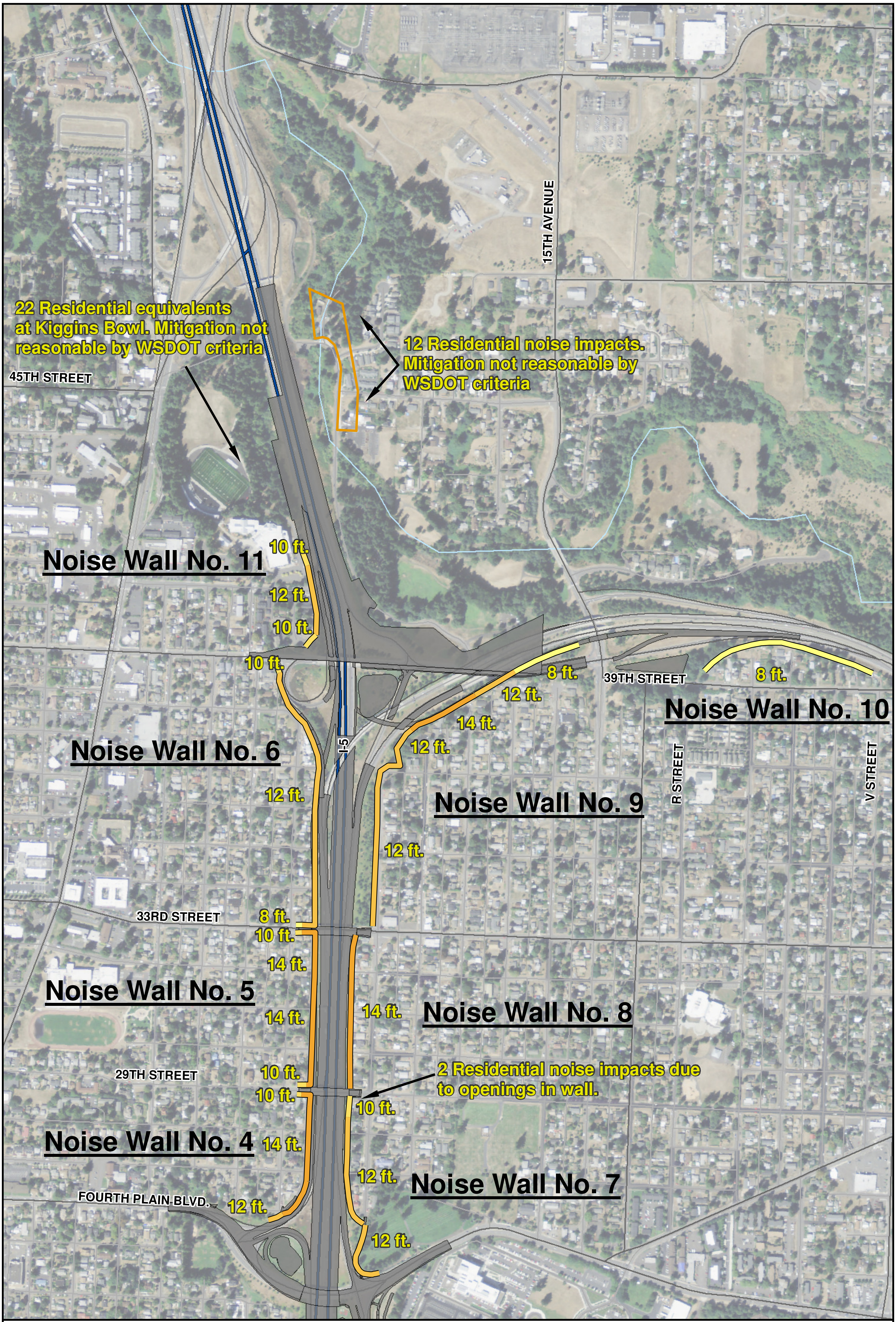

Project Footprint

Community Connector (Noise wall in this section to be integrated with design)

The Village and Pearson Field Trail Facilities

Sound Walls*

Wall Height (ft.)

8
10
12
14
16
18
20

*Sound wall symbols are not to scale

Exhibit 6-8. Traffic Noise Mitigation - North Vancouver

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 24 Jun 2011; File Name: F:\Transfer060811\NOI\NoiseimpactsWalls_MM133_2.mxd

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6.2.2 Cost-Effective Analysis of Evaluated Noise Walls

Exhibit 6-9 summarizes the results of the WSDOT cost criteria (reasonableness) evaluation. Eleven of the twelve noise walls that meet the WSDOT feasibility criteria also meet the WSDOT cost-effectiveness criteria and are recommended for the project. The noise wall evaluated along the eastside of I-5 northbound to mitigate traffic noise impacts that would occur to 12 homes north of SR 500 would meet the feasibility requirement but would not meet WSDOT cost criteria, with the cost exceeding the benefit by $329,684. This wall is not recommended for the LPA or LPA with highway phasing option. With the recommended noise wall, the noise levels at the Normandy Apartments (DT-5) would be reduced sufficiently to meet the WSDOT reduction requirements but continue to exceed the WSDOT noise abatement criteria. Increasing the wall height would improve the noise reduction provided by the wall, but the higher cost would exceed the cost criteria.

