PRELIMINARY

Parametrix ENGINEERING . PLANNING . ENVIRONMENTAL SCIENCES

411 108th AVENUE NE, SUITE 1800
BELLEVUE, WA 98004-5571
T. 425.458.6200 F. 425.458.6363
www.parametrix.com

TECHNICAL MEMORANDUM

Date:	March 18, 2010
To:	Jeff Heilman
From:	Peter Chen
Subject:	Greenhouse Gas Analysis - DEIS Methodology Validation
cc:	
Project Number:	273-3012-004
Project Name:	Columbia River Crossing

INTRODUCTION

At the time when the Columbia River Crossing (CRC) Draft Environmental Impact Statement (DEIS) was prepared there were no methodologies accepted industry-wide that estimated operational energy use and greenhouse gas (GHG) emissions associated with transportation projects. The methodology used in the DEIS was based on a well-established equation that related distances traveled and fuel economy to estimate the amount of fuel consumed. The DEIS methodology was novel in the sense of how it integrated carbon dioxide (CO_2) emission factors for different energy sources (e.g. gasoline, diesel, electricity etc.), utilized traffic simulation data, and accounted for the operational speeds of the project by using different fuel economies according to vehicle class and over a speed distribution.

Since that time, the Environmental Protection Agency (EPA) released the Mobile Vehicle Emission Simulator (MOVES) model. The MOVES model is intended to replace EPA's previous air quality model, MOBILE6, but also estimates operational carbon dioxide equivalent (CO_2e) emissions, which are equated to GHG emissions. Based on stakeholder input and project staff recommendations, the CRC project decided to use the MOVES model to for the operational energy and GHG emissions analyses in the Final Environmental Impact Statement (FEIS).

Since no other methodologies were available at the time when the DEIS was prepared to gauge the accuracy of the estimates, the project team deemed it desirable to confirm the validity of the methodology and conclusions presented in the DEIS.

PURPOSE

The primary purpose of this analysis is to determine if the methodology used in the DEIS produces GHG emission estimates similar to the MOVES model, thereby validating the analysis presented in the DEIS.

The secondary purpose of this effort is to examine the input assumptions made in the DEIS and determine if those values were reasonable, thereby validating the conclusions presented in the DEIS.

APPROACH

To validate the methodology used in the DEIS and its conclusions, the GHG estimates produced by the MOVES model for the FEIS were compared to estimates resulting from the DEIS methodology.

It is important to distinguish the differences between the terms "methodology" and "input assumptions." For the purposes of this report, "methodology" refers to the collection of parameters and their relationships used to derive the estimates, such as traffic volumes, fleet mixes, distance traveled, and operating speeds. The term "input assumptions," in this report, refers to the specific values of parameters. To illustrate the differences between these terms, an example of two different mathematical methodologies is presented below.

Method 1:	**Method 2:**
2 (5 + 3) = x	2 (5 + 3) = x
2 (8) = x	(2 * 5) + (2 * 3) = x
16 = x	(10) + (6) = x
	16 = x

In the example above, the specific sequence of multiplication and addition is the methodology and the numbers are the input assumptions. Both methodologies are valid means to the same answer, so long as the input assumptions are consistent.

Methodology Validation

As defined above, "methodology" refers to the collection of parameters and the relationships between those parameters. Table 1 shows a non-exhaustive list of the different parameters used in the DEIS and MOVES methodologies, which illustrate the similarities and differences.

The methodology used in the DEIS is more simple compared to the MOVES model; it aggregates some parameters (e.g., vehicle classes) and does not account for other parameters (e.g., vehicle age distribution, road type, and drive cycles).

While the DEIS and MOVES methodologies are somewhat different, it was hypothesized that they both produce similar GHG emission estimates. It was also hypothesized that differences in the GHG emission estimates are primarily due to different input assumptions, not the methodology. The two primary input assumptions assumed to have the most substantial effects are the existing fuel consumption rates (FCRs) and the future projections.

To test these hypotheses and determine the magnitude of effect of the two primary input assumptions, the following three scenarios were identified and compared to GHG emission estimates using the MOVES model with MOVES 2005 FCRs and MOVES 2030 projections:

- **Scenario 1 – DEIS 2005 FCRs and DEIS 2030 Projections.** The two primary input assumptions, existing and future fuel economies, remain as they were in the DEIS. This scenario identifies the cumulative effect of both of these input assumptions.
- **Scenario 2 – DEIS 2005 FCRs and MOVES 2030 Projections.** Under this scenario, the existing FCRs remain as they were in the DEIS, but the projected fuel economies are made consistent with those identified by MOVES. By using the same projections (i.e., rates of increase/decrease between existing and future fuel economies according to MOVES), this scenario tests the effect of the existing FCRs.
- **Scenario 3 – MOVES 2005 FCRs and DEIS 2030 Projections.** Under this scenario, the existing FCRs were changed to be consistent with MOVES, but the projected fuel economies are based on the DEIS data. By using the same existing FCRs (according to MOVES), this scenario tests the effect of the future projections.

Table 1. Methodology Comparison

Parameter	Methodology	
	DEIS	MOVES
Volume - Combination Long Haul Truck	200 vph of "Heavy Truck"	100 vph
Volume - Combination Short Haul Truck		25 vph
Volume - Single Unit Long Haul Truck		75 vph
Volume - Motor Home	NA	1 vph
Volume - Motorcycle	NA	3 vph
Volume - Passenger Car	9,750 vph of "Car"	7,300 vph
Volume - Passenger Truck		2,450 vph
Volume - Light Commercial Truck	150 vph of "Medium Truck"	100 vph
Volume - Refuse Truck		2 vph
Volume - Single Unit Short Haul Truck		48 vph
Volume - School Bus	35 vph of "Bus"	2 vph
Volume - Intercity Bus		15 vph
Volume - Transit Bus		18 vph
Road Type	NA	Un/Restricted
Month(s) of Year	NA	June
Weekdays/Weekends	NA	Weekdays
Hour(s) of Day	6:00 - 10:00 AM	6:00 - 10:00 AM
Vehicle Age Distribution	NA	1 Yr old (2%), 2 Yrs old (4%)
Distance Travelled	10 miles	10 miles
Average Speed	50 mph	50 mph
Drive Cycle	NA	Yes
Temperature	NA	55 F
Humidity	NA	75%
Carbon Dioxide Equivalency Factor	100/95	NA

Input Assumptions Validation

The EPA routinely tests the fuel economy of new cars for "city" and "highway" conditions, which typically consist of an average operating speed of 21.2 mph and 48.3 mph over distances of 11.04 and 10.26 miles, respectively (EPA 2009). These tests provide the "EPA rated" fuel efficiencies found at car dealerships.

The Energy Information Administration (EIA) is a branch of the U.S. Department of Energy that gathers information and data from multiple resources, such as the EPA, to provide statistics and forecasts. The EIA produces the Annual Energy Outlook that revisits past data, market trends, technological advances, and policy changes to refine forecasts on an annual basis. These forecasts often serve as the best available data.

To validate the input assumptions presented in the DEIS, the existing and future fuel economies were compared to EIA Annual Energy Outlook data.

ANALYSIS

Methodology Results

The initial sensitivity analysis, Scenario 1, compared the DEIS and MOVES GHG emission estimates that differed by both methodology (DEIS and MOVES) and input assumptions (existing and projected fuel economies). The analysis was conducted for all existing and future alternatives for redundancy (i.e. higher confidence) purposes and is summarized in Table 2.

Table 2. Scenario 1 GHG Emission Comparison

	DEIS Methodology		MOVES Methodology		
Alternative	MT CO2e	Rank (High to Low)	MT CO2e	Rank (High to Low)	% Difference
Existing	229.7	5	273.5	5	19.1%
No Build	289.6	2	389.4	2	34.5%
No Build - Bridge Lift	295.6	1	396.8	1	34.2%
LPACO	277.7	3	371.6	3	33.8%
RP2	274.9	4	367.9	4	33.9%

Although the relative differences ("rank") between alternatives were consistent between the DEIS and MOVES estimates, which are often the focus for decision-making purposes, the absolute differences were more substantial with the MOVES estimates being approximately 34 percent higher.

Due to this magnitude of difference, another analysis, Scenario 2, was conducted that substituted the DEIS future projection rates for fuel economy with the MOVES projections (i.e., projections were held constant and existing fuel economies were the variable parameter). These emission estimates are summarized in Table 3.

Table 3. Scenario 2 GHG Emission Comparison

	DEIS Methodology		MOVES Methodology		
Alternative	MT CO2e	Rank (High to Low)	MT CO2e	Rank (High to Low)	% Difference
Existing	229.7	5	273.5	5	19.1%
No Build	317.7	2	389.4	2	22.6%
No Build - Bridge Lift	324.1	1	396.8	1	22.4%
LPACO	306.7	3	371.6	3	21.1%
RP2	303.5	4	367.9	4	21.2%

Table 3 shows that the alternative ranking remained consistent and the absolute differences between DEIS and MOVES estimates was reduced to approximately 22 percent. This indicates that the different input assumptions related to future fuel economies affects the absolute difference by roughly 12 percent (34 percent difference under Scenario 1 compared to 22 percent difference under Scenario 2; 12 percent effect).

A third scenario examined the effects of the existing fuel economy assumptions by holding the existing fuel economies constant (i.e., the existing fuel economies for the DEIS methodology were made equal the MOVES fuel economies) and letting the projections be the variable parameter. These results are shown in Table 4.

Table 4. Scenario 3 GHG Emission Comparison

	DEIS Methodology		MOVES Methodology		
Alternative	MT CO2e	Rank (High to Low)	MT CO2e	Rank (High to Low)	% Difference
Existing	278.5	5	273.5	5	-1.8%
No Build	354.4	2	389.4	2	9.9%
No Build - Bridge Lift	361.2	1	396.8	1	9.8%
LPACO	335.9	3	371.6	3	10.6%
RP2	332.8	4	367.9	4	10.6%

By changing the existing fuel economy input assumption in the DEIS methodology to equal the MOVES existing fuel economies, the ranking order remained consistent and the absolute difference between the DEIS and MOVES estimates was reduced to approximately 10 percent. By comparing these results to the results for Scenario 1, the existing fuel economy assumptions used in the DEIS has an affect of approximately 24 percent (34 percent difference under Scenario 1 compared to 10 percent difference under Scenario 3; 24 percent effect).

As described above, these three sensitivity analyses were conducted for all future alternatives for increased redundancy. However, focusing on the existing conditions in Table 4 also removes the effects of differing input assumptions related to future projections. Since the existing conditions estimates under Scenario 3 vary only by methodology (i.e., the existing fuel economy input assumptions were standardized), these estimates provide the best "apples-to-apples" comparison of the two methodologies. A difference of 1.8 percent between the two methodologies indicates that the DEIS methodology produces very similar estimates compared to the MOVES model.

Based on these sensitivity analyses, we can identify several conclusions:

- The existing fuel economy input assumption has the greatest effect compared to the future projections input assumption (24 percent effect compared to 12 percent effect, respectively).
- When input assumptions are the same, the DEIS methodology provides CO2e emission estimates that are approximately 1.8 percent within the MOVES estimates; i.e., the additional parameters included in the MOVES model (see Table 1) only affect emission estimates by a nominal amount.
- The input assumptions included in the DEIS and MOVES methodologies result in larger GHG emission estimates and are the primary cause for differences, not the methodology itself.
- Given that the relative difference ("ranking") between alternatives always remained consistent between the DEIS and MOVES estimates for all sensitivity tests, the methodology used in the DEIS and the conclusions drawn from the analyses are valid for evaluating alternatives.

Input Assumptions Results

The three sensitivity tests analyzed above indicate that the primary differences between the DEIS and MOVES GHG emission estimates are not due to the methodologies, rather the input assumptions used in those methodologies.

The DEIS input assumptions for existing and future fuel economies were based on data provided in the ODOT Energy Manual (ODOT 2006) and EIA's Annual Energy Outlook 2007 (EIA 2007). Figures 1 through 3 illustrate the differences between the DEIS and MOVES input assumption for existing fuel economies per vehicle class. These figures also provide a comparison to EIA data; however this data is limited to "highway" conditions at operating speeds of approximately 48.3 mph.

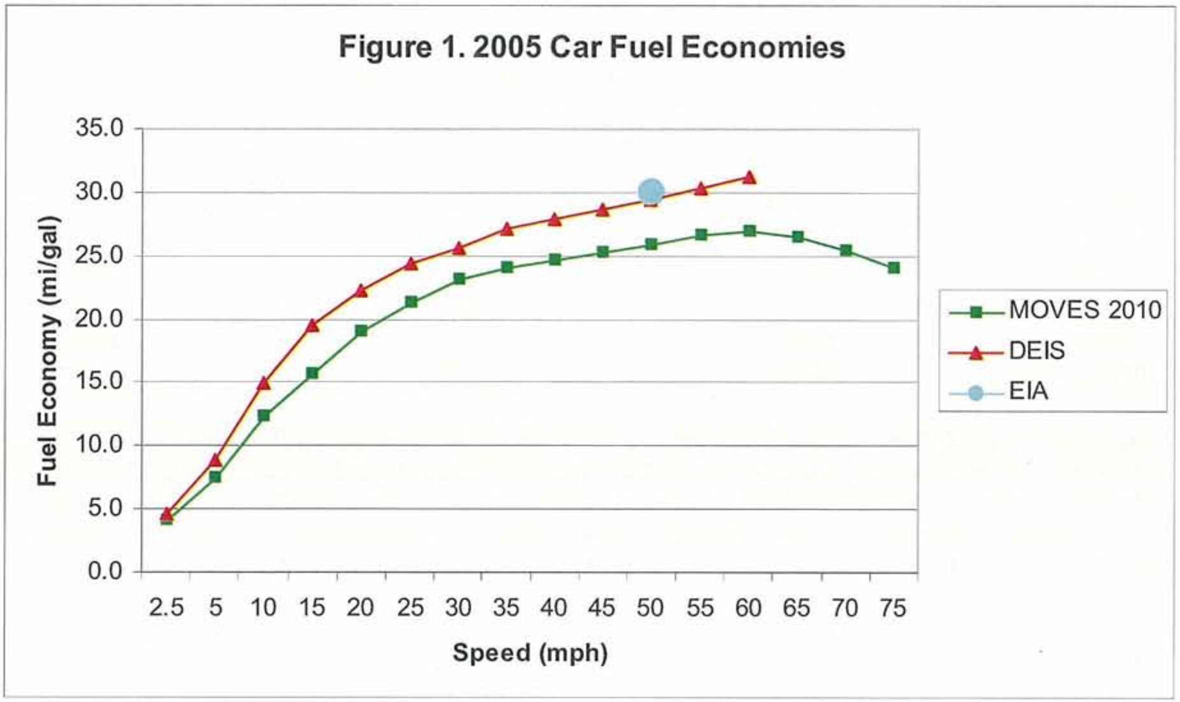


Figure 1. 2005 Car Fuel Economies
Fuel Economy (mi/gal)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2.5 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Speed (mph)
MOVES 2010
DEIS
EIA

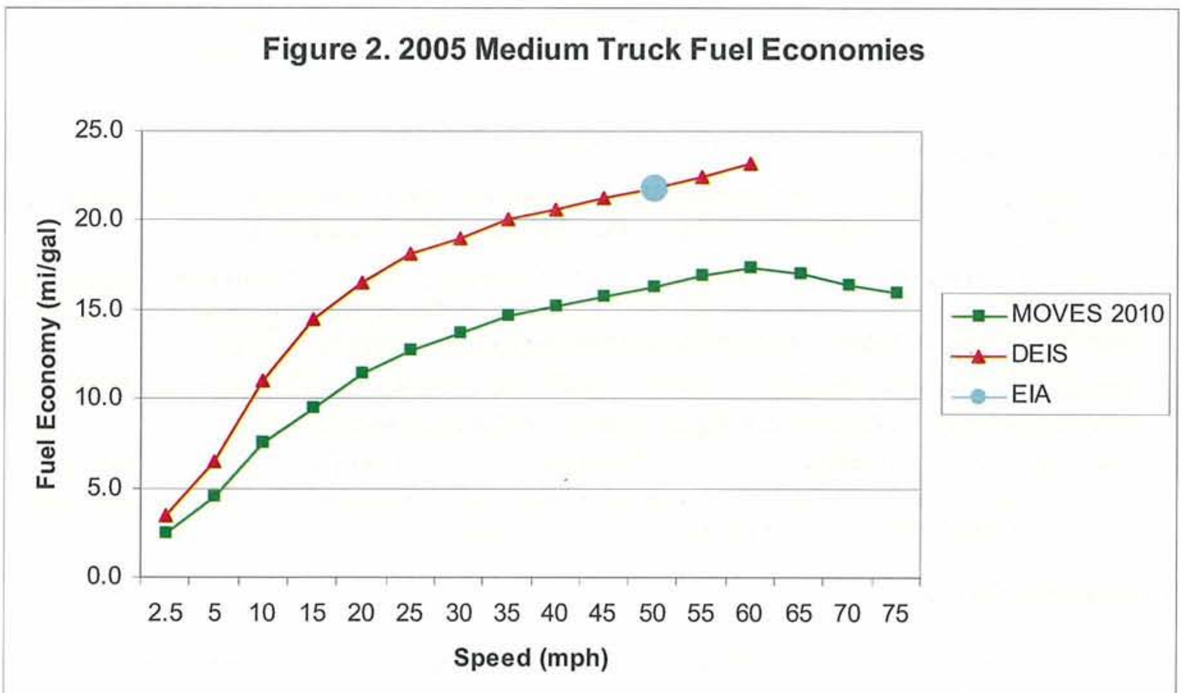
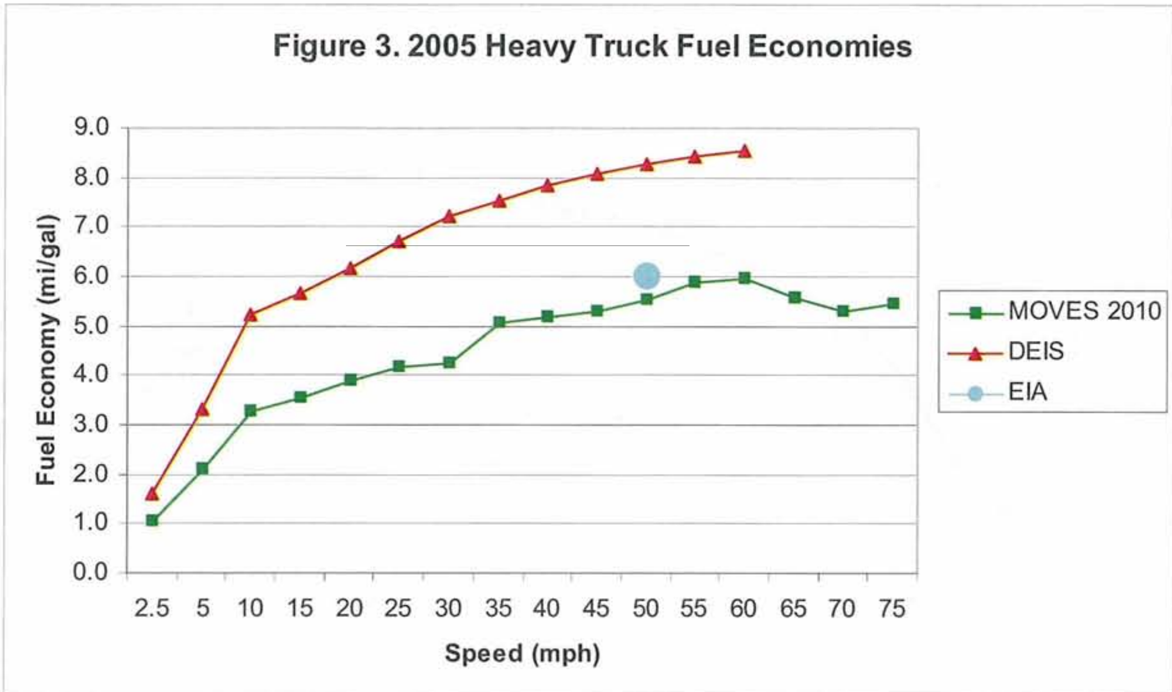


Figure 2. 2005 Medium Truck Fuel Economies
Fuel Economy (mi/gal)
25.0
20.0
15.0
10.0
5.0
0.0
2.5 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Speed (mph)
MOVES 2010
DEIS
EIA



Figures 1 through 3 indicate:

- Both DEIS and MOVES input assumptions for existing fuel economies over a speed distribution are fairly similar.
- The DEIS existing fuel economies are consistently higher (more fuel efficient) compared to MOVES fuel economies for all vehicle classes.
- For two of the three vehicle classes (cars and medium trucks), the DEIS existing fuel economies are more similar to EIA data compared to the MOVES fuel economies.

Figures 4 through 6 compare the future 2030 fuel economies included in the DEIS and MOVES methodologies as well as EIA forecasts.

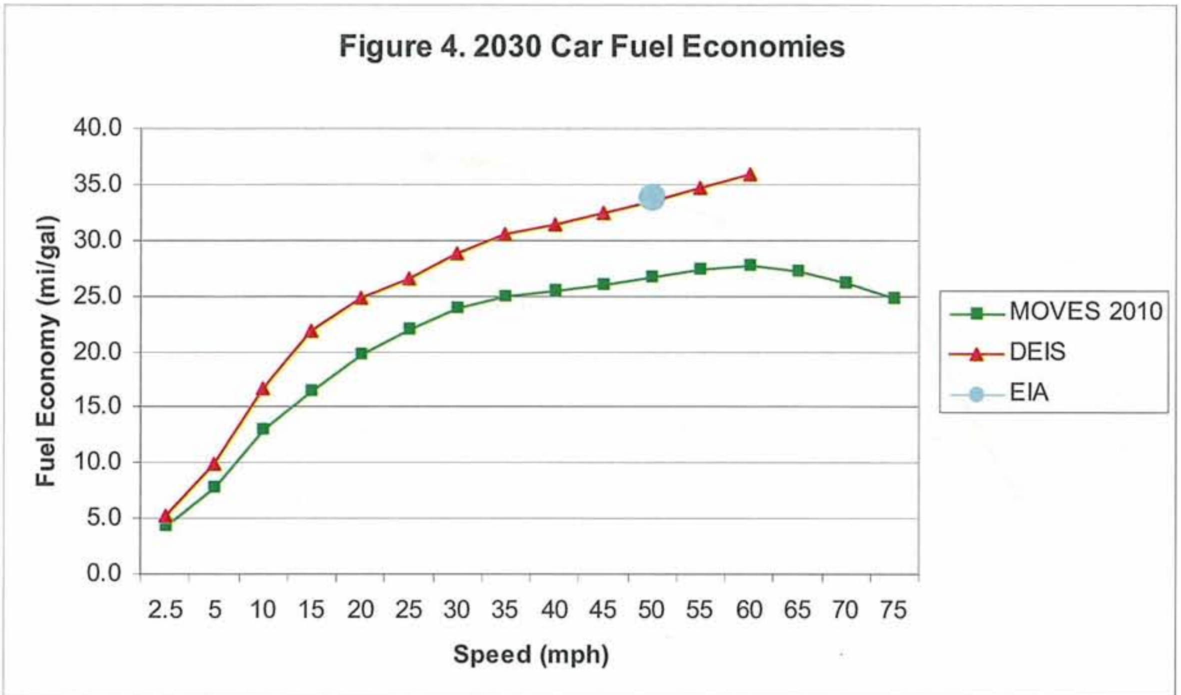


Figure 4. 2030 Car Fuel Economies
Fuel Economy (mi/gal)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2.5 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Speed (mph)
MOVES 2010
DEIS
EIA

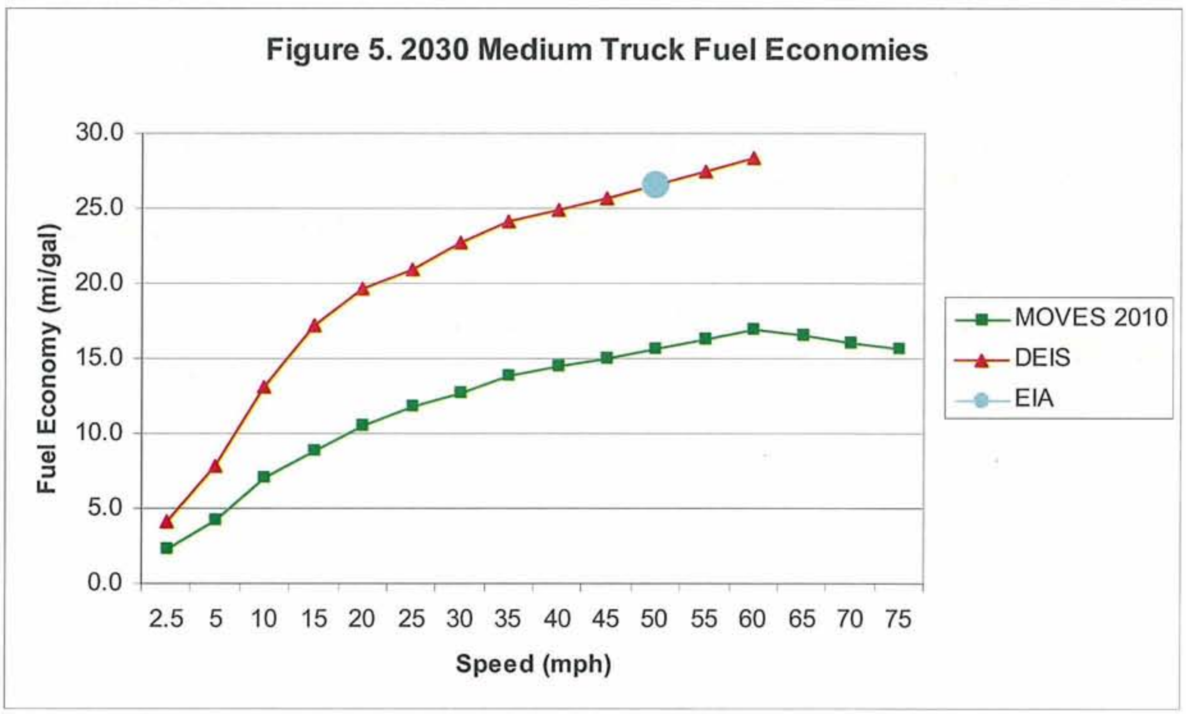
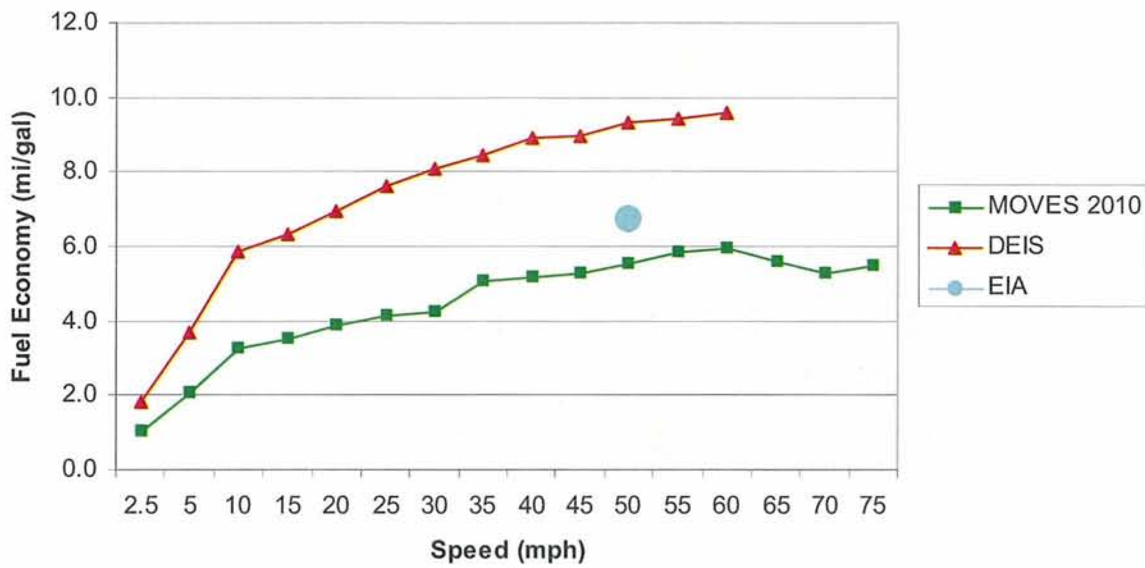


Figure 5. 2030 Medium Truck Fuel Economies
Fuel Economy (mi/gal)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2.5 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Speed (mph)
MOVES 2010
DEIS
EIA

Figure 6. 2030 Heavy Truck Fuel Economies



Figures 4 through 6 indicate:

- Both DEIS and MOVES input assumptions for future fuel economies over a speed distribution are fairly similar.
- The DEIS future fuel economies are consistently higher (more fuel efficient) compared to MOVES fuel economies for all vehicle classes.
- For two of the three vehicle classes (cars and medium trucks), the DEIS future fuel economies are more similar to EIA data compared to the MOVES fuel economies.

These differences in future 2030 fuel economies are due to two factors: existing fuel economies and projections (i.e., rate of increase in fuel efficiency between 2005 and 2030). Future fuel economies were compared to existing fuel economies for both the DEIS and MOVES input assumptions to identify projection rates and are shown in Figures 7 through 9, which also provide a comparison to EIA projections.

Figure 7. 2005 - 2030 Changes in Car Fuel Economy

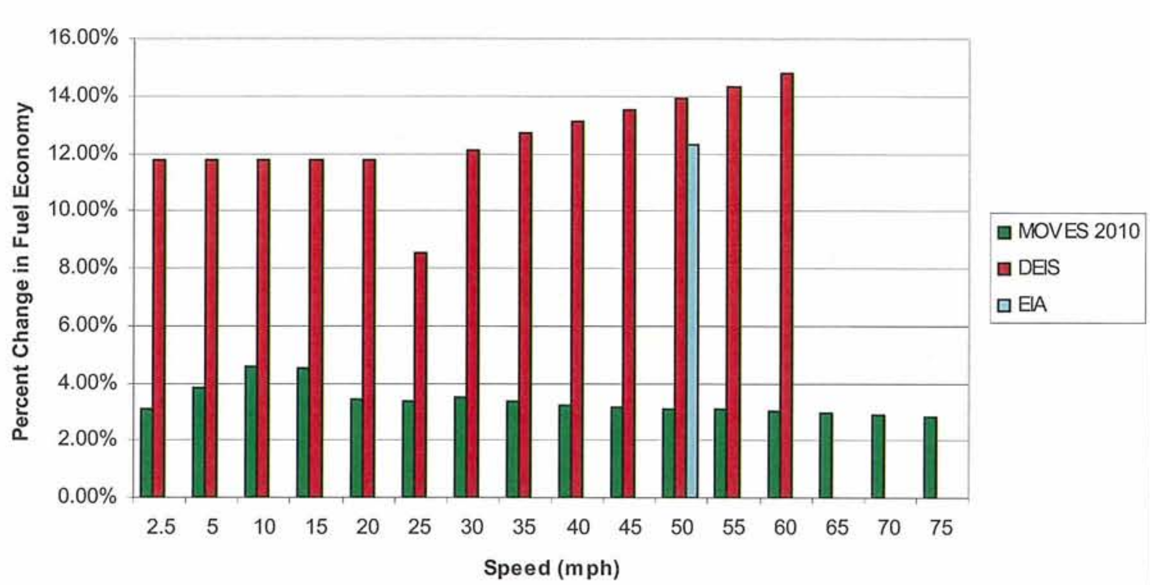


Figure 8. 2005 - 2030 Changes in Medium Truck Fuel Economy

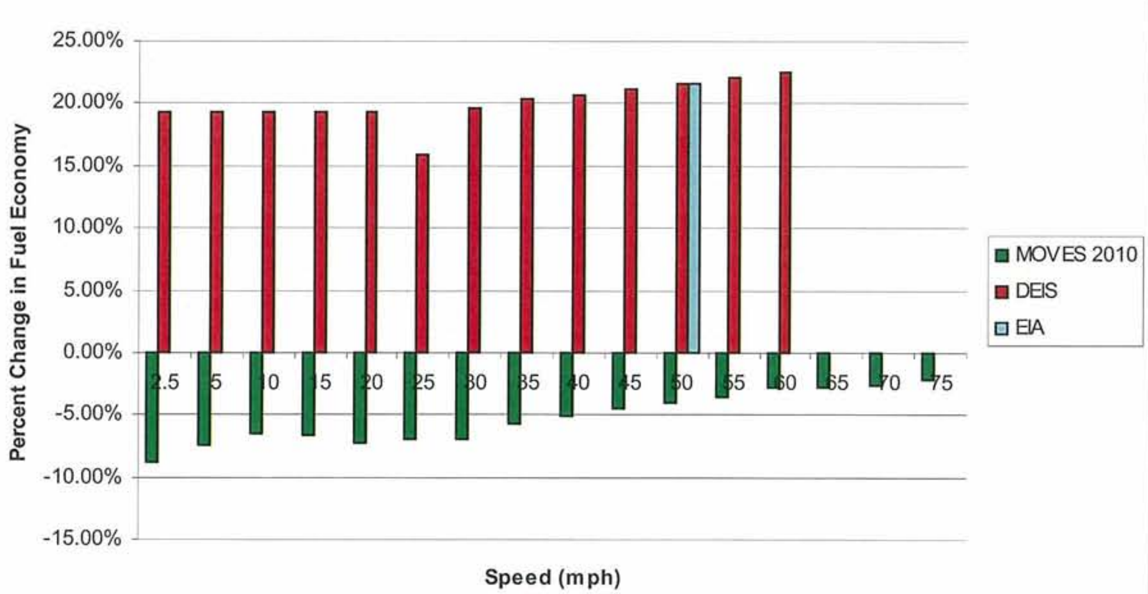
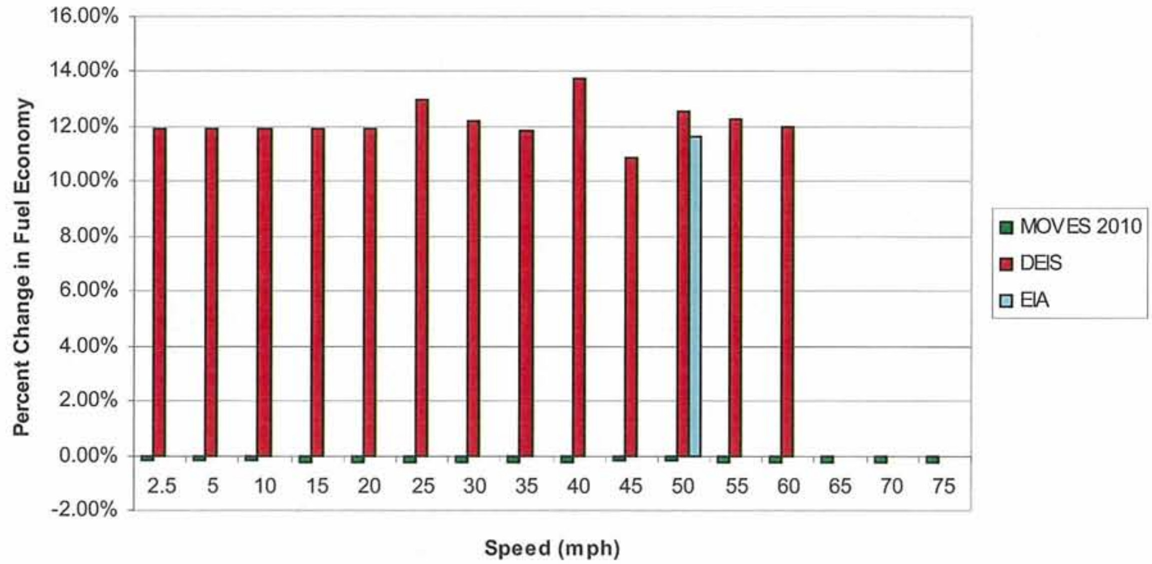


Figure 9. 2005 - 2030 Changes in Heavy Truck Fuel Economy



Figures 7 through 9 show several different trends, including:

- The DEIS projections for cars (9 to 15 percent) are much higher compared to MOVES (3 to 5 percent); EIA projections are most similar to the DEIS projections (12 percent).
- The DEIS projections for medium trucks range between 16 and 23 percent and the EIA projections are also comparable at 22 percent. The MOVES projections are substantially different and suggest that future fuel medium trucks will be less fuel efficient compared to existing medium truck by approximately 2 to 9 percent.
- The DEIS (11 to 14 percent) and EIA projections (12 percent) for heavy trucks are fairly similar, whereas the MOVES projections are essentially flat.

Although similarities and differences between the DEIS, MOVES, and EIA fuel economies cannot be absolutely and empirically identified, background knowledge on these methodologies provides insight and sound deductions on the likely responsible variables: definitions of vehicle classes, technology improvements, and vehicle age distribution.

Vehicle Classes

To be consistent with the Metro travel demand model, the DEIS methodology utilized a vehicle classification system consisting of cars, medium trucks, and heavy trucks. Within this system, the term "car" refers to common passenger vehicles, such as sedans, and excludes other vehicles, such as motorcycles and motorhomes. Conversely, the vehicle types included in MOVES are more specific and similar to FHWA's 13-vehicle classification system; motorcycles and motorhomes, for example, are considered separate vehicle classes. To be consistent with the three-vehicle classification system of Metro's regional travel demand model, the vehicle types in MOVES were aggregated to produce three emission rates, one for each vehicle class in Metro's regional demand model. While the proportion of motor homes is small, their effects do play a role on why the aggregated MOVES fuel economies for "cars" would tend to be lower compared to DEIS estimates.

The definition of "medium trucks" has a similar effect. A common definition is based largely on "looks" and how that vehicle operates in traffic with respect to accelerating, decelerating, and following distances. The MOVES criteria that distinguish medium and heavy trucks, which follow the more strict FHWA classification system, are based on the number of units, axles, and weight. As a result, some trucks that would be commonly considered by the general public as a "heavy truck" is actually classified as a "medium truck," which then reduces the average fuel economy for the medium truck vehicle class. Furthermore, MOVES allows each model year to contain different mixes of vehicle weights and fuel types. It may be that the 2030 fleet for medium trucks is heavier and/or a greater proportion uses diesel compared to the 2005 fleet, therefore resulting in higher emissions on average for the "medium truck" vehicle class (Brzezinski 2010).

Technology Improvements

MOVES also does not speculate on improvements to vehicle fuel efficiency in future model years, unless the improvements are required by regulations already in place. For example, if a pickup truck of a specific size and weight achieves 20 mpg in 2005, a truck of similar size and weight in 2030 will also get 20 mpg, unless there is some regulatory justification for the fuel economy to improve (Brzezinski 2010). The 2007 Corporate Average Fuel Economies (CAFE) standards are included in MOVES2010.

Vehicle Age Distribution

Likely the largest contributor to the differences between DEIS and MOVES assumptions for fuel economies is the vehicle age distribution, which refers to the proportion of vehicles in use that are one year old, two years old, etc. As shown above in Table 1, the DEIS methodology does not include this parameter, whereas MOVES does. Since the DEIS fuel economies were based on data provided by ODOT and EIA, these fuel economies do not include older vehicles that were originally less fuel efficient and are even less fuel efficient over time. For example, the DEIS projections assume that cars (i.e., new cars) operating at 60 mph will achieve a fuel economy of 35.9 mpg and this fuel economy is applied to all car VMT in 2030. This new car fuel efficiency may in fact be consistent with the MOVES projections; however, since MOVES accounts for vehicle age distribution, the proportion of new cars that achieve this fuel economy may be small and the majority of cars have a much lower fuel economy, thus lowering the total 2030 average.

CONCLUSIONS

Three sensitivity analyses were completed to compare the GHG emission estimates from the DEIS and MOVES methodologies. For all three tests, the relative differences ("rank") between alternatives remained consistent, which is often the focus for decision-making purposes. When the input assumptions (i.e., existing and future fuel economies) were made consistent between both methodologies, the resulting GHG emission estimates were within 1.8 percent of each other. The 1.8 percent difference represents the effects of the additional parameters that the MOVES model takes into account. Based on this small difference and since the relative differences always remained consistent between the DEIS and MOVES emission estimates, it was concluded that both methodologies produce very similar emission estimates and that the approach taken in the DEIS was valid.

The existing and future fuel economies assumed in the DEIS and MOVES methodologies exhibit a very similar trend over a speed distribution. Although the MOVES projections take additional factors into account that the DEIS input assumptions do not, such as vehicle age distribution, the DEIS fuel economies are highly consistent with EIA data and generally consistent with MOVES; therefore, the DEIS input assumptions were deemed valid.

Based on the validity of the DEIS methodology and input assumptions, conclusions presented in the DEIS also remain valid.

REFERENCES

Brzezinski, David. 2010. Personal email with EPA staff, David Brzezinski, EPA OTAQ ASD. Email Date: January 4, 2010.

EPA (Environmental Protection Agency). 2009. http://www.fueleconomy.gov/feg/fe_test_schedules.shtml. Date Consulted: December 1, 2009.

EIA (Energy Information Administration). 2007. *Annual Energy Outlook 2007 With Projections to 2030*. Office of Integrated Analysis and Forecasting, U.S. Department of Energy. Washington, DC.

ODOT. 2006. *Draft Energy Manual*. Oregon Department of Transportation.

APPENDIX D

Construction Analysis

Appendix D – Construction Analysis

This appendix consists of spreadsheets that show the data and equations used in the construction analysis. Due to the amount of data, these spreadsheets are particularly large and cannot be completely displayed on 8.5 x 11 or 11 x 17 paper. Since it is difficult to convey the information in a meaningful manner when printing these spreadsheets on numerous successive pages, this appendix has been submitted in electronic format only, which also reduces the amount of paper used for this report.

INTERSTATE 5 COLUMBIA RIVER CROSSING

Geology and Groundwater Technical Report for the Final Environmental Impact Statement

Columbia River CROSSING

May 2011

Title VI

The Columbia River Crossing project team ensures full compliance with Title VI of the Civil Rights Act of 1964 by prohibiting discrimination against any person on the basis of race, color, national origin or sex in the provision of benefits and services resulting from its federally assisted programs and activities. For questions regarding WSDOT's Title VI Program, you may contact the Department's Title VI Coordinator at (360) 705-7098. For questions regarding ODOT's Title VI Program, you may contact the Department's Civil Rights Office at (503) 986-4350.