In the noise sensitive area represented by VE-7, the proposed noise wall design would not reduce future peak-hour noise levels to below the NAC. The required noise wall opening at E 29th Street limits the effectiveness of the noise wall in reducing I-5 traffic noise and the future LPA Full Build noise levels would continue to approach or exceed the NAC. Wrapping the ends of the wall along East 29th and East 33rd would assist in lowering the I-5 traffic noise levels but are not required to achieve the feasibility requirement for the walls. During final design, the openings should be re-evaluated to determine if wrapping the walls along East 29th and East 33rd Street would create any sight-distance safety issues.

The current design parameters of Noise Wall No. 1 require the noise wall to begin near the recently constructed foot bridge. The eastern termini of Noise Wall No. 1 should be re-evaluated during final design to determine the most suitable starting point to integrate with the foot bridge.

Exhibit 6-9. Noise Wall Performance Summary/Vancouver Area

Receiver Number	LPA Noise Levels without Noise Wall[a,b]	LPA Noise Levels with Noise Wall[a,b]	Noise Reduction[a]	Benefited Homes[c]	Capital Available for Mitigation[d]
Noise Wall No. 1 (East side of I-5 - SR 14 to I-5 Community Connector)					
FV-3	67	61	6	17	$698,870
FV-4	66	60	6	1	$37,380
FV-5	65	59	6	1	$37,380
FV-6	67	60	7	1	$41,110
FV-7	65	59	6	6	$224,280
FV-8	66	59	7	6	$224,280
FV-9	74	63	11	8	$531,360
FV-10	67	61	6	10	$411,100
FV-11	64	59	5	10	$373,800
FV-12	77	62	15	2	$147,380
FV-13	65	61	4	0	$37,380
FV-14[e]	72	61	11	0	$0
			Total Available for Noise Mitigation:		**$2,764,320**

Receiver Number	LPA Noise Levels without Noise Wall[a,b]	LPA Noise Levels with Noise Wall[a,b]	Noise Reduction[a]	Benefited Homes[c]	Capital Available for Mitigation[d]
Noise Wall No. 2 (West side of I-5 - Normandy Apartments)					
DT-5	76	66	10	6[f]	$442,140
			Total Available for Noise Mitigation:		**$442,140**
Noise Wall No. 3 (West side of I-5 - E Mill Plain Boulevard to E Fourth Plain Boulevard)					
VW-1	**68**	61	7	2	$89,280
VW-2	64	61	3	4	$149,520
VW-3	**71**	61	10	2	$111,060
VW-4	**67**	61	6	4	$164,440
VW-5	64	61	3	3	$112,140
VW-6	**70**	64	6	4	$207,600
VW-7	**67**	63	4	3	$123,330
VW-8	**72**	64	8	8	$473,280
VW-9	65	60	5	7	$261,660
VW-10	63	60	3	3	$112,140
VW-11	**69**	64	5	4	$193,080
VW-12	62	61	1	0	$0
VW-13	64	64	0	0	$0
VW-14	60	60	0	0	$0
			Total Available for Noise Mitigation:		**$1,997,530**
Noise Wall No. 4 (West side of I-5 - E Fourth Plain Boulevard to E 29th Street)					
VW-15	**74**	63	11	3	$199,260
VW-16	**69**	65	4	3	$144,810
VW-17	**74**	65	9	4	$265,680
VW-18	**72**	62	10	6	$354,960
VW-19	**66**	59	7	4	$149,520
VW-20	**77**	64	13	6	$442,140
			Total Available for Noise Mitigation:		**$1,556,370**
Noise Wall No. 5 (West side of I-5 - E 29th Street to E 33rd Street)					
VW-21	**73**	61	12	4	$251,160
VW-22	**76**	64	12	5	$368,450
VW-23	64	56	8	4	$149,520
VW-24	61	56	5	2	$74,760
VW-25	**66**	59	7	4	$149,520
			Total Available for Noise Mitigation:		**$993,410**
Noise Wall No. 6 (West side of I-5 - E 33rd Street to E 39th Street)					
VW-26	**76**	63	13	4	$294,760
VW-27	**72**	61	11	4	$236,640
VW-28	**74**	62	12	8	$531,360
VW-29	64	57	7	4	$149,520

Receiver Number	LPA Noise Levels without Noise Wall[a,b]	LPA Noise Levels with Noise Wall[a,b]	Noise Reduction [a]	Benefited Homes[c]	Capital Available for Mitigation[d]
VW-30	65	59	6	4	$149,520
VW-31	59	55	4	4	$149,520
VW-32	66	57	9	3	$112,140
VW-33	62	57	5	2	$74,760
VW-34	69	56	13	4	$193,080
			Total Available for Noise Mitigation:		**$1,891,300**
Noise Wall No. 7 (East side of I-5 - E Fourth Plain Boulevard to E 29th Street)					
VE-3	68	65	3	2	$89,280
VE-4	77	64	13	10	$736,900
VE-5	71	61	10	8	$444,240
VE-6	68	59	9	3	$133,920
VE-7	75	68	7	2	$140,120
			Total Available for Noise Mitigation:		**$1,544,460**
Noise Wall No. 8 (East side of I-5 - E 29th Street to E 33rd Street)					
VE-8	77	64	13	2	$147,380
VE-9	64	57	7	1	$37,380
VE-10	73	62	11	8	$502,320
VE-11	67	59	8	4	$164,440
VE-12	76	63	13	5	$368,450
			Total Available for Noise Mitigation		**$1,219,970**
Noise Wall No. 9 (East side of I-5 - E 33rd Street to E 39th Street)					
VE-13	71	65	6	3	$166,590
VE-14	63	57	6	4	$149,520
VE-15	71	62	9	10	$555,300
VE-16	70	63	7	5	$259,500
VE-17	59	59	0	0	$0
VE-18	66	62	4	4	$149,520
VE-19	66	63	3	3	$112,140
VE-20	67	60	7	2	$82,220
VE-21	64	60	4	3	$112,140
VE-22	65	59	6	4	$149,520
VE-23	66	59	7	1	$37,380
VE-24	68	63	5	2	$89,280
VE-25	65	61	4	2	$74,760
VE-26	64	63	1	0	$0
			Total Available for Noise Mitigation		**$1,937,870**
Noise Wall No. 10 (South of SR 500 - R Street to V Street) - LPA Full Build Only					
VE-27	66	58	8	4	$149,520
VE-28	67	57	10	3	$123,330

Receiver Number	LPA Noise Levels without Noise Wall[a,b]	LPA Noise Levels with Noise Wall[a,b]	Noise Reduction[a]	Benefited Homes[c]	Capital Available for Mitigation[d]
VE-29	67	59	8	3	$123,330
VE-30	68	60	8	3	$133,920
			Total Available for Noise Mitigation:		**$530,100**
Noise Wall No. 11 (West side of I-5 - E 39th Street to East 40th Street)					
VW-35	**73**	61	12	8	$502,320
		Total Available for Noise Mitigation:			**$502,320**
Noise Wall Evaluated for East side of I-5/North of SR 500 (not recommended)					
VE-34	60	59	1	0	$0
VE-35	65	64	1	0	$0
VE-36	62	61	1	0	$0
VE-37	67	66	1	0	$0
VE-38	68	68	0	0	$0
VE-39	67	67	0	0	$0
VE-40	68	68	0	0	$0
VE-41	68	67	1	0	$0
			Total Available for Noise Mitigation:		**$0**

a All noise levels in the exhibit are stated as L_{eq} in dBA.

b Bold red numbers throughout exhibit indicate noise levels that approach within 1 dBA or exceed the NAC of 67 dBA L_{eq}.

c Includes residential equivalents for outside activity areas and institutional uses such as schools and churches. These areas include outside use areas such as parks, the Discovery Middle School and Kiggins Bowl.

d Available mitigation capital from WSDOT criteria for cost evaluation.

e FV-14 (undeveloped property) is included here for planning purposes only.

f Only the lower floors of the apartment building would receive a noise reduction benefit. Of the 6 residences facing I-5, only the lower three apartments would receive a benefit.

The cost analysis conducted for the noise walls in the Vancouver area is summarized in Exhibit 6-10. A total of 334 residences (139 with noise levels of 70 dBA or higher) would benefit from construction of the proposed noise walls. Eleven of the twelve evaluated noise walls that would meet WSDOT's feasibility criteria would also meet WSDOT cost criteria. The noise wall evaluated on the east side of I-5 and north the SR 500 interchange would not meet the cost criteria with the cost exceeding the benefit by $854,774. The overall project corridor residual would be $4,900,196 less than the WSDOT allocated capital available for mitigation. The eleven proposed Vancouver area noise walls meet both the WSDOT feasibility and reasonableness criteria and are recommended as part of this project.