Americans with Disabilities Act (ADA) Information

If you would like copies of this document in an alternative format, please call the Columbia River Crossing (CRC) project office at (360) 737-2726 or (503) 256-2726. Persons who are deaf or hard of hearing may contact the CRC project through the Telecommunications Relay Service by dialing 7-1-1.

¿Habla usted español? La informacion en esta publicación se puede traducir para usted. Para solicitar los servicios de traducción favor de llamar al (503) 731-4128.

This page intentionally left blank.

PRELIMINARY

Cover Sheet

Interstate 5 Columbia River Crossing

Geology and Groundwater Technical Report for the Final Environmental Impact Statement:

Submitted By:

Michael Marshall, R.G., L.G.

Eric A. Roth, R.G., L.H.G.

Parametrix

This page intentionally left blank.

TABLE OF CONTENTS

List of Exhibits

This page intentionally left blank.

ACRONYMS

Acronym	Description
BDDM	Bridge Design and Drafting Manual
bgs	Below ground surface
BMP	best management practices
BNSF	Burlington Northern Santa Fe Railroad
C	Celsius
C-TRAN	Clark County Public Transportation Benefit Area
CAA	Clean Air Act
CBD	Central Business District
CD	collector-distributor
CFR	Code of Federal Regulations
CPC	City of Portland Code
COP	City of Portland
CPU	Clark County Public Utilities
CRBG	Columbia River Basalt Group
CRC	Columbia River Crossing
CSZ	Subduction Zone
CTR	Commute Trip Reduction (Washington)
CU1	Confining Unit 1
CU2	Confining Unit 2
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
DEQ	Oregon Department of Environmental Quality
DGER	Division of Geology and Earth Resources
DOGAMI	Oregon Department of Geology and Mineral Industries
DOT	U.S. Department of Transportation
DSL	Oregon Department of State Lands
ECO	Employee Commute Options (Oregon)
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
F	Fahrenheit
FEE	Functional Evaluation Earthquake
FEIS	Final Environmental Impact Statement
FHWA	Federal Highway Administration

ft	feet/foot
FTA	Federal Transit Administration
g	Gravity units
GA	General Authorization
GDM	Geotechnical Design Manual
gpd/ft	gallons per day per foot
gpm	gallons per minute
GPTIA	groundwater pump and treat interim action
HRM	Highway Runoff Manual
I-5	Interstate 5
LPA	Locally Preferred Alternative
LRV	Light Rail Vehicles
M	magnitude
MCL	Maximum containment level
MDR	Methods and Data Report
mgd	million gallons per day
msl	mean sea level
NAVD88	North American Vertical Datum 1988
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OAR	Oregon Administrative Rule
ODOT	Oregon Department of Transportation
OHW	Ordinary high water line
ORS	Oregon Revised Statute
OTC	Oregon Transportation Commission
OWRD	Oregon Water Resources Department
PGA	Peak ground motion acceleration
PGIS	Pollutant Generating Impervious Surface
PHFZ	Portland Hills Fault Zone
POV	Port of Vancouver
Qal	Quaternary alluvial unit
Qfc	Coarse-grained facies
Qff	Fine-grained facies

ROD	Record of Decision
RTC	Regional Transportation Council
SDWA	Safe Drinking Water Act
SEE	Safety Evaluation Earthquake
SGA	Sand and Gravel Aquifer
SPUI	single-point urban interchange
SSA	Sole Source Aquifer
STHB	Stacked Transit Highway Bridge
SWPPP	Stormwater Pollution Prevention Plan
TDM	transportation demand management
TGA	Troutdale Gravel Aquifer
TriMet	Tri-County Metropolitan Transportation District
TSA	Troutdale Sandstone Aquifer
TSM	transportation system management
TSSA	Troutdale Sole Source Aquifer
USA	Unconsolidated Sedimentary Aquifer
USC	United States Code
USGS	U.S. Geological Survey
VMC	Vancouver Municipal Code
VOC	Volatile Organic Compounds
WAC	Washington Administrative Code
WS	Water Station
WSDOT	Washington State Department of Transportation
WTC	Washington Transportation Commission

This page intentionally left blank.

1. Summary

1.1 Introduction

This technical report identifies, describes and evaluates short-term and long-term effects from geologic hazards (steep slope areas, landslides, liquefaction, and earthquake hazard prone areas) to the Interstate 5 (I-5) Columbia River Crossing (CRC) project. Unchecked geologic hazards could adversely impact the project in terms of: construction worker and public safety, agency, and public relations; diminish the quality of natural resources; delay project schedule; and increase project cost. Identifying and mitigating geologic hazards will help prevent or reduce the effects of these potential impacts. This report also identifies potential effects to geologic and hydrogeologic resources that may result from construction and operation of the CRC project. The report provides mitigation measures for potential effects to these resources.

The purpose of this report is to satisfy applicable portions of the National Environmental Policy Act (NEPA) 42 United States Code (USC) 4321 "to promote efforts which will prevent or eliminate damage to the environment". Information and potential environmental consequences described in this technical report would be used to support the Final Environmental Impact Statement (FEIS) for the CRC project pursuant to 42 USC 4332.

The objectives of this report are to:

- Define the project study area and the main project area (Section 1)
- Describe the Locally Preferred Alternative (LPA) project elements and its proposed construction and operation activities (Section 1).
- Describe methods of data collection and evaluation (Section 2).
- Describe existing geologic and hydrogeologic conditions (Section 3).
- Discuss and compare potential effects to the LPA and the No-Build Alternative from geologic hazards; and potential impacts to geologic and groundwater resources from the LPA and the No-Build Alternative (Sections 4 and 5).
- Provide avoidance and mitigation measures to help prevent, eliminate or minimize environmental consequences from the LPA (Section 6).

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
#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 (DOT). 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 Proposed Construction Activities

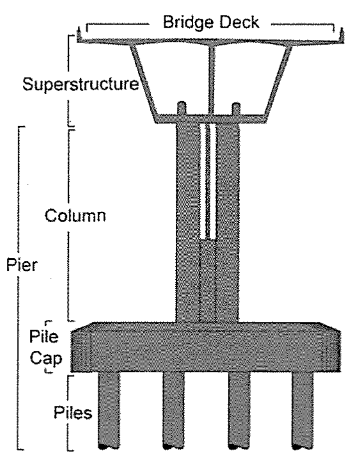
This section describes proposed construction techniques that would likely be used during the CRC project. The type, methods and specifications of these construction activities would be determined in PE preliminary engineering design reports and by the selected Contractors.

1.3.1 Columbia River Crossing (Main Line) Construction

Bridge construction would include the following components: piles or shafts, pile caps, column, superstructure and bridge deck (Exhibit 1-3). The building of the new bridges over the Columbia River requires multiple phases of work. The general sequence for construction is:

- Initial preparation – mobilize construction materials, heavy equipment and crews.
- Conduct soil stabilization to approaches for bridge structures. Stabilization techniques include the use of compaction grouting, jet grouting, or the use of stone columns.
- Installation of structure foundations – driven piles, drilled shafts and/or spread footings.
- Bridge piers – construct cap on top of drilled shafts; construct columns and pier tables. In-water piers would be constructed using barge and/or temporary work bridge support. Temporary work bridges would be constructed using driven piles.
- Bridge superstructure – build or install the horizontal structure of the bridge spans between the bridge support columns.
- Bridge deck – construct the bridge deck on top of the superstructure.

Exhibit 1-3. Basic Bridge Components



NOTE: The bridge type shown is for display purposes only.

1.3.1.1 Pier and Superstructure Construction

In-water foundations (shafts) would be required to support crossing piers. Columns would be constructed after the foundation caps are complete. Barges would be required for cranes, material, and work platforms. Tower cranes would likely be used to construct columns and support superstructure construction. Superstructure would be constructed of structural steel, cast-in-place concrete, or precast concrete.

1.3.1.2 Permanent Foundations

Permanent foundations would likely be anchored 30 feet or less into consolidated portions of the Troutdale Formation (up to 260 feet below ground surface [bgs] or/and elevation of -290 feet NAVD88). The quantity of permanent piles/shafts required is influenced by numerous factors, many of which are unknown at this stage of bridge design. Unknown factors include pile/shaft type, pile/shaft size, number of bridges, and bridge type. For the purposes of this report, foundations may be built using 120-inch-diameter drilled shafts. The Main Line Crossing is anticipated to have spans that range from 270 feet to 500 feet, resulting in 6 new in water piers complexes. The Transit Bridge and North Bound and South Bound Bridges over North Portland Harbor are anticipated to have 13 new in the water piers. No new piers complexes are anticipated for the Main Line Crossing in North Portland Harbor. These pier complexes would likely have seismic upgrades. Exhibit 1-4 summarizes permanent piles needed for construction of the new bridges over the Columbia River.

Exhibit 1-4. Estimated Number of Permanent Piles/Shafts Required for the Columbia River Bridge Multimodal Crossing

Description (From East to West)	Number of Permanent Piles/Shafts	Estimated Depth Below ground surface
I-5 Northbound Bridge	95 / 75	110 to 260 feet
I-5 Southbound Bridge with light rail	95 / 75	110 to 260 feet
Total Permanent Piles for the Columbia River Bridges	**190 / 150**	

1.3.1.3 Temporary Foundations

Temporary foundations would likely be required to support contractor operations. These operations include work and equipment barge moorings, and construction of temporary work bridges. Temporary piles are expected to range between 12- and 48-inches in diameter, with the majority of piles consisting of 24-inch to 48-inch-diameter piles. It is not known at this stage of engineering design how deep temporary piles would need to be driven. In general, temporary piles would extend only into the shallow soil. The quantity of temporary piles required is influenced by numerous factors, many of which are unknown at this stage of bridge design. Unknown factors include pile type, pile/shaft size, number of bridges, and bridge type, among others. Several extraction methods are being considered for temporary piles. Possible techniques include direct pull, vibratory extraction, and cutting the piles below the mud line.

1.3.1.4 Coffer Dams

Cofferdams may be used throughout the project to support installation of piers. Cofferdams would likely consist of sheet pile sections vibrated into place. Piles or drilled shafts would then be installed while water is still in the cofferdam. After pile or drilled shaft installation is complete, a concrete seal (false work) would be placed and the cofferdam would be dewatered. Cofferdams are not watertight and would need to be continuously pumped after dewatering, although the concrete seal would limit the need for this action.

1.3.2 Foundation and Structural Support for Interchanges, Bridge Overpasses, Transit, and Roadways

Interchanges, bridge overpasses, and portions of transit and roadways would be structurally supported by foundations and abutments. These structures would be in turn constructed using shallow footings, piles and shafts, and retaining walls. Subsurface conditions may also be modified by soil stabilization techniques such as jet grouting, compaction grouting, and/or stone columns.

1.3.2.1 Geotechnical Borings

Geotechnical boreholes would be used to characterize subsurface soil and water table conditions in areas where potential shafts, piles, footings, and/or retaining walls are needed support project construction. Geotechnical information is typically used to evaluate material strength and compressibility to help determine the type and specifications for structural support. Further information on geotechnical boring program is provided in the technical reports provided by Shannon & Wilson (2008) and Parsons Brinckerhoff (2009).

1.3.2.2 Shallow Footings

Shallow footings would be installed when appropriate for project elements such as bridge overpasses and light rail stations that do not require a high degree of structural support. Depending on location and structure type shallow footings may extend up to 15 feet below grade and may be composed of precast concrete forms. Where possible, the use of shallow footings is preferred versus piles to reduce cost. Shallow footings would likely be used for all park and ride structures and light rail stations.

1.3.2.3 Drilled Shaft and Driven Pile

Driven piles and drilled shafts would generally be used as foundation elements to anchor supporting bridge abutments, retaining walls, and bridge piers.[1] Drilled shafts would be used for in-water piers, with driven piles used to support construction equipment and activities for the Columbia River and North Portland Harbor bridges. A summary of estimated number and depths of piles and shafts for the interchanges and bridges is presented in Exhibit 1-5.

Some of the foundation options proposed for this project involve the driving of small- or large-diameter piles using an impact pile hammer. After the pile is driven, steel reinforcement and concrete may be placed inside the pile's annulus. The reinforcement is used to tie the pile to the structure it is supporting.

Some of the foundation options proposed for this project involve the drilling of small- or large-diameter shafts using an auger. Drilled shafts would require installation using either temporary or permanent casings to prevent sloughing and caving of soils. Casings would likely be installed using an oscillator, which rotates the casing back and forth, driving it downward, until it reaches the required tip elevation. Other potential methods of casing installation, such as rotator (rotates the pile as it is driven downward) or vibratory hammer, are also possible. Drilled shafts would likely be proofed using an impact hammer prior to final construction. Reinforcing steel is

[1] Spread footings may also be used for foundation structures instead of pile or shafts, when appropriate conditions exist. The use of spread footing would reduce the amount of subsurface disturbance, and reduce project costs.

installed in the annulus of the shaft and shaft concreted into placed. It is likely that steel casing would be left in place at in-water and deep shaft locations.

Foundation construction for the interchanges would require the transfer of vertical loads from weak near-surface soils to stronger material at depth. Exhibit 1-5 contains estimated pile and shaft depths using preliminary geotechnical recommendations for the bridge and interchange locations. All depths and elevations shown are subject to change.

Based on geotechnical boreholes completed within the study area, the deep foundations would likely extend into the Troutdale Formation. The Troutdale Formation is located between approximately 110- and 260-feet bgs for foundations over the Columbia River.[2] Foundations would likely be constructed to these depths for the Columbia River Crossing, and the SR 14, and Mill Plain interchanges. Shallower foundation depths within the USA would likely be used for the Marine Drive and SR 500 Interchanges.

Exhibit 1-5. Estimated Number and Depths of Piles/Shafts Required for Interchanges and Associated Bridge Overpasses

Bridges	Foundation Type[b]		Area of Structure (sq.ft. x 1,000)	Estimated Pile Tip Depth Below Existing Ground/ Mudline[c] (feet bgs)	Estimated Number of Piles	Approximate Depth to Groundwater[d] (feet bgs)	Occurrence of Excavations
	Shafts	Piles					
Victory to Marine Drive Bridges	X	X	430	125 to 160	140 to 240 shafts 1,000 to 2,000 piles	25	High
North Portland Harbor Bridge	X		460	130 to 160	90 to 130 shafts 900 to 1,500 piles	10	High
Hayden Island Bridge	X	X	310	180 to 260	220 to 310 shafts 1,900 to 2,500 piles	10	High
SR 14 Bridges[b]	X		530	120 to 130	170 to 210 shafts	10	High
Evergreen Bridge[b]	X	X	30	50 to 70	90 to 160 piles 10 to 30 shafts	90	Low
Mill Plain to 33rd Street Bridges[b]	X	X	180	80 to 90	130 to 240 shafts 440 to 740 piles	150	Moderate
SR 500 Interchange and 39th Street Bridges[b]	X	X	130	50 to 80	20 to 40 shafts 150 to 260 piles	150	Low

a Foundation data from Shannon & Wilson "Geotechnical Data Columbia River Crossing," March 5, 2008.

b Foundation data from WSDOT Geotechnical Division, "I-5, XL-2268, MP 0.0 to 3.0 Columbia River Crossing project Washington Landside Structures and Retaining Walls Conceptual Geotechnical Recommendations for Biological Assessment" Memorandum, November 5, 2008.

c Columbia River pile depths assume 30 feet embedment into the Troutdale Formation.

d Clark County water level contour map (Clark County 2005). Contours were created by computer model of data originating from various sources in the 1990s.

1.3.2.4 Retaining Walls

Retaining walls would be constructed to provide support for soil where vertical or near vertical grade changes are necessary to for bridge approach abutments and underpasses. Proposed

[2] Dependent on geotechnical conditions.

retaining walls would be constructed partially below the ground surface. Trenching and excavation activities are anticipated in the immediate vicinity of proposed wall locations.

1.3.2.5 Ground Stabilization

Subsurface soils would need to be stabilized or strengthened to support ground improvements such as bridge abutments at Hayden Island, Marine Drive and Victory Blvd, Tomahawk Island, and along river embankment areas of Hayden Island and North Portland Harbor, and upland areas such as Burnt Bridge Creek. Ground stabilization is necessary based on geotechnical information suggesting soil liquefaction and lateral displacement potential under a design earthquake (Shannon & Wilson 2008, Parsons Brinkerhoff 2009, FEI 2010). Estimated areas for stabilization are up to 600 feet from the shore line and 50 feet from the structure dripline or abutment. The depth of soil stabilization is estimated to occur at or above the ordinary high water (OHW) line (approximately 21.2 feet NAVD88) to a depth of up to 90 feet below ground surface. Soil stabilization and strengthening may be conducted using a variety of methods including, but not limited to, compaction grouting, jet grouting, and/or stone columns.

In addition the levee system along the southern embankment of the North Portland Harbor may be modified for construction of transit and roadway. Modification may require a portion of the levee to be removed and rebuilt as part of this effort.

1.3.3 Excavation, and Fill, and Dewatering

Cut and fill soil moving techniques would be used to support construction of transit and roadway. In general cut would be used to lower the grade of roadway and transit, where fill would be used to elevate roadway or track bed and/or increase the features load bearing capacity. Exhibit 1-6a through Exhibit 1-6c displays the location of proposed cut and fill.

Dewatering of excavations may occur for structures that extend below the water table. These structures include, but are not limited to tunnels and retaining walls (Exhibits 1-6a through 1-6c). Dewatering techniques may employ the use of sheet piles to limit groundwater flow into the excavation.

1.3.4 Limited Debris Removal

Some disturbance to in-water river sediments will occur from limited debris removal of riprap or concrete within North Portland Harbor. Removal is necessary for the installation of drilled shafts for new bridge foundations. Removal will likely occur using a clamshell bucket and barge support. The project estimates that it will take seven days to remove up to 90 cubic yards of material. Material will be characterized and disposed at an approved uplands facility.

1.3.5 Demolition Work

1.3.5.1 I-5 Bridges

Deconstruction and removal of the existing bridges superstructure, columns, pile caps, and the tops of piles within the navigation channels or above the mudline would be required. Demolition of the bridges would occur after the opening of the replacement bridges. The bridges would be demolished using a top-down approach, and may utilize barges.

1.3.5.2 Acquired Structures

A number of buildings and structures would be acquired and demolished to accommodate the project right-of way. Further information on these properties is provided in the Acquisitions Technical Report. Demolition materials from these structures would need to be managed, recycled and/or disposed of accordingly.

1.3.6 Permanent Stormwater Management and Treatment Facilities

Stormwater from newly constructed impervious surfaces is required to be managed and treated under applicable city, state and federal regulations. These include Vancouver Municipal Code (VMC), City of Portland Charter and Code (CPC), Washington State Pollution Control Act, State of Oregon Revised Statues - Chapter 486b, and Federal Clean Water Act (CWA) and Safe Drinking Water Act (SDWA) (Section 7).

Construction must comply with WSDOT and ODOT Stormwater National Pollutant Discharge Elimination Systems (NPDES) General Permit, and be consistent with the Highway Runoff Manual (HRM)(WSDOT 2010) and City of Portland Stormwater Management Manual (COP 2008). Federal, state, and local agencies with direct jurisdiction over aspects of stormwater management in the study area include EPA, Washington State Department of Ecology (Ecology), State of Oregon Department of Environmental Quality (DEQ), City of Portland, and the City of Vancouver.

Objectives for permanent stormwater management include:

- Provide source control to prevent pollutants entering into stormwater.
- Provide water quality treatment facilities for new or existing pollution-generating impervious surfaces (PGIS)[3] in accordance with the agency requirements PGIS include:
  - Highways and ramps, including non-vegetated shoulders.
  - Light rail guideway subject to vehicular traffic (referred to as a semi-exclusive guideway where the tracks are subject to cross-traffic or non-exclusive where vehicles such as buses can travel along the guideway).
  - Streets, alleys and driveways.
  - Bus layover facilities, surface parking lots and the top floor of parking structures.
- Provide flow control for new and replaced impervious areas in accordance with state and local requirements.

Conduct maintenance on water quality treatment facilities and flow controls to ensure they are performing as intended.

[3] PGIS are defined as surfaces that are considered a significant source of pollutants in stormwater runoff.

Exhibit 1-6a. Fourth Plain to SR 500 Project Element Locations

Columbia River CROSSING

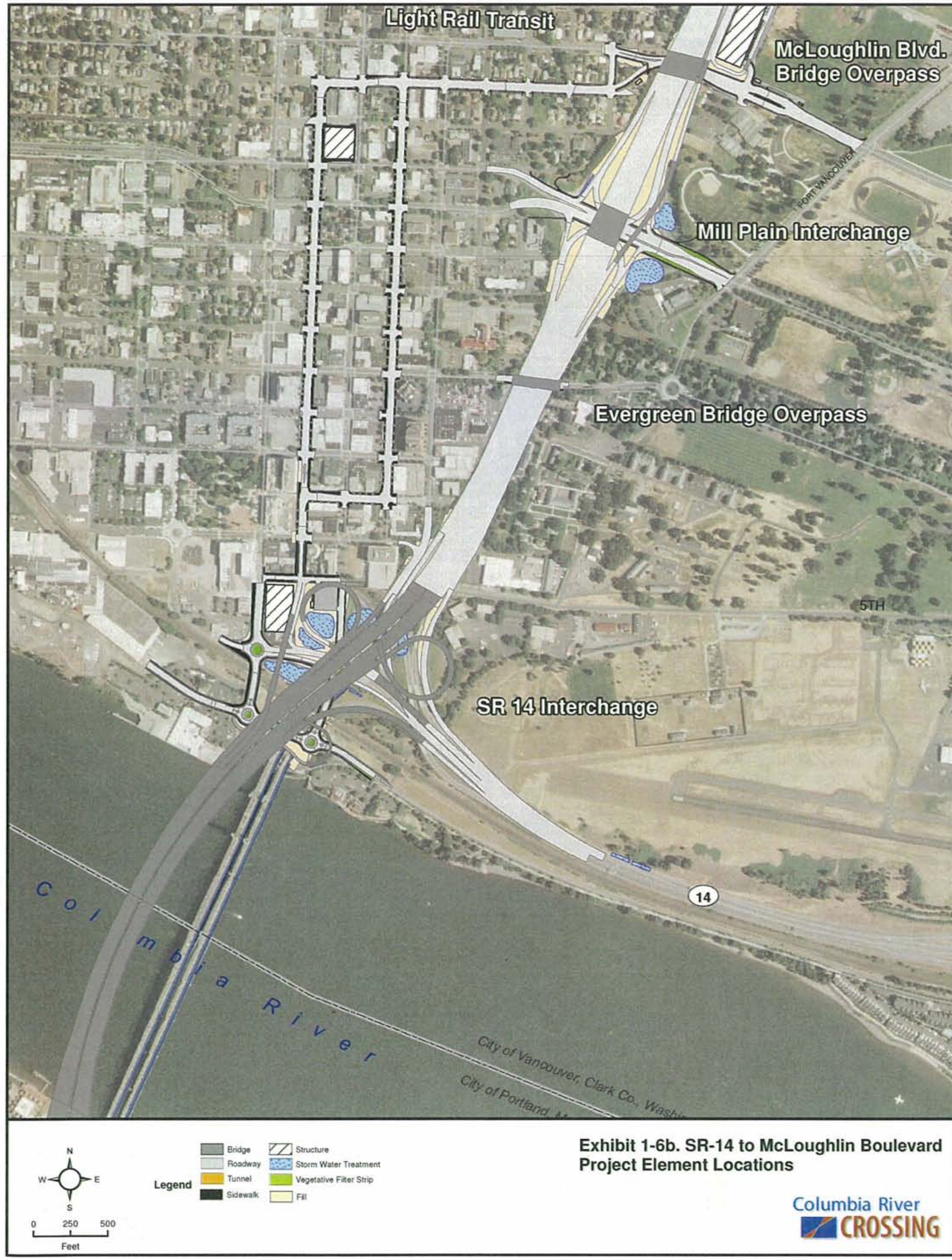


Exhibit 1-6b. SR-14 to McLoughlin Boulevard Project Element Locations

Columbia River CROSSING

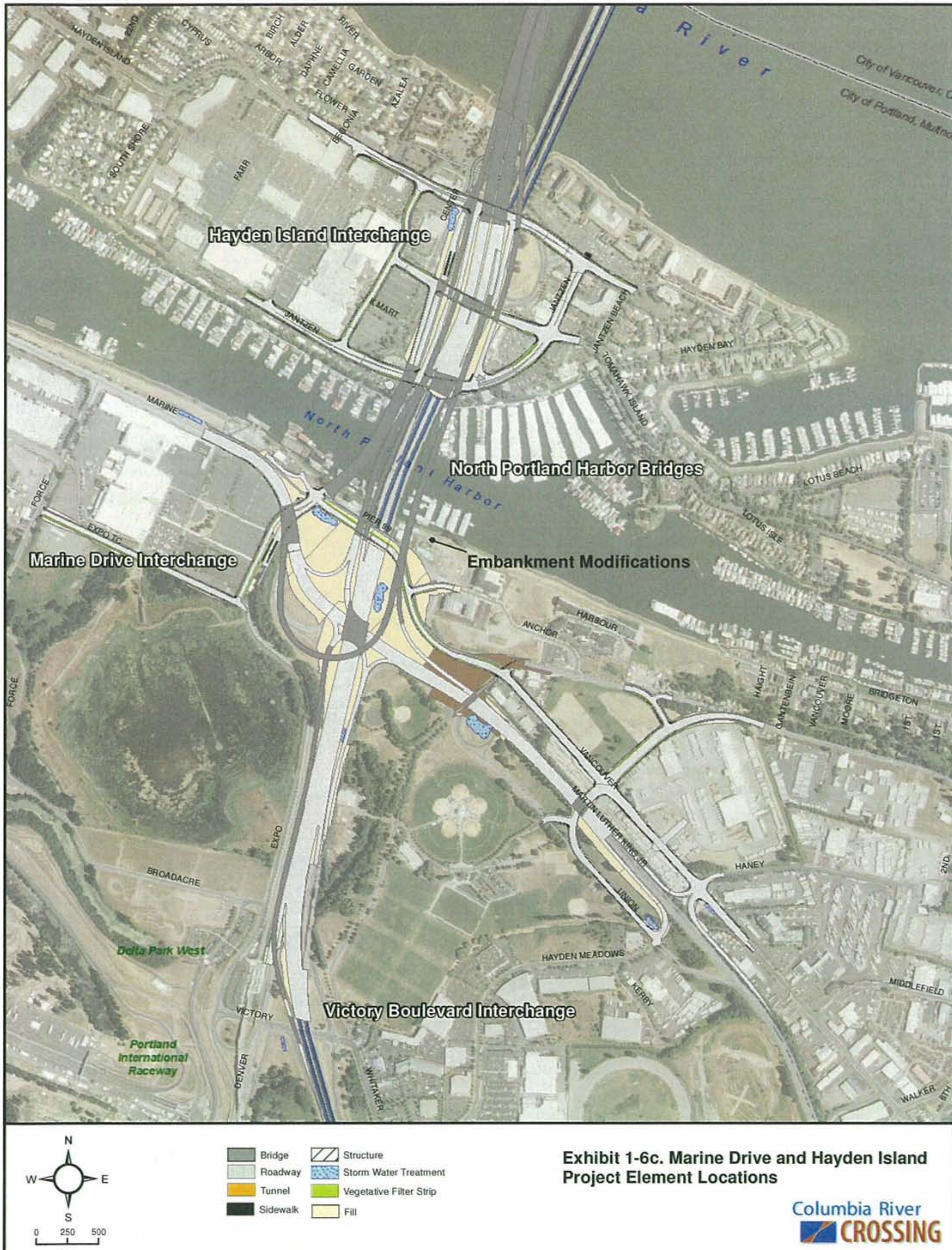


Exhibit 1-6c. Marine Drive and Hayden Island Project Element Locations

Exhibits 1-7a through 1-7c) displays the location of the proposed stormwater conveyance system and treatment facilities. The stormwater system would manage and treat water within the Columbia River and Burnt Bridge Creek Watersheds.

The proposed project would increase PGIS by approximately 50 acres, which may reduce natural infiltration rates and increase stormwater pollutants loads of suspended sediments, nutrients, polycyclic aromatic hydrocarbons (PAHs), oils and grease, antifreeze from leaks, cadmium and zinc from tire wear, and copper from wear and tear from brake pads, bearings, metal plating, and engine parts. However, the project would reduce untreated impervious surface acres from 325 acres to approximately 150 acres (change of 175 acres). Additional information on the proposed stormwater conveyance system and treatment facilities is provided in the Water Quality and Hydrology Technical Report.

1.4 Long-term Effects

Long-term effects are defined as future effects to the completed project from geologic hazards, or the effects from the completed project on geologic resources. Geologic hazards include earthquakes, landslides, steep slopes, and soil erosion. Geologic resources include rock and aggregate, and groundwater resources. For the purpose of this summary, these potential effects are placed in context with respect to the No-Build Alternative.

1.4.1 Geologic Hazards

1.4.1.1 Earthquakes

Compared to the No-Build Alternative, the LPA has significant long-term benefits from the effects of earthquakes. At least one mega-earthquake of up to magnitude (M) M9 is anticipated to occur in the Pacific Northwest in the next 50 to 300 years. Long-term benefits of the LPA include improved public safety, minimizing damage to infrastructure, and limiting economic disruption.

The LPA would replace the existing I-5 bridges and other identified project elements with new structures. Construction and design would utilize advancements in earthquake engineering and safety standards, and more up-to-date conceptual understanding of geologic conditions to meet projected site-specific ground motion disturbances. In contrast, the No-Build Alternative would retain the existing I-5 bridges and structures. Adverse effects from a mega-earthquake to the I-5 bridges are potentially significant because the existing bridges are approximately 53 and 94 years old and nearing their designed lifespans. In addition, state and federal seismic codes were not in place during the bridge design and construction.

The LPA would stabilize weak soils along the Columbia River, Hayden Island, around Marine Drive, and Burnt Bridge Creek that would be susceptible to liquefaction during a future seismic event(s). Soil would be stabilized using ground improvements such as soil mixing and stone columns. Existing soil stabilization issues would not be addressed by the No-Build Alternative. As such, significant adverse effects could occur from liquefaction under the No-Build Alternative.

1.4.1.2 Steep Slopes

Steep slopes are slopes that have grades greater than 25 percent, and have the potential to cause slope instability, soil erosion, and uncontrolled stormwater runoff. These adverse effects have the potential to damage infrastructure and diminish surface water quality.

Compared to the No-Build Alternative, the LPA may have some long-term benefits from the potential effects of landslides and steep slopes. No previous landslides have been identified in the project area, and the only steep slopes are within the Burnt Bridge Creek drainage area.

The LPA would stabilize steep slopes and reduce soil erosion in the Burnt Bridge Creek drainage area through grading slope angles, managing stormwater volume and flow, and vegetative planting. In contrast, the No-Build Alternative will not mitigate existing steep slopes, however it has not been determined that significant adverse effects from steep slopes will occur in the Burnt Bridge Creek area.

1.4.2 Resources

1.4.2.1 Geologic Resources

Compared to the No-Build Alternative, the LPA would have significant beneficial effects to geologic resources. The LPA would use top soil, fill, aggregate, and quarry rock from local permitted sites as building materials. Material needs for the LPA would result in expanding existing surface mine operations and/or opening new surface mines. This would likely result in long-term economic benefit to quarry operators and related services. However, mining operations could potentially cause environmental damage if not mitigated correctly. In contrast the No-Build Alternative would have limited economic benefit because only limited resources would be available for operation and maintenance.

1.4.2.2 Groundwater Resources

Compared to the No-Build Alternative the LPA would have significant beneficial effects to groundwater resources. Groundwater resources include the Troutdale Aquifer which is designated a sole source aquifer (SSA) by the U.S. Environmental Protection Agency and a critical aquifer recharge area by the City of Vancouver. The Troutdale Sole Source Aquifer (TSSA) provides the main source of drinking water to the City of Vancouver, and supplements the City of Portland's drinking water supply. Because the TSSA is accessible and productive, it is a significant and unique economic and natural resource. However, due to these attributes the TSSA is vulnerable to pollution and anthropogenic effects. Stormwater from roadways can contain pollutants such as metals, oil and grease, and microbes. Stormwater from these PGIS can infiltrate to the water table and diminish groundwater quality if not managed or treated correctly.

The LPA would provide long-term management and treatment of stormwater-generated from PGIS associated with roadways. The LPA would:

- reduce untreated impervious surface acres from 325 acres to approximately 150 acres (change of 175 acres);
- provide additional source control to help prevent pollutants from entering the stormwater system;
- improve the management of stormwater volume and flow rates; and
- increase and improve existing stormwater treatment facilities.

This would likely result in improved local groundwater quality for the TSSA and surface water quality for drainage areas around Columbia River and Burnt Bridge Creek. This is in sharp contrast to the No-Build Alternative where limited source control, management, and treatment facilities are in place for stormwater generated from PGIS.

1.5 Temporary Effects

Temporary effects are defined as short-term effects to resources that occur during construction of the LPA. For the purpose of this summary, these potential effects are placed in context with respect to the No-Build Alternative.

1.5.1 Geologic Hazards

1.5.1.1 Earthquakes

No temporary effects from earthquakes are expected to occur with the No-Build or the LPA alternatives. This is based on the assumption that a low probability exists that a significant seismic event would occur within the LPA construction window estimated to be 5 years.

1.5.1.2 Non-Seismic Settling

Compared to the No-Build Alternative, the LPA would have significant adverse effects from settling if not correctly mitigated. Soil settling and consolidation can occur throughout the project area where compressible soils or non-structural fill exists. Settling around structures occurs as the load equilibrates to soil conditions over time. Settling can result in a variety of adverse effects such as cracks in roadways and compromised foundations. The greatest potential for settling is thought to occur on Hayden Island and the shoreline of the Columbia River where construction fill has been used to extend shorelines and fill depressions. Retained fill or cut and cover fill may also not be suitable for construction and result in long-term adverse effects from settling.

The LPA would construct roadways and structures on compressible soils or fill. Effects from settling could be mitigated through proper geotechnical assessment, design and construction. In contrast, non-seismic settling around structures has already occurred for the No-Build Alternative.

1.5.1.3 Soil Erosion

Compared to the No-Build Alternative, the LPA would have some adverse effects to soil erosion if not correctly mitigated. Construction activities could expose erosive soils to wind and stormwater. Adverse effects from soil erosion include:

- plugging of stormwater catch basins;
- deposition of soil surface water on roadways;
- diminished surface water quality at the Columbia River, Vanport Wetland, and Burnt Bridge Creek; and
- potential to undermine existing roadway and structures.

The LPA would expose soils to erosion during construction from excavation, fill, clearing, and grading. It is estimated that the LPA will disturb approximately 415 acres of near surface soils[4].

---

[4]A summary of ground disturbance by watershed is as follows: Burnt Bridge Creek – 0.1 acre vegetated and 55 acres non-vegetated; Columbia River – 0.6 acre vegetated and 240 acres non-vegetated; Columbia Slough – 0.2 acre vegetated and 105 acres non-vegetated; Fairview Creek 1.3 acre vegetated and 10.5 acres non-vegetated.

Mitigation includes, but is not limited to, preparing and implementing stormwater pollution prevention plans and grading plans; hydroseeding; management of stockpile fill; and best management practices (BMPs). In contrast the No-Build Alternative would conduct relatively little soil-disturbing activities.

1.5.2 Resources

1.5.2.1 Geologic Resources

Compared to the No-Build Alternative, the LPA may have some short-term adverse effects on geologic resources. Geologic resources include top soil, fill, aggregate, and rock. Local geologic resources are not unique, but are limited in number and material types and volumes. Approximately 33 mine sites are within 10 miles of the project area.

The LPA may place a temporary strain on existing resources during construction until existing mines can expand or new mine sites can be located. In contrast, the No-Build Alternative will not place a strain on existing resources.

1.5.2.2 Groundwater Resources

Compared to the No-Build Alternative, the LPA has no distinct short-term effects on groundwater resources.

1.6 Proposed Mitigation

To prevent or minimize effects to geologic and groundwater resources, or the effects to structures and landforms from geologic hazards, the following potential mitigation and minimization measures were identified for the LPA.

1.6.1 Geologic Hazards

- Adequately assess existing geologic hazards such as, but not limited to, faults, ancestral landslides, steep cut slopes, and soil liquefaction during the preliminary engineering stage of the project. Site specific assessments should include the use of geotechnical drilling, test pitting, material testing, geophysical techniques and/or inclinometers and monitoring wells installation. Assessment would include recommended options for avoiding or mitigating geologic hazards.
- Adequately assess soil stabilization techniques to minimize soil liquefaction during the preliminary engineering stage of the project. Stabilization techniques include the use of soil mixing, compaction grouting, jet grouting, or the use of stone columns.
- Design and implement seismic upgrades to existing and future structures. Upgrades must adhere to applicable Federal, State and City building codes or standards, and utilize advancements in earthquake science and construction materials, and updates in the conceptual model. Structural designs would take into consideration stormwater infiltration or other changed conditions near shallow footings, retaining walls and/or other structures that could increase the potential for soil liquefaction during a future seismic event.

- Prepare and implement erosion control and stormwater pollution prevention plans and grading plans during construction. Plans would adhere to Oregon Department of Transportation (ODOT) and Washington State Department of Transportation (WSDOT) guidelines.
- Inspection and observation monitoring should be conducted throughout the project to ensure the appropriate measures are being conducted.

1.6.2 Geologic and Hydrogeologic Resources

- Recycle or reuse to the extent practical aggregate, quarry rock, asphalt and concrete materials.
- Evaluate local geologic resources for future material needs.
- Prepare and implement stormwater discharge permits for construction.
- Stormwater treatment facilities would be located to the extent possible away from City of Vancouver well head protection zones for Water Station 1 and Water Station 3.

Exhibit 1-7a. Fourth Plain to SR 500 Stormwater Systems

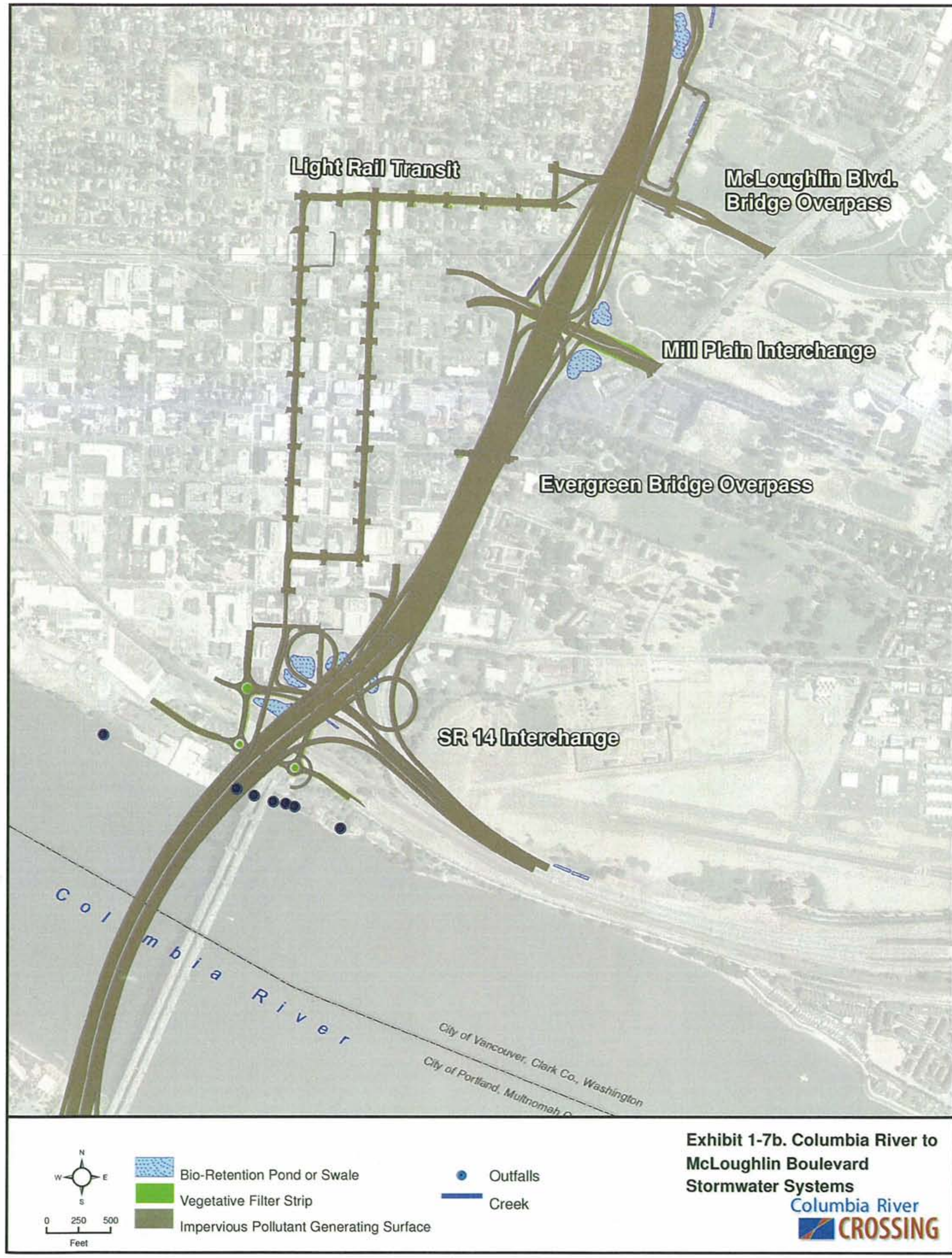


Exhibit 1-7b. Columbia River to McLoughlin Boulevard Stormwater Systems

PRELIMINARY

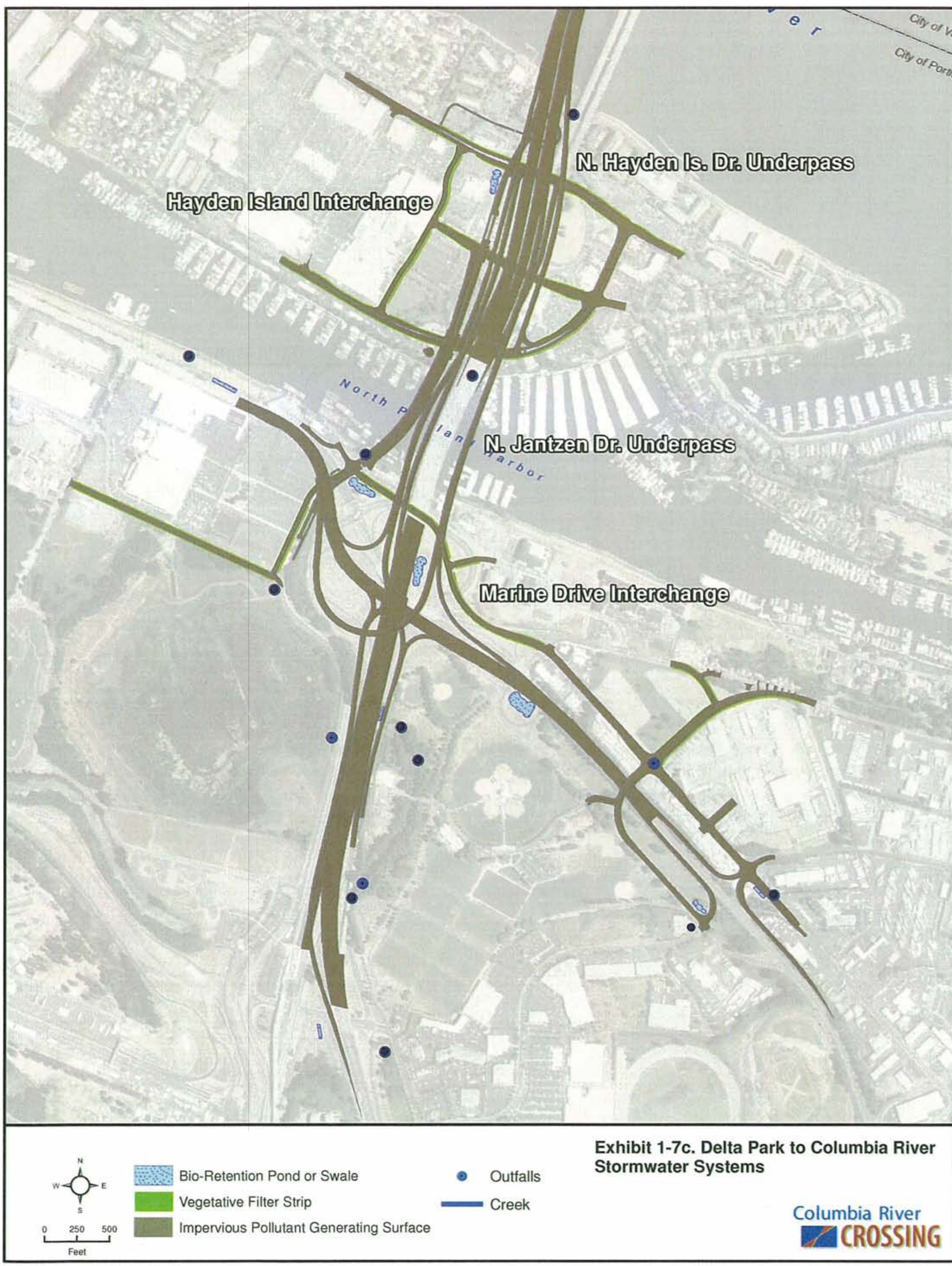


Exhibit 1-7c. Delta Park to Columbia River Stormwater Systems

Columbia River CROSSING

2. Methods

This section describes the methods in which data is collected and evaluated.