Exhibit 6-10. Details and Cost Analysis for Evaluated Noise Walls

Noise Wall Designation	Heights Along Wall (ft)[a]			Length (ft)[b]	Wall Area (sq.ft.)[c]	Cost[d]	Available Capital[e]	Residual Capital[f]
	Min	Avg	Max					
No. 1	10	11.96	12	2,803	33,522	$1,790,075	$2,764,320	+$974,245
No. 2	10	10.9	12	477	5181	276,665	$442,140	+165,475
No. 3	8	14.3	18	2,474	35,351	$1,983,650	$1,997,530	+13,880
No. 4	10	13.1	14	949	12,432	$663,869	$1,556,370	+892,501

Noise Wall Designation	Heights Along Wall (ft)[a]			Length (ft)[b]	Wall Area (sq.ft.)[c]	Cost[d]	Available Capital[e]	Residual Capital[f]
	Min	Avg	Max					
No. 5	10	12.3	14	1,147	14,150	$755,610	$993,410	+$237,800
No. 6	8	11.6	12	1,937	22,432	$1,197,869	$1,891,300	+$693,431
No. 7	10	11.6	12	1,158	13,426	$716,948	$1,544,460	+$827,512
No. 8	14	14	14	976	13,670	$729,978	$1,219,970	+$489,992
No. 9	8	11.2	14	2,624	29,471	$1,573,751	$1,937,870	+364,119
No. 10	8	8	8	1,073	8,585	$458,439	$530,100	+$71,661
No. 11	10	11.4	12	665	7,584	$404,986	$502,320	+$97,334
East of I-5/North of SR 500	10	10	10	1,601	16,007	$854,774	$0	-$854,774

a Minimum, average, and maximum noise wall heights in feet.
b Length of proposed noise walls in feet.
c Total noise wall surface area in square feet.
d Cost of noise wall based on $53.40 per square foot from WSDOT criteria for cost evaluation. The cost has been rounded to the nearest whole dollar.
e Available mitigation capital from WSDOT criteria for cost evaluation.
f Residual mitigation capital: positive value is within the allowable capital based on WSDOT criteria; negative value exceeds the criteria.
avg = average
ft = feet
max = maximum
min = minimum
sq.ft. = square feet

6.2.2.1 Summary of Cost-effective Analysis for Evaluated Noise Walls

The eleven noise walls in Vancouver area meet the WSDOT reasonableness (cost effectiveness) criteria, respectively. The eleven noise walls are recommended to be included as part of the LPA Full Build. All but Noise Wall No. 10 are recommended for the LPA with highway phasing option, as this wall is outside this option’s smaller project area. All noise wall designs stated in this report should be verified during the final design stage to account for the greater level of project design that will be available at that time.

6.2.3 Light Rail Noise and Vibration mitigation

Light rail noise and vibration impacts were considered for mitigation measures as required by the FTA. The following sections provide an overview of noise and vibration mitigation measures and those measures recommended for inclusion with the project.

6.2.3.1 Light Rail Noise Mitigation

There are several forms of noise mitigation that are commonly considered when noise impacts are identified. Mitigation measures evaluated for reducing noise impacts from light rail for the Columbia River Crossing Project include:

- **Sound Barriers.** Construction of noise barriers between a roadway or guideway and the affected receivers would reduce noise levels by physically blocking the transmission of noise. The heights of barriers depend on the proximity of the roadway or tracks to the barrier, location of the noise-sensitive properties, and topographical conditions. Typically, barriers for light rail range from four to eight feet tall.

- **Track Lubrication at Curves.** Trackside lubricators can be effective at reducing wheel squeal that sometimes occurs on tight-radius curves. There are currently several areas on existing light rail alignments that use trackside lubricators, and their effectiveness at reducing wheel squeal is documented.
- **Special Trackwork at Crossovers and Turnouts.** The impacts of light rail wheels over rail gaps at some sections of special trackwork increases light rail noise by 6 dBA or more. The use of spring-rail, flange-bearing, and moveable-point frogs in place of standard rigid frogs allows the gap to remain closed, thus reducing noise levels. Another option is to install risers on standard crossovers that support the wheels over the gap, thereby reducing noise.
- **Reduced Train Speed.** Although normally in conflict with project objectives, reducing train speed can reduce noise.
- **Building Sound Insulation.** Insulating affected structures can reduce noise levels inside homes that would be impacted by noise. This technique does not reduce exterior noise levels and would be used as a final measure to reduce noise to acceptable levels for sensitive receptors such as residences.

Project Noise Mitigation

Exhibit 6-11 provides a summary of the noise impacts, mitigation measures, and future project noise levels after mitigation was applied. The sections below provide descriptions of the mitigation measures. Aerial photos of the analysis areas and mitigation are at the end of this section.

Portland Noise Mitigation

The 16 noise impacts at the floating homes would be best mitigated with the installation of tall traffic safety barriers or sound barriers along the elevated structure. A 3 to 4 foot acoustical absorbent wall, or 6 foot reflective wall would be effective at reducing noise levels at these homes by 7 to 10 dBA. Similar wall are in use on similar transit systems and they have provided 10 dBA or more in noise reduction. Exhibit 6-13 provides an aerial view of the area, noise impacts and potential mitigation measures.

Downtown Vancouver

There are no noise impacts in the downtown Vancouver segment and no noise mitigation is recommended.