2.1 Study Area

The study area considers regional geology of northwest Oregon and southwest Washington with a focus on local soil, geologic, and hydrogeologic conditions within the main project area (Exhibit 2-1).

The main project area defines the area most likely to have direct impacts from construction and operation of the CRC project. The main project area is based on the designs of the alternatives evaluated in the CRC DEIS and additional alternatives proposed in this report. This area extends five miles from north to south between the I-5/Main Street interchange in Vancouver and the I-5 Victory Boulevard interchange and Martin Luther King Boulevard near NE Union in North Portland. North of the river, the main project area extends west into downtown Vancouver, and east near Clark College to include potential transit alignments and park and ride locations.

2.2 Data Collection Methods

Data sources and data collection methodologies presented in this technical report are consistent with those described in the Methods and Data Report (MDR) for geology and soils (Parametrix, 2007). The data used in the analysis were obtained on a regional basis due to the geographic extent of the geologic environment.

Existing maps and technical reports published by the: United States Geological Survey (USGS); Oregon Department of Geology and Mineral Industries (DOGAMI); Washington State Department of Natural Resources Division of Geology and Earth Resources (DGER); ODOT; WSDOT; and the NRCS were reviewed for the basis of the geologic, hydrogeologic, geologic hazard, and soils information.

In addition, site-specific geotechnical information has been gathered to characterize subsurface conditions and support preliminary foundation design, type, size and locations (Shannon & Wilson 2008 and 2009, Parsons Brinckerhoff 2009, FEI 2010, WSDOT 2010). Applicable and appropriate information from these reports is presented in Section 4.

Information on water rights for the vicinity of the LPA was obtained from the Oregon Water Resources Department (OWRD), Ecology, and the USGS. The water right information consists of extracted water use for domestic, industrial, or agricultural purposes including extraction locations and water right ownership.

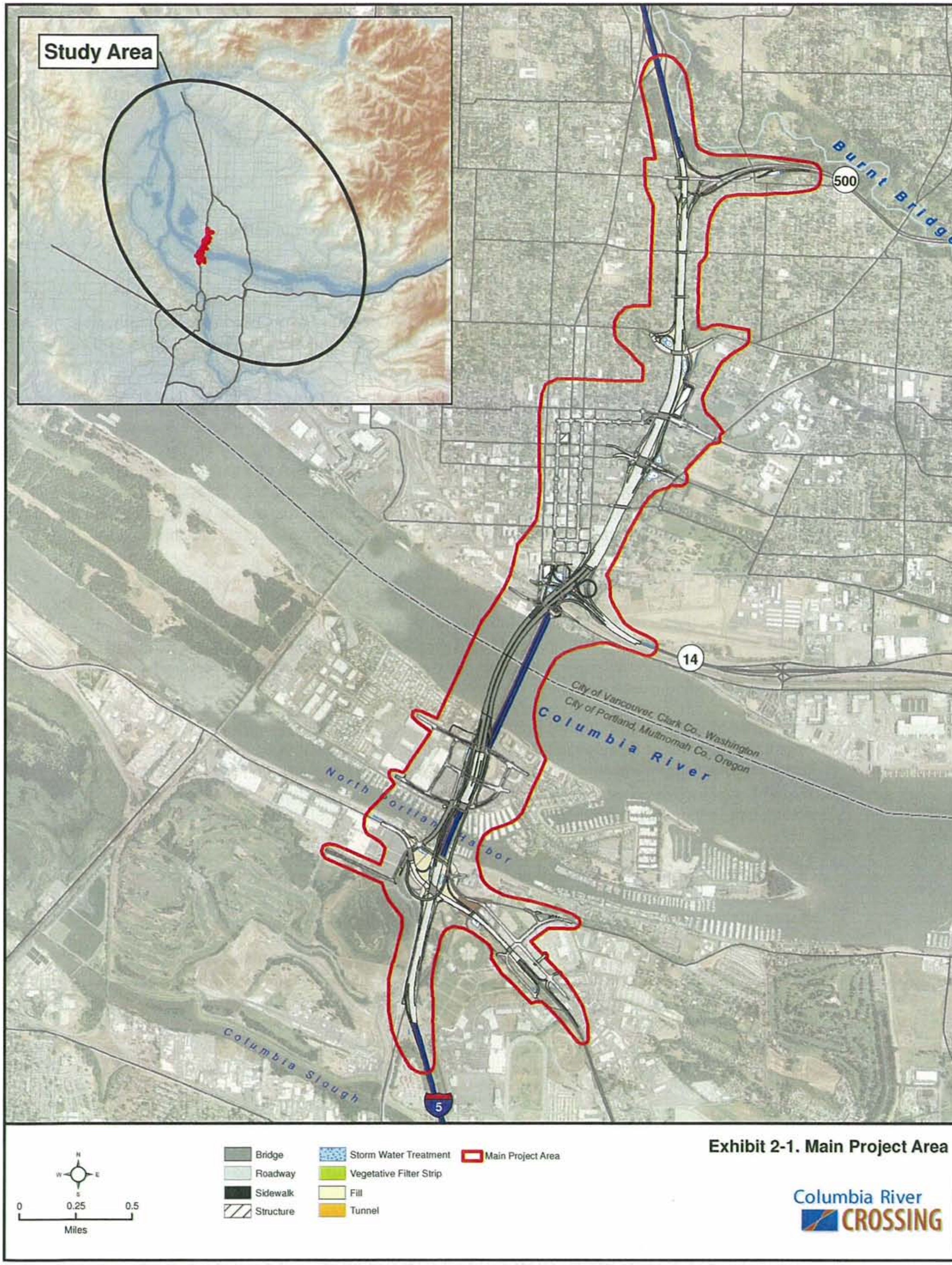


Exhibit 2-1. Main Project Area

2.3 Effects Guidelines

Applicable state and federal guidelines were used to determine direct effects from geologic hazards. These include:

- WSDOT Environmental Procedures Manual Chapter 420: Earth, Geology and Soils, Version M 31-11.03, June 2008; and
- ODOT NEPA Guidance by Discipline, Volume II, Geology / Geotechnical, November 22, 2006.

2.4 Data Analysis Methods for Temporary and Long-term Effects

Long-term and short-term effects were assessed qualitatively by comparing available information on existing geologic hazards and hydrogeologic conditions to available information on construction and operation of the CRC project. Short-term effects were assessed in terms of how construction activities may be affected by existing geologic hazards such as steep slopes, soil stability issues; or how geologic resources such as aggregate mines or soil erosion may be affected by project construction. Long-term effects were assessed on how project operations may be affected by geologic hazards such as earthquakes; or how hydrologic resources such as groundwater flow and quality may be affected by project operations.

Potential cumulative effects from this project are evaluated in the Cumulative Effects Technical Report. Please refer to this report for an evaluation of possible cumulative effects.

2.5 Mitigation Measures Approach

The approach for potential long-term and short-term mitigation and minimization measures include avoidance of geologic hazards such as landslides, steep slopes, and soils that have a potential for liquefaction; and measures to limit soil erosion and degradation of groundwater resources through management and treatment of stormwater runoff and infiltration.

Long-term and short-term effects to the project from existing geologic conditions will be mitigated in part through focused subsurface investigations, which help to evaluate geologic hazards in the proposed construction areas and by designing components of the built structures to reduce the impacts of these effects. These investigations will be conducted in accordance with generally accepted industry practice and will collect information to establish the design criteria for built structures. A separate geotechnical report(s) will be prepared as part of mitigation measures during the engineering design. The geotechnical report will quantitatively assess liquefaction, settlement, slope stability, and other geologic hazards.

2.6 Coordination

Project communication and coordination was conducted with Tova Peltz from ODOT and William Hegge from WSDOT during preparation, review and approval the Geology and Groundwater Discipline Report.

This page intentionally left blank.

3. Affected Environment

This section presents the existing geologic and hydrogeologic conditions within the I-5 CRC project area.

3.1 Climate

The CRC project area is located in a temperate climate where summers are generally warm and dry, with average highs in July of approximately 81° Fahrenheit (F) (27° Celsius [C]) and lows of 58°F (14°C). Winter temperatures can be mild to cold, and very moist, with average highs in January of 46°F (8°C) and lows of 37°F (3°C). Precipitation averages 37.5 inches per year.

3.2 Geologic Setting

Oregon and Washington are located on the North American continent crustal plate near a convergent plate boundary with the Juan de Fuca oceanic crustal plate. The Cascadia Subduction Zone (CSZ) convergent boundary is located approximately 70 miles off the coast of Oregon and Washington. The oblique convergence of the North American Plate with the Juan de Fuca Plate has created northwest-trending fault zones and crustal blocks (Baldwin 1976). The major structural features in the region are shown in Exhibit 3-1.

The project area is located in the northern Willamette Valley, within the Portland basin. The Portland basin, a north-west trending structural basin, encompasses approximately 1,310 square miles, and is characterized by relatively low topographic relief with areas of buttes and valleys containing steep slopes (McFarland and Morgan 1996). The basin is bordered to the east by the foothills of the Cascade Mountains, to the west by the Tualatin Mountains, to the south by the Clackamas River, and to the north by the Lewis River. Exhibit 3-2 shows the topographic relief and major drainages for the Portland Basin.

The Portland Basin was formed by the folding and faulting of Eocene to Miocene basement rock due to the regional tectonic compressional regime (described below), contributing to the formation of the Tualatin Mountains west of the project area as well as the Portland basin and Cascade Mountains east of the project area. Sedimentary deposits have filled the topographic depressions created by crustal down-warping of the basin. Sedimentary deposits in the basin generally consist of conglomerate, gravel, sand, silt, and some clay from volcanic, fluvial, and lacustrine material (Pratt et al. 2001). Late Pleistocene catastrophic flood deposits cover much of the surface within the project area (Waitt 1985; Madin 1994 Phillips 1987). Deposits originating from an ancestral Columbia River underlie the catastrophic flood deposits. These sedimentary deposits overlie Miocene basalt flows of the Columbia River Basalt Group (Swanson et al. 1993). The Columbia River Basalt Group (CRBG) overlies lava flows and volcanic breccias of Oligocene age (Schlicker and Finlayson 1979).

3.3 Geologic Units

Geologic units that are present within the study area are described below by increasing age. Several subsurface investigations have been conducted for the project to evaluate the subsurface conditions and provide recommendations to support the Type, Size, and Location (TS&L) level of project design (Shannon & Wilson 2008; Parsons Brinckerhoff 2009; WSDOT 2008).

Geologic units in the project area are shown on Exhibit 3-3. Exhibit 3-4 displays the lithologic contacts based on analysis of borings completed for the project.

3.3.1 Artificial Fill (Qaf)

Artificial fill material was used to modify existing topographic relief and typically consists of sand and silt, with some gravel and debris and local areas of sawdust and mill ends. Fill areas mapped with inferred contacts represent lakes and marshes that may have been drained rather than filled. Fill material ranges in thickness up to 45 feet in Oregon and 25 feet in Washington and is common in developed areas of the Willamette River and Columbia River floodplains. However, thickness and distribution are highly variable (Beeson et al. 1991).

3.3.2 Alluvium (Qal)

Alluvial deposits, Holocene in age, include material derived from present day streams and rivers, their floodplains, and abandoned channels. The alluvial deposits are typically Holocene to upper Pleistocene in age. Alluvial material consists of unconsolidated gravel, medium to fine sand, silt, and organic-rich clay. Cobble-sized material may be present within existing or abandoned stream channels. Thickness is typically less than 45 feet, but may be up to 150 feet thick locally. Within the project area, alluvium is exposed at the surface from just south of the Columbia Slough in Oregon to approximately 1/4 mile north of the Columbia River in Washington (Beeson et al. 1991; Phillips 1987).

3.3.3 Catastrophic Flood Deposits (Qff/Qfc)

The catastrophic flood deposits resulting from the Pleistocene-aged Missoula Floods described by Bretz et al. (1956) are derived from the repeated failure of ice dams located on the Clark Fork River in northwestern Montana. Glacial Lake Missoula was created by ice dams from the advancing front of the Purcell Trench lobe of the Cordilleran ice sheet. The floods released approximately 500 cubic miles of water, flooding portions of eastern Washington, the Columbia Gorge, and the northern Willamette Valley (Bretz et al. 1956; Allen, Burns, and Sargent 1986; Allen, Burns, and Burns 2009). The flooding occurred at least 40 times during the Pleistocene (16,000 to 12,000 years ago), depositing boulders, cobbles, gravel, sand, and silt (Waitt 1985). The flood waters would be impounded by a valley constriction south of Kelso and backup to elevations as much as +350 feet mean sea level (msl). As flood water velocities were reduced, sediment loads were deposited in foreset bedded gravel and sand similar to delta deposition (Robinson, Noble, and Carr 1980). This deposit is subdivided into two facies by Madin (1994) and Phillips (1987): a fine-grained facies (Qff) and coarse-grained facies (Qfc). Both are present in the project area. The finer sediments consist of primarily coarse sand to silt. The coarser sediments consist of pebble to boulder gravel with a coarse sand to silt matrix. Coarse sediments are subangular to well-rounded and are poorly sorted. The unit is exposed at the surface, beginning south of Lombard Street and extending to the southern limit of the secondary main project area in Oregon. In Washington, the coarse-grained facies begins north of SR 14 and extends to Burnt Bridge Creek.

3.3.4 Troutdale Formation (Tt)

The Troutdale Formation (Miocene to Pliocene in age) underlies the catastrophic flood deposits and consists of coarse- to fine-grained fluvial sedimentary rock derived from the ancestral Columbia River (Trimble 1963). The unit is a friable to moderately strong conglomerate with minor sandstone, siltstone, and mudstone. Pebbles and cobbles are composed of Columbia River Basalt (described below), exotic volcanic, metamorphic, and plutonic rocks. The matrix and interbeds are composed of feldspathic, quartzo-micaceous, and volcanic lithic and vitric sediments. The formation exhibits cementation mantling on some of the grains. Thickness of the

Troutdale Formation typically ranges between 200 and 300 feet in the study area (Beeson et al. 1991).

3.3.5 Miocene and Older Rocks

The Columbia River Basalt Group (CRBG) (late Miocene and early Pliocene in age) consists of numerous basaltic lava flows which cover approximately 63,000 square miles and extend to thicknesses greater than 6,000 feet. The CRBG is composed of dark gray to black, dense, crystalline basalt and minor interbedded pyroclastic material. Beneath the CRBG are upper Eocene to lower Miocene volcanic and marine sedimentary rocks. The volcanic rocks typically consist of altered basalt, basaltic andesite, and pyroclastic rocks. The marine sedimentary rocks typically consist of fossiliferous tuffaceous shale and sandstone with minor conglomerate lenses (Madin 1994).

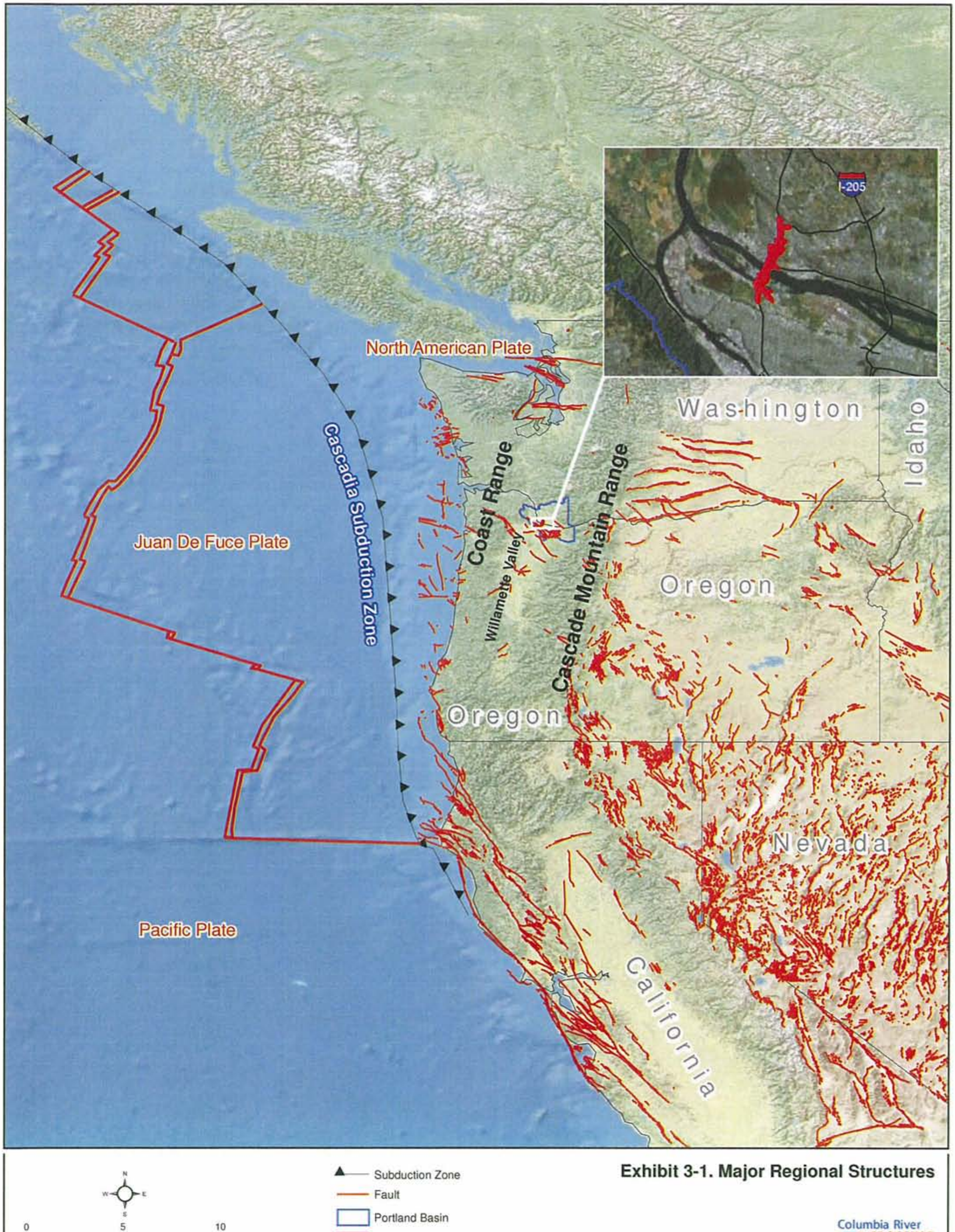


Exhibit 3-1. Major Regional Structures

Columbia River CROSSING

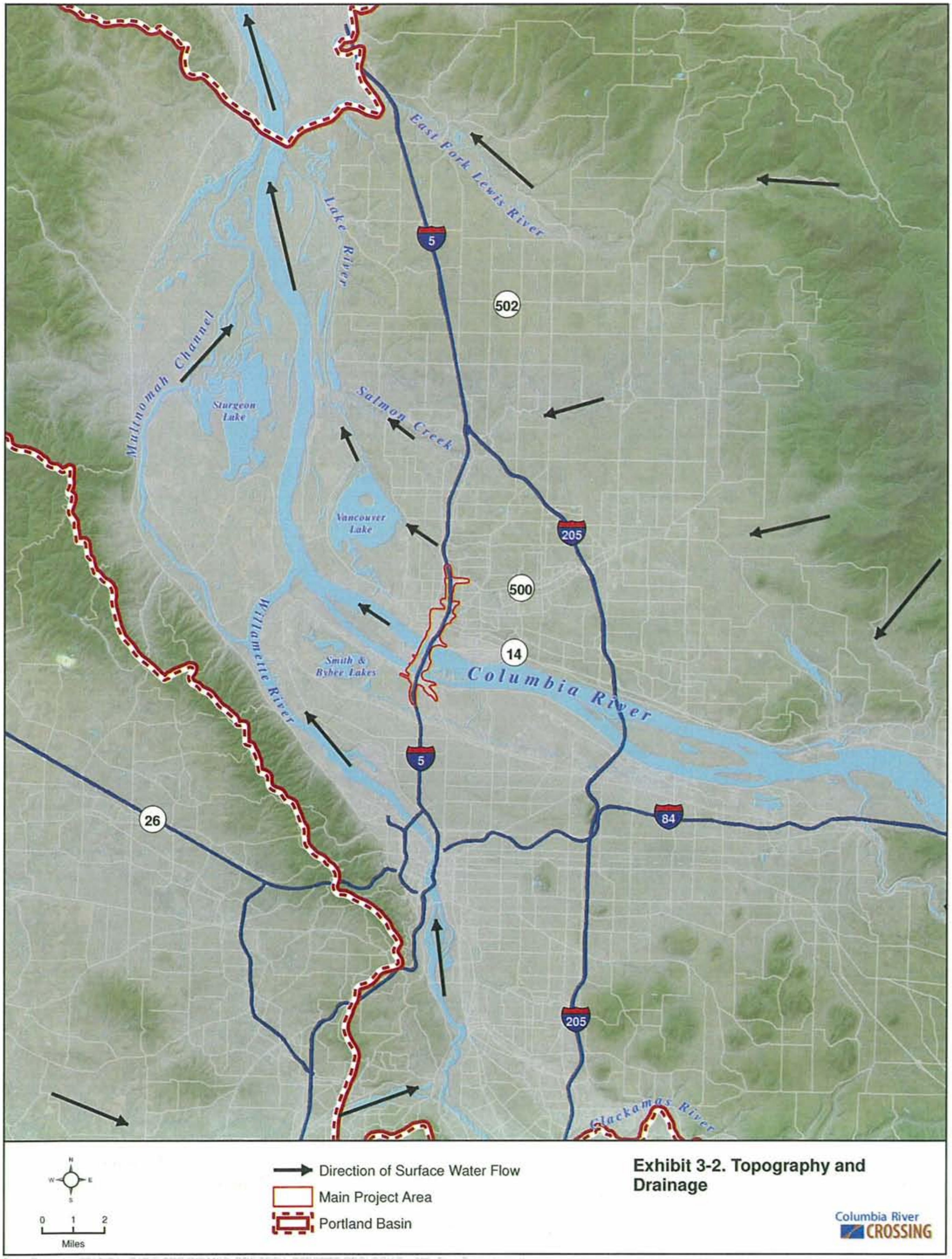


Exhibit 3-2. Topography and Drainage

Columbia River CROSSING

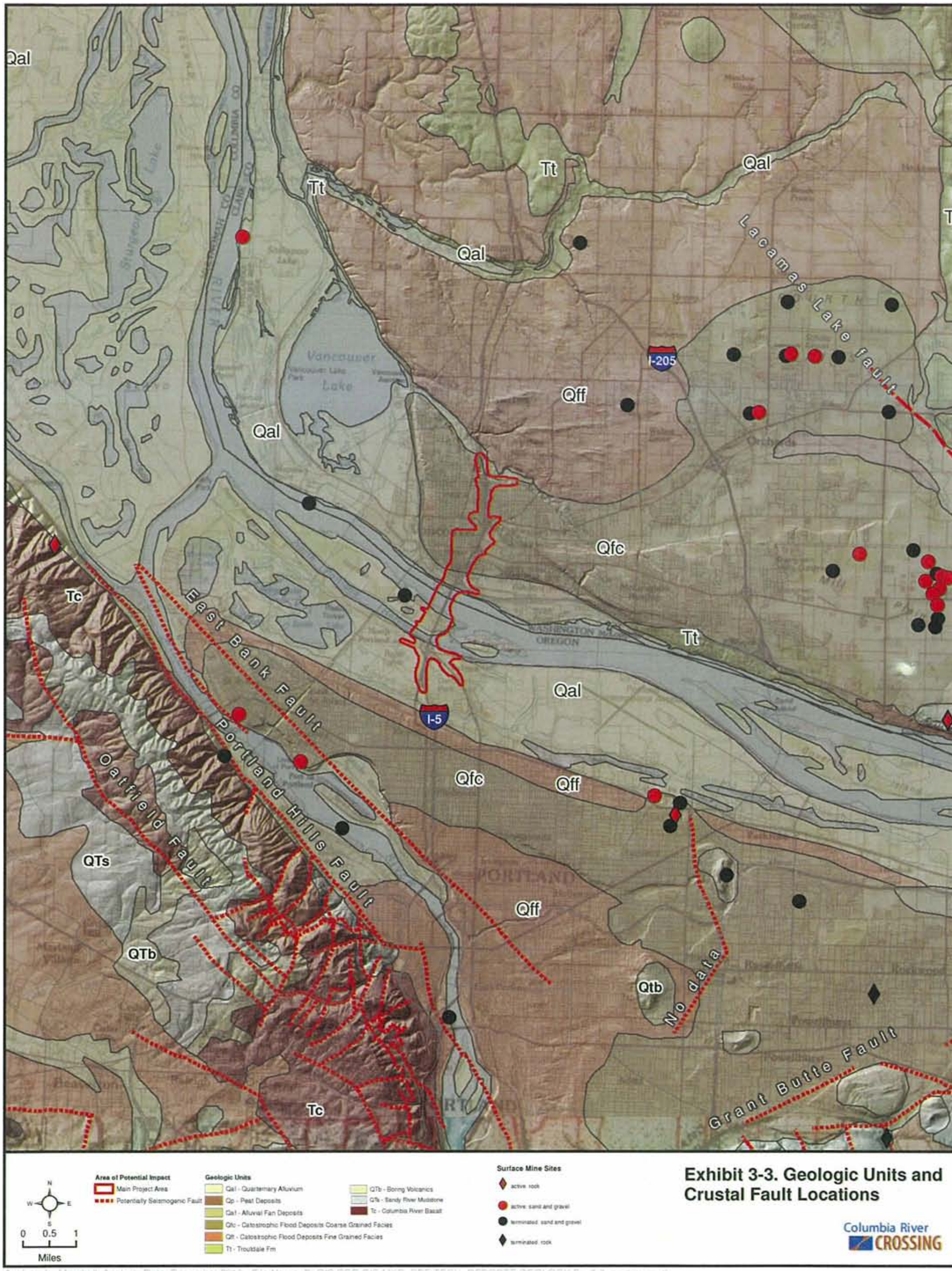


Exhibit 3-3. Geologic Units and Crustal Fault Locations

Analysis by Marshall; Analysis Date: December 2010; File Name: P:\GIS\CRC\GIS\MXD\PDF\TECH_REPORTS\GEOLOGY\Ex_3-3_geology.mxd

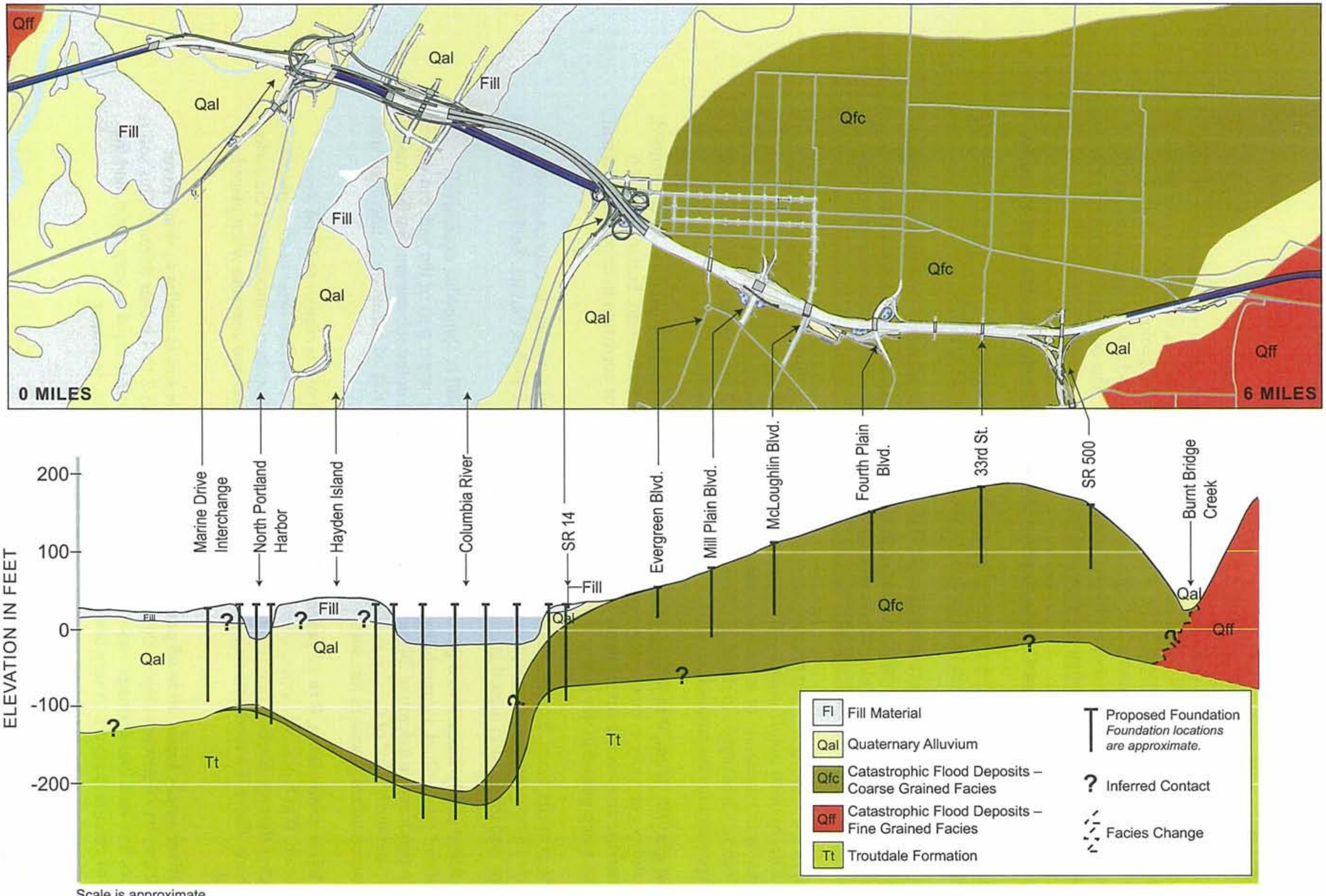


Exhibit 3-4. Generalized Schematic Subsurface Profile

Columbia River CROSSING

3.4 Soil

Soil is a general term used to describe the unconsolidated layers of mineral and organic matter that covers most of the earth's land surface. The soil in the project area is formed by the physical and chemical weathering or breakdown of the upper portion of the geologic unit parent material described in Section 4.3 by interaction with the climate, micro- and macro-organisms, and the characteristics of the parent material (Singer and Munns 1999). The soil types identified at the ground surface in the project area are shown in Exhibit 3-5.

3.4.1 Natural Resources Conservation Service - Clark County Soil Survey

Based on the Natural Resources Conservation Service (NRCS) information for Clark County, the following soils types have been identified in the project area (McGee 1972).

Hillsboro silt loam, 0 to 3 percent slopes (HiA) - This soil is moderately well-drained, surface runoff is very slow, and the hazard of erosion is none to slight. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil. The shrink-swell potential characteristics require extra design precautions for structures.

Hillsboro silt loam, 3 to 8 percent slopes (HoB) - This soil is well-drained and moderately permeable. Surface runoff is slow and the erosion hazard is slight but may erode easily if not protected with vegetation or mechanical means. There is a high risk of corrosion to uncoated steel and concrete when placed in this soil. The shrink-swell potential characteristics require extra design precautions for structures.

Lauren gravelly loam, 0 to 8 percent slopes (LgB) - This soil is somewhat excessively drained. Permeability generally is moderately rapid, but it is rapid in the substratum. Surface runoff is slow, and the erosion hazard is slight. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil.

Lauren gravelly loam, 8 to 20 percent slopes (LgD) - This soil is similar to Lauren gravelly loam, 0 to 8 percent slopes, except that the surface layer is 1 to 2 inches thinner. Surface runoff is medium, and the erosion hazard is moderate.

Wind River sandy loam, 0 to 8 percent slopes (WnB) - This soil is somewhat excessively drained and easily tilled. Permeability is moderately rapid in the upper part of the soil, but water tends to perch above a depth of 24 inches. Permeability is rapid in the substratum. Surface runoff is slow, and the hazard of erosion is slight. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil.

Wind River sandy loam, 8 to 20 percent slopes (WnD) - This soil is similar to Wind River sandy loam, 0 to 8 percent slopes, except that it is steeper and the surface layer in most places is 1 to 2 inches thinner. Surface runoff is medium, and the hazard of erosion is moderate if the surface is left bare. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil.

Wind River sandy loam, 30 to 65 percent slopes (WnG) - This soil is similar to Wind River sandy loam, 0 to 8 percent slopes, except that the surface layer is 2 to 4 inches thinner. This soil is on slopes that lead into drainage ways and streams. Surface runoff is rapid to very rapid, and the hazard of erosion is severe to very severe if the surface is left bare in winter.

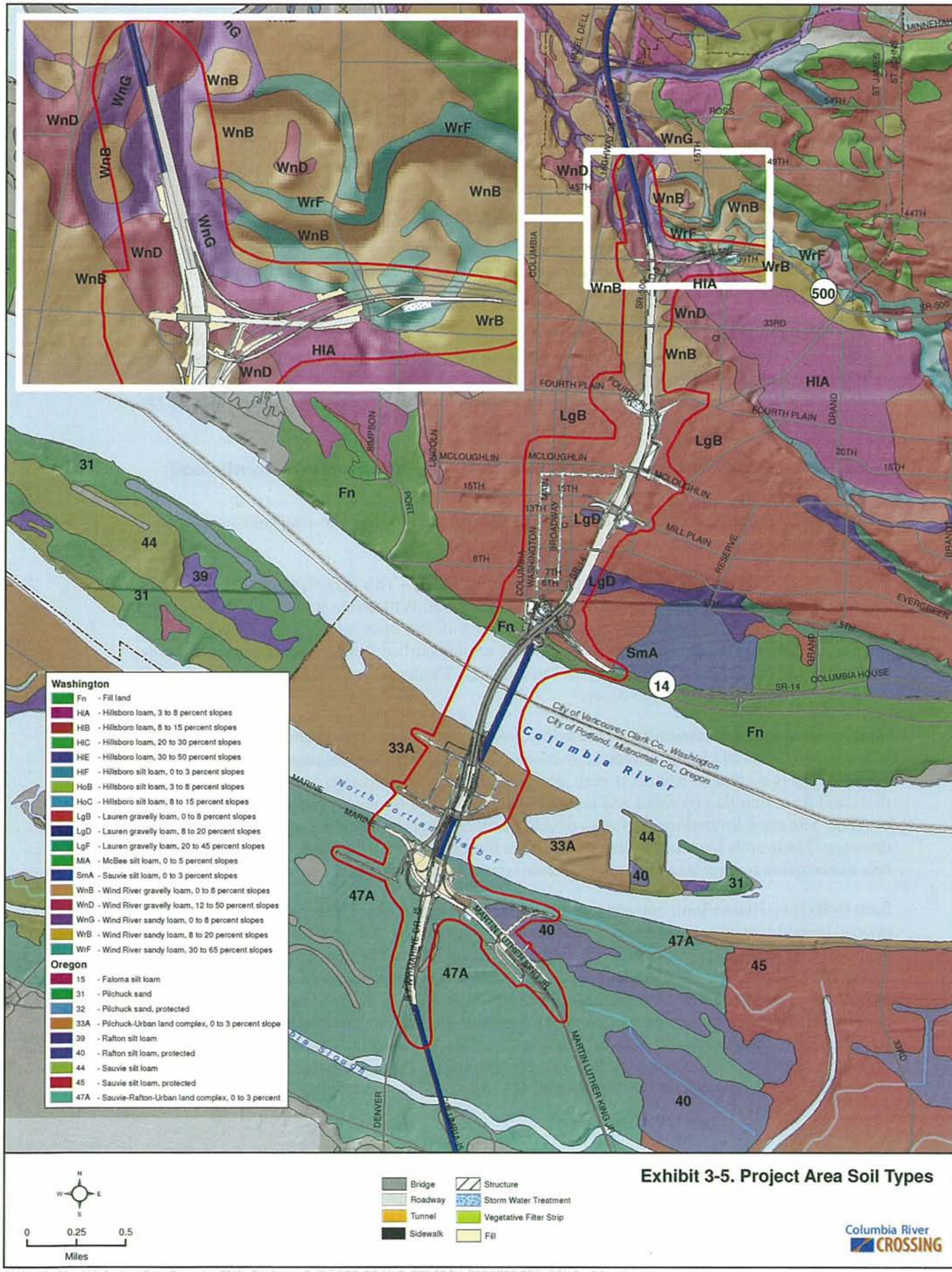


Exhibit 3-5. Project Area Soil Types

Wind River gravelly loam, 0 to 8 percent slopes (WrB) - This is the dominant soil in the area between Vancouver and Orchards. In most places the slope is nearly level and is generally less than 3 percent. It is similar to Wind River sandy loam, 0 to 8 percent slopes, except for the texture of the surface layer. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil.

Wind River gravelly loam, 12 to 50 percent slopes (WrF) - This soil is similar to Wind River sandy loam, 0 to 8 percent slopes, except that 15 to 50 percent of it is gravel, and the surface layer is generally 1 to 2 inches thinner. Surface runoff is medium to very rapid, and the hazard of erosion is moderate to very severe.

Sauvie silt loam, 0 to 3 percent slopes (SmA) - This soil is moderately well-drained, surface runoff is very slow and erosion hazard is slight but erodes easily if not protected with vegetation or mechanical means. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil. The shrink-swell potential characteristics require extra design precautions for structures.

3.4.2 Natural Resources Conservation Service - Multnomah County Soil Survey

Based on the information in the Multnomah County Soil Survey the following soils have been identified in the project area (Green 1983).

Pilchuck-Urban land complex, 0 to 3 percent slopes (33A) - This complex consists of excessively drained soil on floodplains of the Columbia and Willamette Rivers. This soil formed in sandy alluvium or sandy dredge spoils. In most areas of this complex the soils have been graded, cut, filled, or otherwise disturbed. In areas of undisturbed Pilchuck soils, permeability is very rapid and available water capacity is 3 to 6 inches. The hazard of soil blowing is moderate in areas not protected by vegetative cover.

Rafton silt loam, protected (40) - This hydric soil is very poorly drained and is on broad flood plains of the Columbia River. It formed in recent alluvium with some mixing of volcanic ash. Permeability is moderate. Runoff is very slow, and the hazard of erosion is slight. The soils are protected from flooding by dikes and levees but are subject to frequent ponding from December to April. The main limitations for urban development are frequent ponding and very poor drainage. These soils have been identified to have hydric soil characteristics. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil.

Sauvie-Rafton-Urban land complex, 0 to 3 percent slopes (47A) - This hydric soil consists of poorly drained Sauvie soils and very poorly drained Rafton soils. Large areas of these soils have been filled, graded, cut, or otherwise disturbed. These soils have been covered by as much as 10 feet of fill material. The fill material is generally transported and consists of soil material, as well as concrete, asphalt, and other impervious materials. Permeability is moderately slow in the Sauvie soil. Runoff is slow, and the hazard of erosion is slight. The main limitations of these soils for urban development are the seasonal high water table and moderately slow permeability. These soils have been identified to have hydric soil characteristics. There is a moderate risk of corrosion to uncoated steel and concrete when placed in this soil.

3.4.3 Potential Construction Issues due to Soil

The NRCS (2004) has identified 26 different types of soil hazards that typically impact construction projects because they affect the design, installation, and maintenance of many built structures. The following soil types have been identified in the main project area. The location of these soils are presented on Exhibit 3-5. A summary of these characteristics is presented in Exhibit 3-6.