E 17th Street Noise Mitigation

The 15 noise impacts along E 17th Street will be mitigated with sound insulation. Because the alignment along E 17th Street is at grade in the center of the roadway, sound walls are not feasible. Therefore, a residential sound insulation program is the recommended form of mitigation for these residences. Exhibit 6-15 provides an aerial view of the area, noise impacts and potential mitigation measures.

McLoughlin Boulevard Noise Mitigation

The 19 noise impacts along McLoughlin Boulevard will also be mitigated with sound insulation for the same reasons given for the residences along E 17th Street. Exhibit 6-15 provides an aerial view of the area, noise impacts and potential mitigation measures.

After construction of the alignment, several tight radius corners should be checked for wheel squeal. This includes the corners at Washington and Broadway Streets at 7th Street and McLoughlin Boulevard. If wheel squeal is present, the installation of wayside track lubricators may be necessary. No other noise mitigation is recommended for this project.

Note the insulation of homes will not reduce the exterior noise levels. However, for the single-family residences along E 17th Street and McLoughlin Boulevard, the back yards are all well shielded from the train by the homes, so exterior noise levels in the back yards, where most people use as their primary outdoor use, are predicted to have noise levels below the FTA criteria. Only the front yards will continue to exceed the FTA criteria along E 17th Street and McLoughlin Boulevard.

Exhibit 6-11. Noise Mitigation Analysis

Rec#[a]	Area Description[b]	Land Use[c]	Number of Units[d]	Existing Noise[e]	Light Rail Noise Contribution[f]	Project Noise w/ Mitigation[g]	Criteria[h] Moderate	Impacts[i]	Mitigation[j]	Residual Impacts[k]
Portland										
FH2	First Row of Homes (nearest tracks)	SF	8	63	63	56	61	8	Wall	0
FH3	Second Row of Homes (Second set of homes from the tracks)	SF	8	63	61	56	61	8	Wall	0
E 17th Street										
17-1	17th Ave Alignment (C-D north)	SF	1	62	61	65	59	64	Insulation	0 (1 ext)
17-2	17th Ave Alignment (C-D south)	SF	2	62	61	65	59	64	Insulation	0 (2 ext)
17-3	17th Ave Alignment (D-E north)	SF	2	62	61	65	59	64	Insulation	0 (2 ext)
17-4	17th Ave Alignment (D-E south)	SF	1	62	62	65	59	64	Insulation	0 (1 ext)
17-5	17th Ave Alignment (E-F north)	SF	1	64	62	66	61	65	Insulation	0 (1 ext)
17-6	17th Ave Alignment (E-F south)	SF	1	64	61	66	61	65	Insulation	0 (1 ext)
17-7	17th Ave Alignment (F-G north)	SF	4	65	63	67	61	66	Insulation	0 (4 ext)
17-8	17th Ave Alignment (F-G south)	SF	3	65	62	67	61	66	Insulation	0 (3 ext)
McLoughlin Boulevard: Washington Street to I-5										
MC-1	Res D to E South	SF	4	64	**63**	**63**	61	4	Insulation	0 (4 ext)
MC-2	Res E to F North	SF	2	64	**62**	**62**	61	2	Insulation	0 (2 ext)
MC-3	Res E to F South	SF	4	64	**63**	**63**	61	4	Insulation	0 (4 ext)
MC-4	Res F to G North	SF	2	66	**62**	**62**	62	2	Insulation	0 (2 ext)
MC-5	Res F to G South	SF	4	66	**63**	**63**	62	4	Insulation	0 (4 ext)
MC-7	Res G to I-5 South	SF	3	68	**63**	**63**	63	3	Insulation	0 (3 ext)

a Receivers shown on Exhibits 4-12, and 4-13.
b General description of the area of analysis.
c Land Use: SF = single-family; MF = multi-family.
d Number of individual apartments or homes affected.
e Existing noise levels in L_{dn} for category 2 land use, or L_{eq} for category 1 or 3 land uses.
f Noise from operation of the light rail only. This is the noise level used to determine impacts with the FTA criteria. Levels in **bold red** exceed FTA criteria.
g Exterior noise level with mitigation.
h FTA impact criteria.
i Number of units impacted by project noise.
j Mitigation Measures.
k Remaining impacts with mitigation (ext = external noise levels at homes where sound insulation is recommended).

6.2.3.2 Light Rail Vibration Mitigation

Where vibration impacts are considered to be significant, they warrant consideration of reasonable and feasible mitigation. The following vibration mitigation measures were evaluated for use on this project:

- **Ballast Mats.** Ballast mats are a rubber-type material that is placed between the track ballast and the supporting concrete base. Ballast mats can be effective at reducing vibration when the frequency of the vibration impact is included as a design consideration.
- **Resilient Fasteners and Rail Boots.** Resilient fasteners are vibration-reducing fasteners that attach between the rail and ties. Rail boots are similar to resilient fasteners, but used for embedded track. As with ballast mats, fasteners can be effective at reducing vibration when the frequency of the vibration impact is included as a design consideration. For locations with embedded track, rail boots can accomplish similar vibration reduction.
- **Tire Derived Aggregate (TDA).** TDA normally consists of 12 inches of shredded rubber ballast under the standard ballast. This mitigation method has been employed by transit agencies, and further research is needed prior to committing to TDA for vibration mitigation.
- **Special Trackwork at Crossovers and Turnouts.** The FTA cites that light rail train wheels over rail gaps of special trackwork may increase light rail vibration by about 10 VdB in some conditions. The use of spring-rail, flange-bearing or moveable-point frogs in place of standard rigid frogs allows the gap to remain closed, reducing vibration levels.
- **Reduced Train Speed.** Reducing train speeds from those assumed in the noise and vibration analysis could reduce vibration generated by the project. This measure can be used in combination with other mitigation measures.
- **Rail Grinding/Wheel Truing.** These regular maintenance activities can address impacts only slightly above the threshold.

Portland Segment Vibration Mitigation

There are no vibration impacts predicted in the Portland segment as the alignment is elevated and there are no vibration sensitive receiver near the alignment.