Hydric soils or wet soils are described as having a groundwater table or perched water that occurs within 1.5 feet of the ground surface. This condition likely occurs during the wetter months of the year. The high water table creates areas of standing water and can fill excavation sites with water. These soils are mapped throughout much of the project area. Hydric soils in Oregon occur from the Columbia River south to the southern bank of the Columbia Slough in the Rafton silt loam and the Sauvie-Rafton-Urban land complex. In Washington, hydric soils have not been identified within the main project area.

Erosion is the detachment and movement of soil particles, primarily by water, down slope. Soils can contain fine-grained material that may be low in density, rendering them more susceptible to erosion when exposed to high velocity flow of water, severe wind conditions, or intense precipitation events. These soil units generally consist of permeable, low-density soils such as young alluvium and other surficial deposits that occur within the project area. Section 20.740.130 Geologic Hazard Areas requires the identification of erosion hazards areas. The Lauren gravelly loam, 8 to 20 percent slopes Wind River sandy loam, 8 to 20 percent slopes, Wind River sandy loam, 30 to 65 percent slopes Wind River gravelly loam, 12 to 50 percent slopes have been identified in the main project area to have moderate to severe erosion hazard.

Shrink-Swell Soils are clay rich soils that can experience changes in volume of up to thirty percent or more depending on moisture, clay type and content, and wetting / drying cycles. Foundations placed in expansive soils may lift structures during periods of high moisture, and settle during periods of low moisture. Expansive soil will also exert pressure on the vertical face of a foundation or retaining wall resulting in lateral movement. The Hillsboro silt loam, 3 to 8 percent slopes and Sauvie silt loam, 0 to 3 percent slopes soils have been identified as soils possessing some characteristics of shrink-swell soils that may require special consideration during design.

Corrosive soils are soils where soil chemistry, moisture, texture, acidity, and soluble salts are contributing factors that relate to construction materials susceptibility to corrosion. Concrete and steel structures in soil may degrade more rapidly in corrosive soils. The Hillsboro silt loam 0 to 8 percent slope soil has been identified as having a high risk of corrosion to uncoated steel and concrete when placed in this soil. The Lauren gravelly loam, 0 to 8 percent slopes, Wind River sandy loam, 0 to 8 percent slopes, Wind River sandy loam, 8 to 20 percent slopes, Wind River gravelly loam, 0 to 8 percent slopes, Hillsboro loam, 0 to 3 percent slopes, Sauvie silt loam, 0 to 3 percent slopes, Rafton silt loam, protected, and Sauvie-Rafton-Urban land complex, 0 to 3 percent slopes have been identified as having a high to moderate risk of corrosion to uncoated steel and concrete when placed in these soils.

Exhibit 3-6. Properties of Project Area Soils

Soil Unit	Map Label	USCS	AASHTO	Slopes(%)	Erosion Hazard Rating	Corrosive Rating	Shrink-Swell Issues	Hydric Features
Hillsboro silt loam	HiA	ML, SM	A-2, A-4	0 to 3	Slight	High	Yes	No
Hillsboro silt loam	HoB	ML	A-4	3 to 8	Moderate	High	Yes	No
Lauren gravelly loam	LgB	ML, GM, SM	A-1, A-2, A-4	0 to 8	Slight	Moderate	No	No
Lauren gravelly loam	LgD	ML, GM, SM	A-1, A-2, A-4	8 to 20	Moderate	Moderate	No	No
Wind River sandy loam	WnB	SM	A-1, A-2, A-4	0 to 8	Moderate	Moderate	No	No
Wind River sandy loam	WnD	SM	A-1, A-2, A-4	8 to 20	Severe	Moderate	No	No
Wind River sandy loam	WnG	SM	A-1, A-2, A-4	30 to 65	Severe	Moderate	No	No
Wind River gravelly loam	WrB	SM	A-1, A-2, A-4	0 to 8	Slight	Moderate	No	No
Wind River gravelly loam	WrF	SM	A-1, A-2, A-4	12 to 50	Severe	Moderate	No	No
Sauvie silt loam	SmA	ML, SM	A-4, A-6	0 to 3	Slight	Moderate	Yes	No
Pilchuck-Urban land	33A	SM	A-2	0 to 3	Slight	Moderate	No	Yes
Rafton silt loam, protected	40	ML, CL	A-4, A-6	0 to 2	Slight	Moderate	No	Yes
Sauvie-Rafton-Urban land	47A	ML, CL	A-4, A-6	0 to 3	Slight	Moderate	No	Yes

Note: The ratings (slight, fair, moderate, etc.) are as classified by the Natural Resource Conservation Service (McGee 1972 and Green 1983) based on specific criteria determined by NRCS. These ratings do not necessarily reflect the opinions of CRC.

USCS – Unified Soil Classification System

AASHTO – American Association of State Highway and Transportation Officials

3.5 Geologic Resources

A geologic resource is defined as a mineral-bearing rock or other deposit (aggregate) that can be extracted profitably under present economic conditions or a deposit that is not currently recoverable but may eventually become available. Either known deposits that are not recoverable at present or unknown deposits that may be inferred to exist but have not yet been discovered are considered geologic resources. Minerals includes soil, coal, clay, stone, sand, gravel, metallic ore and any other solid material or substance excavated for commercial, industrial or construction use from natural deposits. Aggregate resources are naturally occurring and readily available sand, gravel, and quarry rock resources commonly used in road building or other construction. Exhibit 3-3 presents the locations of permitted mining operations in the vicinity of the main project area. The exhibit displays 33 active mines that were identified within 10 miles of the project area.

3.5.1 Washington

Active mining operations are not identified in the immediate vicinity of the LPA in Washington (DGER 2008). An inactive gravel deposit of good grade and quality has been identified, but the area appears to be highly developed with residential and commercial properties (Johnson et al. 2005). Twenty eight active mines have been identified in the State of Washington within 10 miles of the LPA.

3.5.2 Oregon

Active mining operations are not identified within the main project area in Oregon. The closest resource to the LPA are sand and gravel pits located along US 30 south of the Portland International Airport, approximately 5 miles southeast of CRC (Gray et al. 1978; MLRR 2009). Five active mines have been identified in the State of Oregon within 10 miles of the LPA.

3.6 Groundwater

The hydrogeologic setting controls the availability, quantity, and quality of groundwater resources in the Portland-Vancouver area. This section presents an overview of the hydrogeologic units, their characteristics, influences on groundwater flow, and beneficial use.

3.6.1 Hydrogeologic Units

A hydrogeologic unit is any soil or rock unit that displays distinct properties regarding its ability to store or influence groundwater movement. Within the Portland Basin the designation of the hydrogeologic units closely resembles that of the geologic units. Hydrogeologic units are directly influenced by the environment in which geologic materials were deposited, the type of material, its thickness, and its extent. In general, these physical attributes and their spatial relationships to each other help define the hydrogeologic setting. Detailed descriptions of the hydrogeologic units can be found in Swanson et al. (1993).

Exhibit 3-7 illustrates a comparison of geologic units and hydrogeologic units for the Portland Basin. The following eight hydrogeologic units are present in the Portland Basin:

- Unconsolidated Sedimentary Aquifer (USA)
- Troutdale Gravel Aquifer (TGA) or the Consolidated Gravel Aquifer
- Confining Unit 1 (CU1)
- Troutdale Sandstone Aquifer (TSA)
- Confining Unit 2 (CU2)
- Sand and Gravel Aquifer (SGA)
- Older Rocks
- Undifferentiated Fine-Grained Sediments

The eighth unit is applied in areas of the basin where the TSA and the SGA appear to have pinched out or where there is insufficient information to characterize the aquifer units. Where this occurs CU1 and CU2 cannot be separated and are mapped as undifferentiated fine-grained sediments. The older rock subsystem, consisting of older volcanic and marine sedimentary rocks of generally low permeability, is present at depths estimated to range up to 1,600 feet in the central area of the basin. With the exception of lava flows associated with the CRBG, these older rocks are poor aquifers and too deep to be used as a primary source of water in the region. Due to these conditions, no further discussion is presented regarding the older rock unit.

The Portland Basin aquifer system can also be grouped into three major subsystems:

- Upper sedimentary subsystem (USA and TGA)
- Lower sedimentary subsystem (CU1, TSA, CU2, and SGA)
- Older rocks

This grouping is based on regionally continuous contacts between units of different lithologic and hydrogeologic characteristics (Swanson et al. 1993). For the purposes of this report, only the upper sedimentary subsystem is described further. This is because the upper sedimentary system is the primary source of groundwater beneficial use within the Portland-Vancouver area, aquifers in the lower sedimentary system are confined due to the regional presence of CU1, and proposed project subsurface construction activities only pertain to this system.

3.6.2 Upper Sedimentary Subsystem

The upper sedimentary subsystem consists of the USA and the underlying TGA. The USA is composed of unconsolidated material associated with the Pleistocene-aged catastrophic flood deposits and Quaternary alluvium deposits. The TGA is composed of unconsolidated, semi-cemented and/or cemented material associated with the Pleistocene-aged Troutdale Formation.

Both the TGA and the overlying USA are composed of coarse-grained materials, predominantly sands and gravels that can be difficult to differentiate on the basis of drilling conditions and/or the presence of cementation or a sandy matrix. The base of the USA is most commonly identified by the transition to the underlying conglomerate or weathered gravel of the Pleistocene-aged Troutdale Formation. Deposition of the TGA was followed by a period of erosion and subsequent deposition of unconsolidated sediments. The contact between the TGA and the overlying USA is also marked by a permeability contrast, although both aquifers are permeable and productive.

The thickness of the USA in Portland typically is between 50 and 100 feet, with local accumulations of greater than 250 feet (Snyder 2008). The generally high permeability of the USA in Portland varies substantially due to the high degree of heterogeneity of the aquifer materials, which can result in some local areas of perched ground water. The relatively high permeability TGA also contains large variations (McFarland and Morgan 1996).

The USA and TGA contain the majority of water supply wells and are the primary aquifers for drinking water and will continue to be the source of water supply as demands increase. This use is demonstrated in Clark County where over 90 percent of the 7,111 wells inventoried are completed in the USA or TGA and are less than 300 feet in depth (Gray & Osborne 1996). In addition, a majority of municipal water supply wells for the City of Vancouver are completed in the USA (HDR 2006). These aquifers supplied more than 80 percent of groundwater extracted from the Portland area in 1987–88 (Collins and Broad 1993). Further discussion of groundwater beneficial use is presented below.

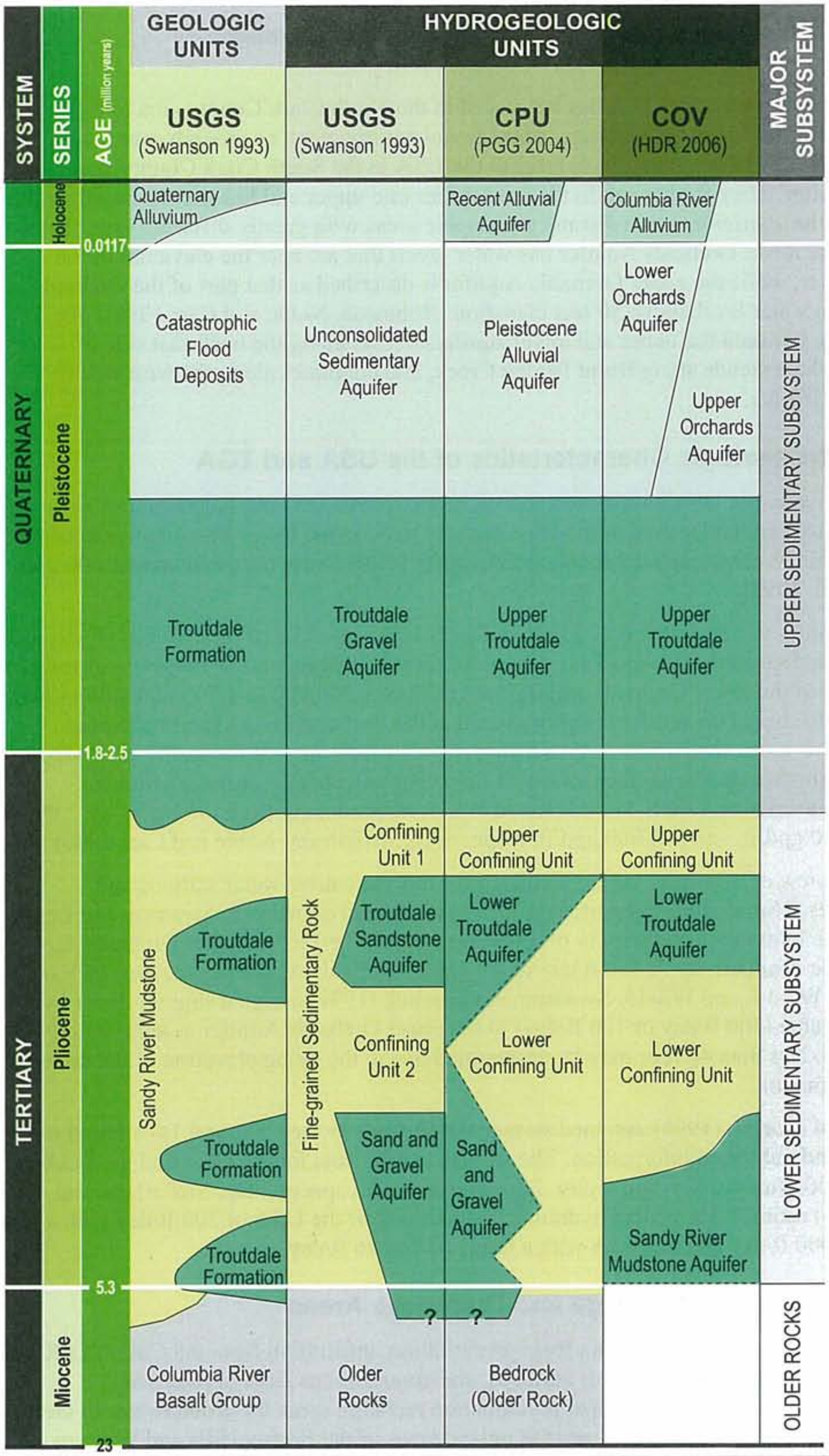


Exhibit 3-7. Geological Units and Comparison of Hydrogeologic Unit Terminology
Geology Technical Report

Columbia River CROSSING

Different terminology for the USA has been used in the South Clark County area to further differentiate the unit based on lithology, depositional environment, or groundwater levels. Robinson, Noble and Carr, Inc. (1980) refer to the USA in the South Clark County area as the Orchards Aquifer. They further subdivide this aquifer into upper and lower units based on the separation of the aquifer into two distinct geographic areas with greatly differing water level elevations. The lower Orchards Aquifer has water levels that are near the elevation of the Columbia River, while the upper Orchards Aquifer is described as that part of the Orchards Aquifer with a water level above 50 feet elevation (Robinson, Noble and Carr 1980). The transition zone between the upper and lower aquifers occurs along the northeast side of Vancouver Lake, extends along Burnt Bridge Creek, and continues along the west side of McLoughlin Heights.

3.6.2.1 Hydrogeologic Characteristics of the USA and TGA

Wells completed in the USA have maximum yields between 1,000 and 6,000 gallons per minute (gpm). The most productive area of the USA appears to be in the lower floodplain area of the Columbia River. Wells completed in the consolidated TGA commonly yield up to 1,000 gpm (Swanson et al. 1993).

The USA's ability to transmit and yield groundwater is the result of its relatively high intrinsic permeability and saturated thickness (i.e., its transmissivity). Mundorff (1964) estimated that the transmissivity of the lower Orchards Aquifer ranges from 1,900,000 to 3,500,000 gallons per day per foot (gpd/ft), based on aquifer tests completed at the former ALCOA facility located approximately 3 miles west of the LPA. The aquifer tests indicate that the aquifer's transmissivity is fairly uniform throughout the facility's well field. The calculated transmissivities for Vancouver water station 1 (WS-1), WS-3, and WS-4, all producing from the USA, are 2,000,000 gpd/ft, 878,900 gpd/ft, and 586,000 gpd/ft, respectively (Robinson, Noble and Carr 1980).

Based on a review of transmissivities calculated for the Vancouver water stations and transmissivities estimated from reported pump test yields and drawdown, Swanson and Leschuk (1991) assign a hydraulic conductivity of 1,000 feet/day (ft/day) to the lower Orchards Aquifer, and a hydraulic conductivity of 390 ft/day to the upper Orchards Aquifer in the area of Vancouver WS-8, WS-9, WS-14, and WS-15. Swanson and Leschuk (1991) assign a slightly lower hydraulic conductivity value (300 ft/day or 100 ft/day) to the upper Orchards Aquifer in areas where the aquifer thins to less than 40 ft or may be unsaturated due to the rising elevation of the underlying Troutdale Formation.

McFarland and Morgan (1996) assigned storage coefficients to the USA and TGA based on aquifer tests and published information. The storage coefficients for the USA and the TGA are 0.003 and 0.0008 (unitless), respectively. Based on specific capacity data, McFarland and Morgan (1996) estimated a median hydraulic conductivity of the USA of 200 ft/day with a range of 0.03 to 70,000 ft/day and the TGA with a range of 7 to 16 ft/day.

3.6.2.2 Groundwater Recharge and Discharge Areas

Recharge to the USA and TGA occurs from precipitation, infiltration from the Columbia River and streams, infiltration from pervious surfaces, and contributions from drywells and underground sewage disposal. Principal precipitation recharge areas for groundwater in the LPA, with the exception of Hayden Island, are the upland areas of the Boring Hills and Western Cascade Mountains (Exhibit 3-8). Groundwater recharge on Hayden Island is primarily from infiltration from the Columbia River. The combined average recharge rate is estimated to be about 22 inches/year (Snyder et al. 1994) for the Portland Basin. The highest rates (up to 49 inches/year) occur in the Cascade Range and the lowest rates (near zero inches/year) at the Columbia and Willamette Rivers. Seasonal fluctuations in precipitation affect groundwater elevations and aquifer saturated thickness. Heavy spring and winter precipitation increase groundwater elevation and aquifer saturated thickness, and lower precipitation in the summer and fall months decrease groundwater elevations and aquifer saturated thickness. Changes in groundwater elevations and saturated thickness affect the rate and direction of groundwater discharge. In general, groundwater locally discharges to the Columbia and Willamette Rivers, North Portland Harbor, and Burnt Bridge Creek.

3.6.2.3 Flow Direction and Gradient

The movement of groundwater (flow direction and gradient) is generally controlled by topography, river levels, and supply well pumping. However, due to the high transmissivity of the USA, groundwater gradients in the project area remain relatively flat. Exhibit 3-8 indicates that groundwater at elevations approximately 250 feet above msl of the Cascade Mountain Range foothills generally flows west towards the Columbia or Willamette Rivers.

The groundwater table elevation along the banks of the Columbia River and North Portland Harbor is influenced by river stage elevation which is in turn influenced by tidal fluctuations, precipitation events, and upstream dam releases. The rapid response between changes in river stage and corresponding changes in groundwater levels indicates a high interconnectivity between the river, the USA, and the upper portion of the TGA (Parametrix et al. 2008). Groundwater table fluctuations due to river stage changes are less significant with increasing distance from the Columbia River.

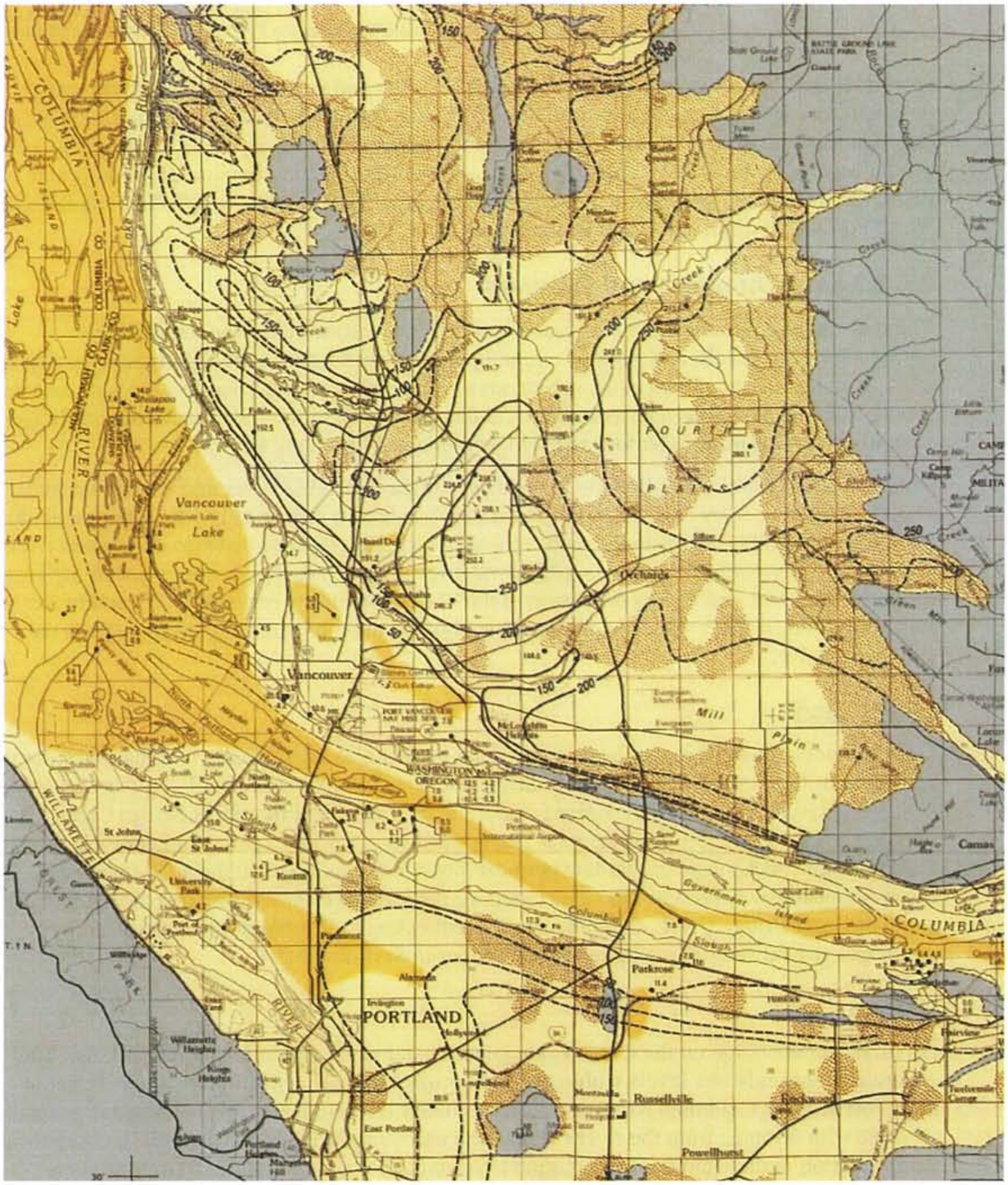
Washington

Groundwater elevations in the Washington main project area are typically less than 50 feet msl just south of the Burnt Bridge Creek drainage and decrease to approximately 20 feet msl at the Columbia River. Water level elevations sharply increase north of the Burnt Bridge Creek drainage to approximately 150 feet msl. The large observed drop in groundwater levels south of Burnt Bridge Creek suggests that low permeability conditions exists in the area of the creek. This lower permeability condition functions to reduce the volume of groundwater recharge to the area south of Burnt Bridge Creek. Groundwater flow direction in Washington is influenced by municipal groundwater pumping discussed further in Section 4.6.2.4.