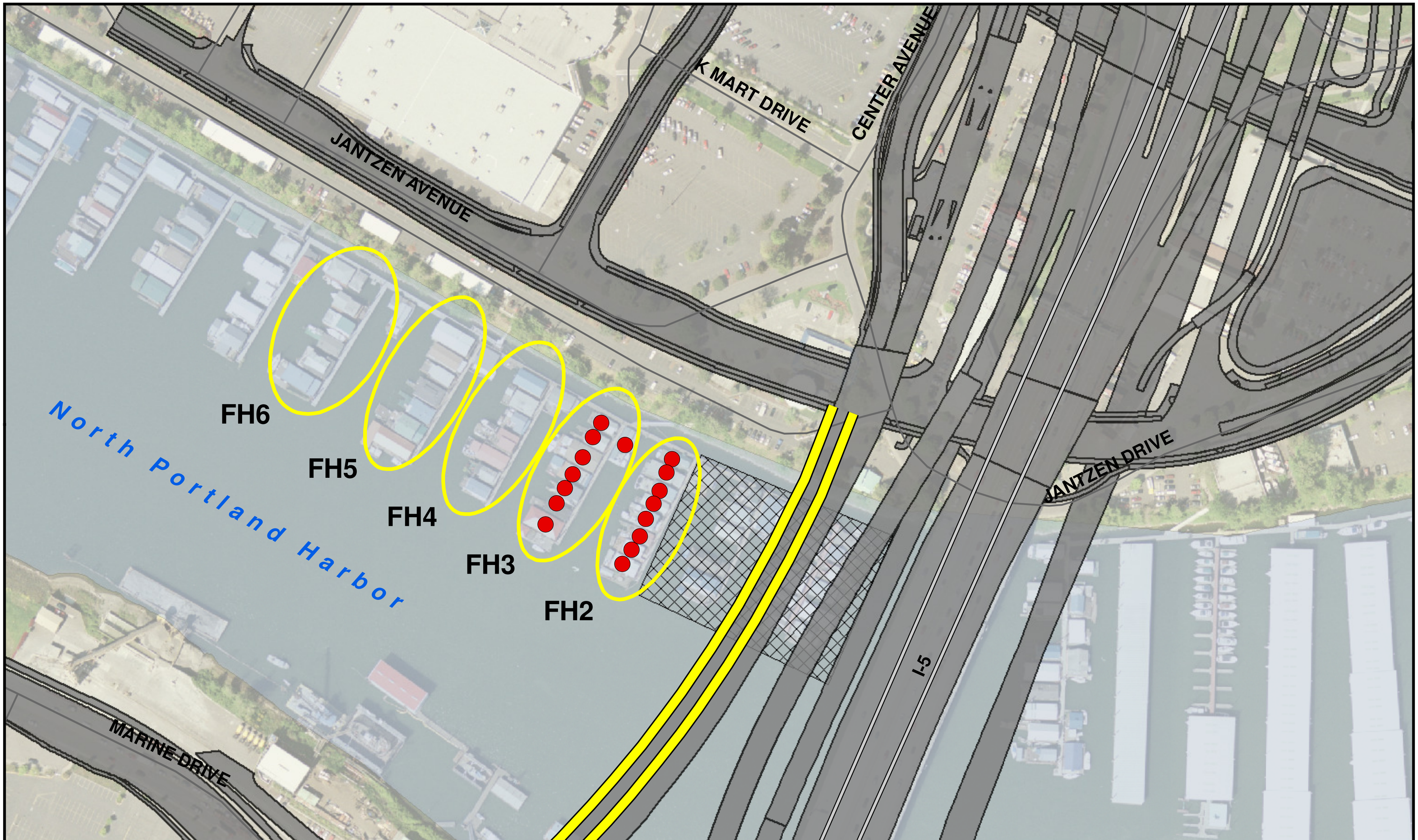
Vancouver Segment Vibration Mitigation

Vibration impacts were identified at the Smith Towers and 14 single-family residences along E 17th Street or 19 single-family residents along McLoughlin Boulevard, depending on alternative selected. Because all the vibration impacts are along embedded track way, the use of rail boots is the only feasible form of mitigation. Rail boots will typically reduce vibration levels by 5 VdB, which would bring all the predicted vibration levels to, or below, the FTA 72 VdB criteria for residential land uses. Receiver MC-5, with a predicted level of 77 VdB. would be the only location where there is still a potential for vibration impact. The receiver represents four homes between F and G Streets. Because of the 5 VdB safety factor included in this analysis, the rail boots should be sufficient to mitigate all the vibration impacts. Some additional testing may be performed during final design to assure the vibration levels at MC-5 are below the 72 VdB criteria. No other vibration mitigation would be required. Exhibit 6-12 provides a summary of the vibration levels with and without mitigation. Exhibits 6-14 and 6-15 show the vibration impacts and mitigation for the Vancouver Segments.

Exhibit 6-12. Projected Vibration Levels

Rec#[a]	Area Description[b]	Land Use[c]	Vibration Criteria[d]	Vibration Level[e]	Vibration Mitigation[f]	Level w/ Mitigation[g]
Downtown Vancouver						
WA-1	Smith Towers	MF	72	**76**	Rail Boot	71
17-1	17th Ave Alignment (C-D)	SF	72	72	Rail	67
17-2	17th Ave Alignment (C-D)	SF	72	72	Rail	67
17-3	17th Ave Alignment (D-E)	SF	72	72	Rail	67
17-4	17th Ave Alignment (D-E)	SF	72	73	Rail	68
17-5	17th Ave Alignment (E-F)	SF	72	73	Rail	68
17-7	17th Ave Alignment (F-G)	SF	72	76	Rail	71
17-8	17th Ave Alignment (F-G)	SF	72	74	Rail	69
MC-1	Res D to E South	SF	72	76	Rail Boot	71
MC-2	Res E to F North	SF	72	73	Rail Boot	68
MC-3	Res E to F South	SF	72	76	Rail Boot	71
MC-4	Res F to G North	SF	72	73	Rail Boot	68
MC-5	Res F to G South	SF	72	77	Rail Boot	**72**
MC-7	Res G to I-5 South	SF	72	76	Rail Boot	71

a Receivers shown on Exhibits 4-13 and 4-16.
b General description of the area of analysis.
c Land Use: SF = single-family; MF = multi-family; CO = commercial.
d FTA vibration impact criteria.
e Predicted vibration level.
f Amount the predicted level exceeds the criteria.
g Number of individual structures affected.



N
W E
S

0 150 300
Feet

- Project Footprint - LPA Option A
- Noise Wall or Larger Traffic Barrier
- Noise Analysis Groups
- Floating homes displaced by project
- Noise Impact

Exhibit 6-13. Portland Noise and Vibration Analysis and Impacts

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 11 Aug 2011; File Name: F:\Transfer060811\NOI\NoiseExhibits_4-14_6-13.mxd

N
W E
S
0 220 440
Feet

Project Footprint
Analysis Groups
Vibration Impacts Only

Exhibit 6-14. Downtown Vancouver Noise and Vibration Mitigation

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 13 Jun 2011; File Name: F:\Transfer060811\NOI\NoiseExhibits_4_15.mxd

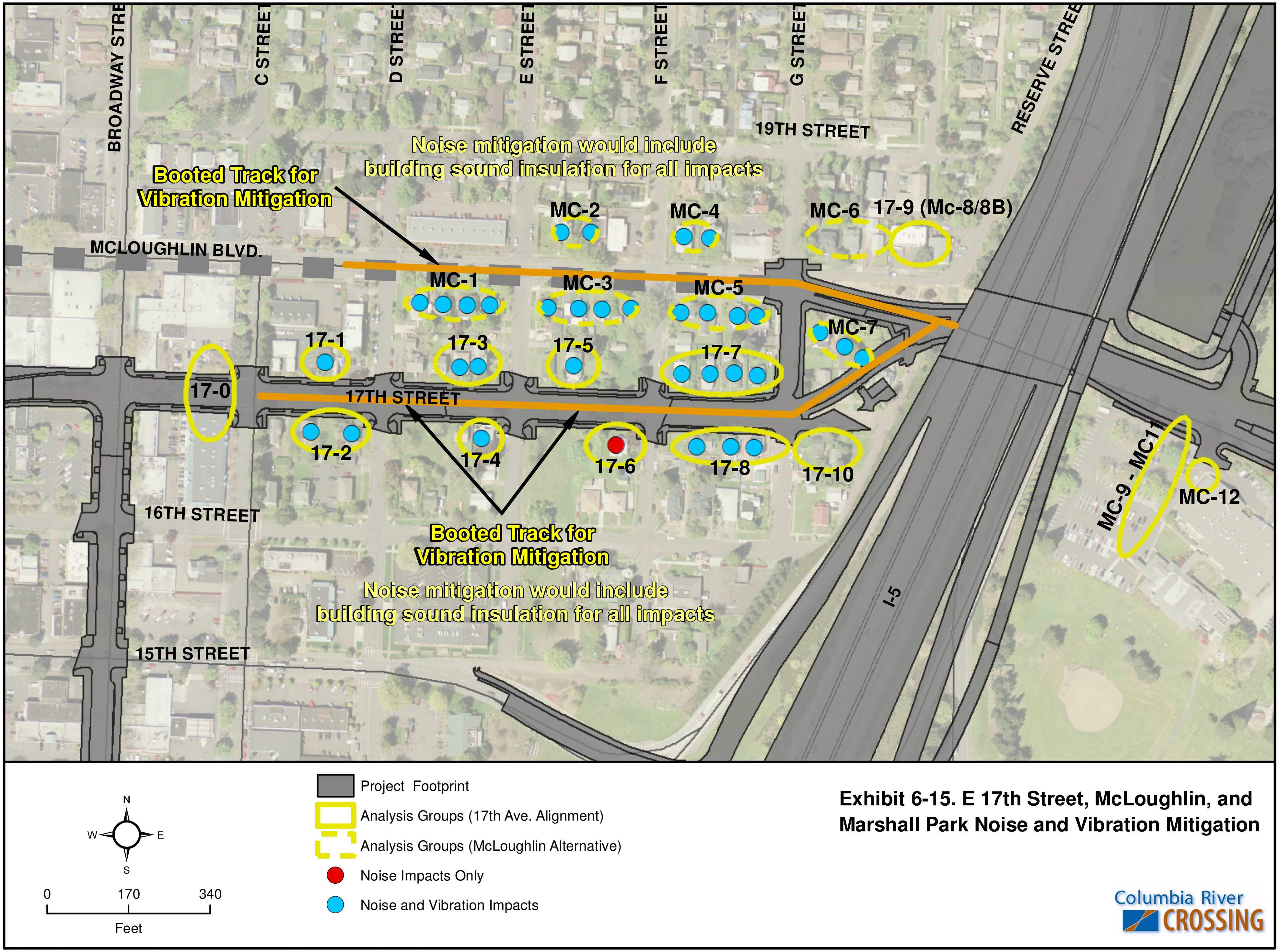


Exhibit 6-15. E 17th Street, McLoughlin, and Marshall Park Noise and Vibration Mitigation

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 28 Jun 2011; File Name: F:\Transfer060811\NOI\NoiseExhibits_2.mxd

6.3 Proposed Mitigation for Adverse Effects during Construction

Several construction noise and vibration abatement methods—including operational methods, equipment choice, or acoustical treatments—could be implemented to limit the effects of construction. The following sections contain some of the more common construction noise and vibration abatement methods.

6.3.1 Construction Noise Mitigation

Operation of construction equipment could be prohibited within 500 feet of any occupied dwelling unit in evening or nighttime hours (7:00 p.m. to 7:00 a.m.) or on Sundays or legal holidays, when noise and vibration would have the most severe effect. Mufflers would be required on all engine-powered equipment, to be installed according to the manufacturer's specifications, and all equipment would be required to comply with U.S. Environmental Protection Agency (EPA) equipment noise standards.

WSDOT could limit activities that produce the highest noise levels (such as hauling, loading spoils, jack hammering, 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 auger is not likely to be feasible for this project) or limiting the time the activity could take place. Other less effective methods of reducing noise from pile driving include coating the piles, using pile pads, or using piston mufflers. In the event that pile driving exceeds the limits set forth in Exhibit 2-14, a noise variance would be requested from the local jurisdiction.

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

A complaint hotline could also 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 met state, local, and any manufacturer's specifications for noise emissions. Equipment not meeting the standards could be removed from service until proper repairs were made, and the equipment re-tested for compliance. This procedure is recommended for all haul trucks, loaders, excavators, and other equipment that would be used extensively at the construction sites and that would contribute to potential noise effects.

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

- Require all engine-powered equipment to have mufflers that were 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.
- Where possible, schedule the construction of the residential noise barriers early in the project. In some jurisdictions, this may be a requirement in order to get any noise variances.
- 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.
- Use broadband back-up alarms or restrict the use of back-up beepers during evening and nighttime hours and use spotters. In all areas, Occupational Safety and Health Administration (OSHA) will require back-up warning devices and spotters for haul vehicles.
- Use pile driving noise shroud and/or employ auguring techniques where possible to limit effects of pile driving.
- Additional noise mitigation measures might be implemented as more details on the actual construction processes are identified.

6.3.2 Construction Vibration

WSDOT could require vibration monitoring of all activities that might 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 had 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 can be kept to a minimum.

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7. Permits and Approvals

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 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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