Oregon

Groundwater elevation on the Oregon side generally ranges between 10 and 30 feet msl. The generalized groundwater levels within the main project area are typically less than 20 feet in elevation near the Columbia River and North Portland Harbor. Water level elevations generally increase with distance from the river (McFarland and Morgan 1996; Snyder 2008). Groundwater flow direction in the vicinity of the Marine Drive interchange is generally from south to north discharging to North Portland Harbor. Based on available information, groundwater flow direction is more difficult to determine on Hayden Island, but likely flows generally from the center of the island toward the Columbia River and North Portland Harbor.

PRELIMINARY



Legend

---100--- GROUNDWATER LEVEL CONTOUR. Shows altitude, in feet, of groundwater level, Spring 1988, in the unconsolidated sedimentary aquifer. Dashed where approximate. Contour is variable. Datum is sea level.

•6.9 FIELD LOCATED WELL. Completed in the USA. Number is altitude in feet above sea level.

Exhibit 3-8. Groundwater Level Contour Map USA, Spring 1988

Geology Technical Report

0 — 5 miles

Approximate Scale

Source:
McFarland, W.D. and Morgan, D.S. 1996 Description of Ground-Water Flow System in thePortland Basin, Oregon and WashingtonU.S. Geological Survey Water Supply Paper 2470-A

Columbia River CROSSING

3.6.2.4 Influence on Groundwater Flow from Pumping

Groundwater flow in the downtown portion of the City of Vancouver is influenced by water supply wells. These wells include Vancouver drinking water supply wells at water station (WS) WS-1 and WS-3; the Port of Vancouver (POV) groundwater pump and treat interim action (GPTIA) extraction well, and Great Western Malting Company supply wells No. 4 and No. 5.

Exhibit 3-9 displays simulated groundwater flow and direction resulting from the pumping of these supply wells. Exhibit 3-9 indicates that a majority of the groundwater flow in the downtown Vancouver area is influenced by wells at WS-1. No drinking water supply wells are currently used within the Oregon side of the main project area. Therefore, groundwater within the main project area on the Oregon side of the study area is not influenced by pumping.

City of Vancouver

Vancouver pumps an average of 26 millions of gallons per day (mgd) from the USA, Troutdale, and Sand and Gravel Aquifers, with peak demands up to approximately 53 mgd in 2003 (HDR 2006). Vancouver maintains 16 water stations, but only extracts groundwater from nine water stations, each with several production wells (Hoiland 2010 personal communication).

Based on the anticipated population growth for the Vancouver, average demand on the water system is estimated to increase between approximately 35 mgd by 2012, and to 40 mgd by 2026 (Hoiland 2010 personal communication). These increases in demand will increase stress to the aquifer. Replacement wells would likely be installed and three decommissioned at WS-1. Extraction rates for city water supply wells vary seasonally based on user demands. Water demands on the system are highest during the summer and lowest during the winter (HDR 2006).

WS-1

WS-1 is located southeast of the intersection of Fort Vancouver Way and E. Fourth Plain and is composed of 12 wells (#1 through #5, and #7 through #13). The wells range in depth from 235 to 280 feet bgs. All wells at this water station extract water from the USA. Each well is capable of producing between 900 and 2,800 gpm, for a total pumping capacity of approximately 22,770 gpm (32.8 mgd). Current water production at this water station is averaging 5.5 mgd (Hoiland 2010 personal communication). However, production is limited to approximately 27 mgd due to the wellhead treatment system capacity. Treatment consists of aeration/air stripping, chlorination, and fluoridation.

WS-3

WS-3 is located northwest of NW 42nd Street and NW Washington Street and is composed of three wells (#1 through #3). The wells range in depth from 259 to 275 feet bgs. All wells at this water station extract water from the USA. Each well has a pumping capacity of approximately 2,000 gpm, or a total pumping capacity of 6,200 gpm (8.9 mgd). Current water production at this water station is averaging 4.2 mgd (Hoiland 2010 personal communication). This water station capacity is limited to 8.6 mgd due to water rights. Water at the well head is treated by chlorination and fluoridation.

Port of Vancouver (POV)

Design and placement of the POV GPTIA extraction well is based on a groundwater flow model developed through a combined effort completed on behalf of the POV and Clark Public Utilities

(CPU) (Parametrix et al. 2008). The well was installed to remove and hydraulically control solvent contaminated groundwater. Start-up of the well occurred in June 2009, pumping at a rate of 2,500 gpm (3.6 mgd) on a continuous basis. Groundwater from the well is treated using air stripping towers.

Great Western Malting Company

Great Western Malting currently operates two production wells, No. 4 and No. 5 which influence groundwater flow in the western portion of downtown Vancouver. Groundwater from the wells is treated using an air stripper tower. Treated water is used for germination of malt and as process water for cooling. The wells are capable of producing 4,000 gpm, but are currently extracting water at a combined rate of 3,600 gpm (5.2 mgd).

3.7 Current and Future Groundwater Beneficial Use Survey

The purpose of a beneficial groundwater use survey is to identify the current use of groundwater in the vicinity of the LPA. A review of available well information identified approximately 73 potential wells in Washington and 49 wells in Oregon within one mile of the CRC LPA. Verification of the information in the databases is beyond the scope of this work. Exhibit 3-10 displays the locations of identified supply wells in the vicinity of the main project area.

3.7.1 Oregon

The City of Portland primarily uses Bull Run water for domestic drinking water supply. The Bull Run watershed is a 102-square-mile municipal watershed located about 26 miles east of downtown Portland and is within the Mt. Hood National Forest. Rain provides 90-95 percent of the water in the watershed, averaging 130 inches a year. Occasionally, groundwater from the Columbia South Shore Well Field east of the Portland International Airport augment drinking water supply in summer and early fall as needed depending on Bull Run water supply or when winter storms increase the turbidity levels above acceptable levels. The well field extracts groundwater primarily from the Lower Sedimentary groundwater system that consists of the TSA and SGA.

3.7.2 Washington

The City of Vancouver relies on groundwater extracted from the USA, TGA, and the SGA for its domestic water supply. The City of Vancouver pumps an average of 26 mgd from the aquifers with peak demands up to approximately 53 mgd in 2003. Vancouver extracts groundwater from 9 water stations each with several production wells. The service area of the City of Vancouver water supply system is primarily within the city limits with some service extending beyond the northeast city limit boundary. The area north of the city and most of Clark County is served by Clark County Utilities which use wells located throughout its service area. Based on the anticipated population growth for the city, demand on the water system was estimated to increase to between 61 and 71 mgd by 2012 and between 74 and 90 mgd by 2026 (HDR 2006). These increases in demand will add additional stress to the aquifer.

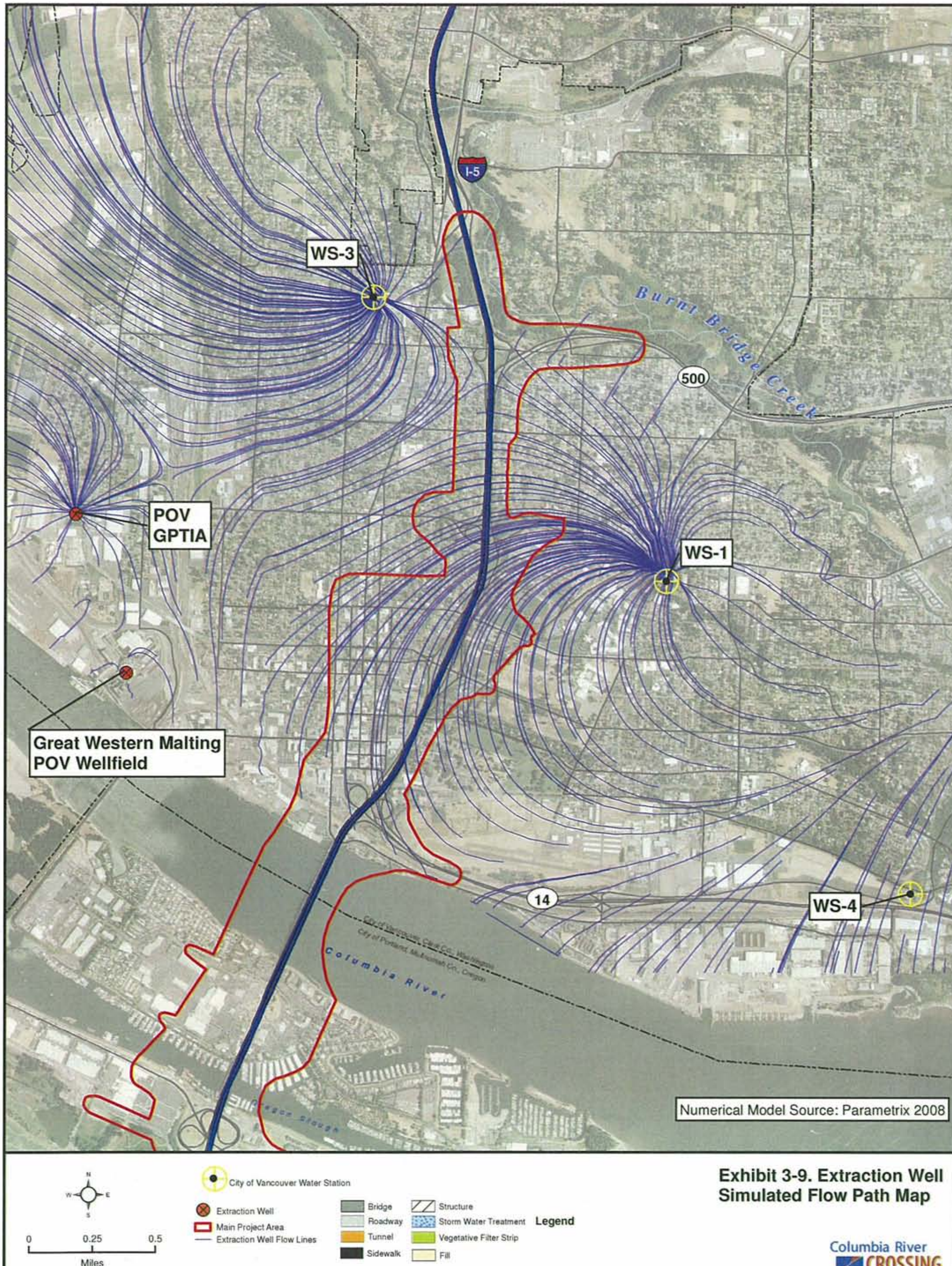


Exhibit 3-9. Extraction Well Simulated Flow Path Map

PRELIMINARY

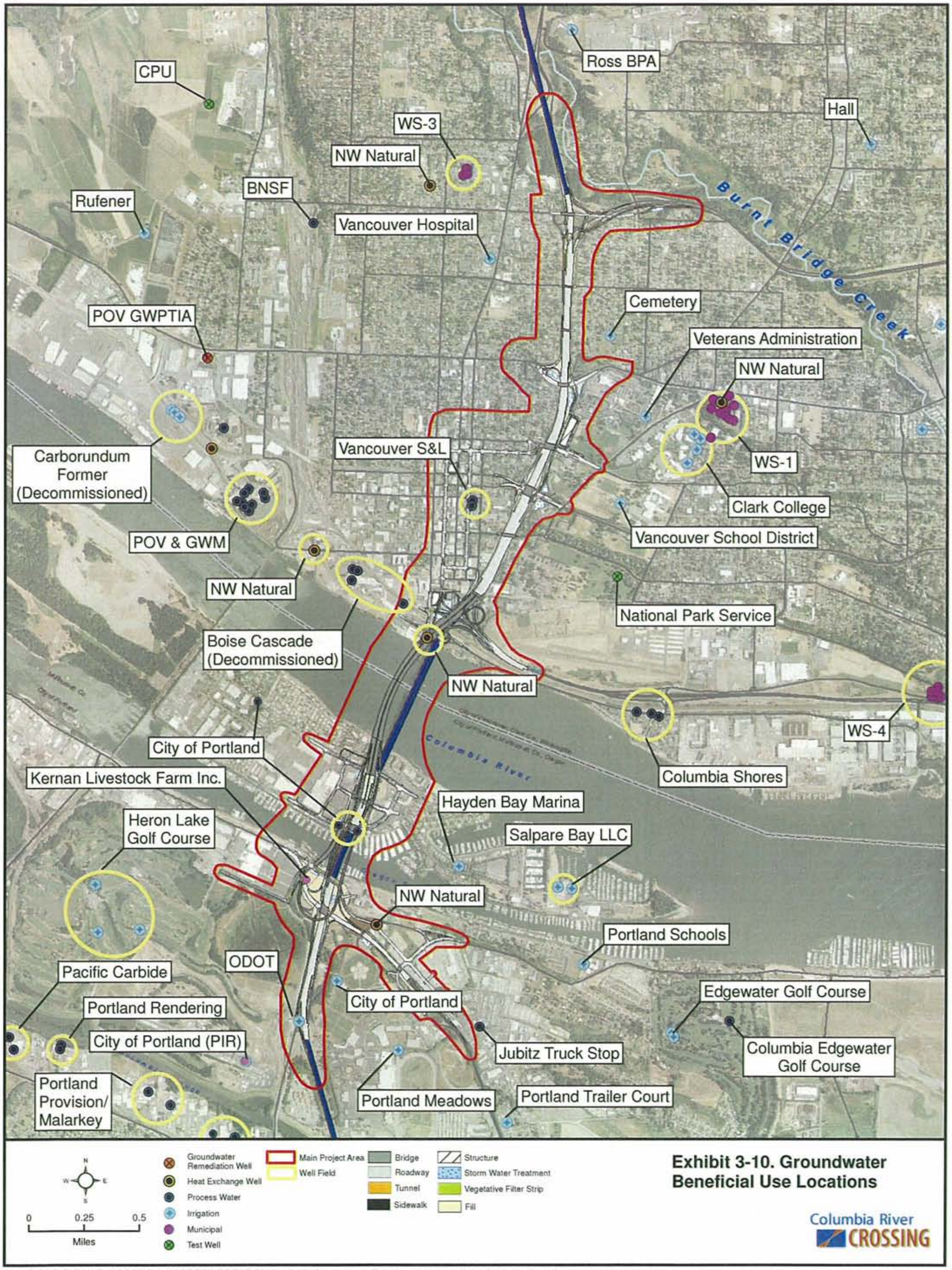


Exhibit 3-10. Groundwater Beneficial Use Locations

Sole Source Aquifer Designation and Critical Aquifer Recharge Area

The EPA designated the Troutdale Aquifer System, Clark County, Washington, as a sole source aquifer (TSSA) in July 2006 (EPA 2006). A sole source aquifer is defined as "an aquifer or aquifer system which supplies at least 50 percent of the drinking water consumed to the area overlying the aquifer and for which there is no alternative source or combination of drinking water sources which could physically, legally and economically act to supply those dependent upon the aquifer" (EPA 2006).

Prior to the EPA's designation of the Troutdale Aquifer System as a TSSA, the City of Vancouver recognized its dependence on the aquifer and the importance of protecting the resource. The City of Vancouver has designated the entire area within the city boundaries as a Critical Aquifer Recharge Area as specified the Water Resources Protection Ordinance VMC Title 14 Section 26, dated 2002 (VMC 14.26). The ordinance requires minimum standards to protect critical aquifer, establishes compliance standards for business and industry to manage hazardous materials, and creates special protection areas around city well heads. Special protection areas are defined as areas that are 1,900 radial feet from any municipal water supply well. As such the city applies development restrictions to activities inside the special protection areas pursuant to VMC 14.26.135. These restrictions mainly address Class I and II Operations, septic systems, and infiltration systems.

3.8 Groundwater Quality

Groundwater is particularly susceptible to contaminants from historical commercial, industrial, and agricultural activities at the ground surface. As stipulated in the Safe Drinking Water Act (SDWA) and Washington Administrative Code (WAC) Chapter 290, suppliers of drinking water must monitor for and meet primary and secondary drinking water standards. From approximately January 1979 to November 2010 the City of Vancouver sampled and analyzed groundwater from its water stations for the following classes of compounds: inorganics, volatile organic compounds (VOCs), herbicides, pesticides, insecticides, radionuclides, fumigants, dioxins, and nitrate. Analytical results for WS-1 and WS-3 are tabulated on Washington Department of Health's website (WDH 2009).

The most recent water quality report published by the City of Vancouver in 2009 provides the health-related standards that are intended to protect public health against harmful common groundwater contaminants. The samples collected from the treated water distribution system were below the highest concentrations allowed or the maximum contaminant level (MCL).
Exhibit 3-11 presents the concentrations detected in 2009 and 2010. More detailed information on groundwater impacts as a result of hazardous material releases can be reviewed in the Hazardous Materials and Water Quality and Hydrology technical reports.

Exhibit 3-11. Contaminant Concentrations in Groundwater for the Troutdale Aquifer Detected in 2009 in Vancouver and 2010 in Portland

Contaminant	MCL (mg/L)	Portland[a] Highest Detected Level (mg/L)	Vancouver[b] Highest Detected Level (mg/L)
Fluoride	4.0	0.14	0.89
Total Nitrates	10.0	0.18	5
Sodium	20.0	8.8	32

mg/L = milligrams per liter

MCL = maximum contaminant level

a City of Portland 2010 Water Quality Report (COP 2010). Includes only a 3 percent blend of water coming from the Portland well field, as such, these concentrations are not fully reflective of groundwater quality.

b City of Vancouver 2009 Water Quality Report (COV 2009).

3.9 Geologic Hazards

Geologic hazards are natural geologic processes that can create environmental conditions that endanger human lives and threaten property. The following geologic processes are discussed below: Slope movement (steep slopes, landslides, soil types, ground settlement); Earthquake processes (ground motion, fault rupture, liquefaction, and earthquake-induced slope failure); and Volcanic processes (lava flows, ash fallout, pyroclastic flows, and lahars).

3.9.1 Steep Slopes

Exhibit 3-12 displays the locations of steep slopes in the project area. Steep slope hazard areas are typically defined as areas where there is no mapped or designated landslide hazard, but where there are slopes equal to or greater than 25 percent (Das 1983). Steep slopes have the potential to cause slope instability, soil erosion, and uncontrolled stormwater runoff. These effects are common in southwest Washington and Oregon. The degree of these effects is dependent on soil type and thickness, vegetation, underlying soil conditions, the amount, rate, and duration of precipitation, and slope angle.

Naturally occurring steep slopes occur within the drainages of Burnt Bridge Creek, located in the northern part of the project area. No other naturally occurring steep slopes are present within the main project area.

3.9.2 Landslides

Exhibit 3-12 displays the locations of landslides for the project area. Landslide hazard areas are typically defined as areas that, due to a combination of slope inclination, soil type, geologic structure and presence of water, are susceptible to failure and subsequent downhill movement. Historical landslides are typically masses of soil and/or rock that at one time in the past were moving rapidly or may have been moving slowly, but may be currently not moving. Active landslides are masses of soil and/or rock that are currently undergoing some sort of failure, either rapidly or slowly.

No landslides have been mapped in the main project area. However, one landslide is mapped along the north slope of Burnt Bridge Creek approximately 2 miles northwest of the SR 500 interchange and two landslides are located on the north slope of Salmon Creek west of I-5. These mapped landslides are not expected to impact the project. However, the landslides are within the fine-grained facies of the catastrophic flood deposits and are bordered by slopes that exceed 25 percent.

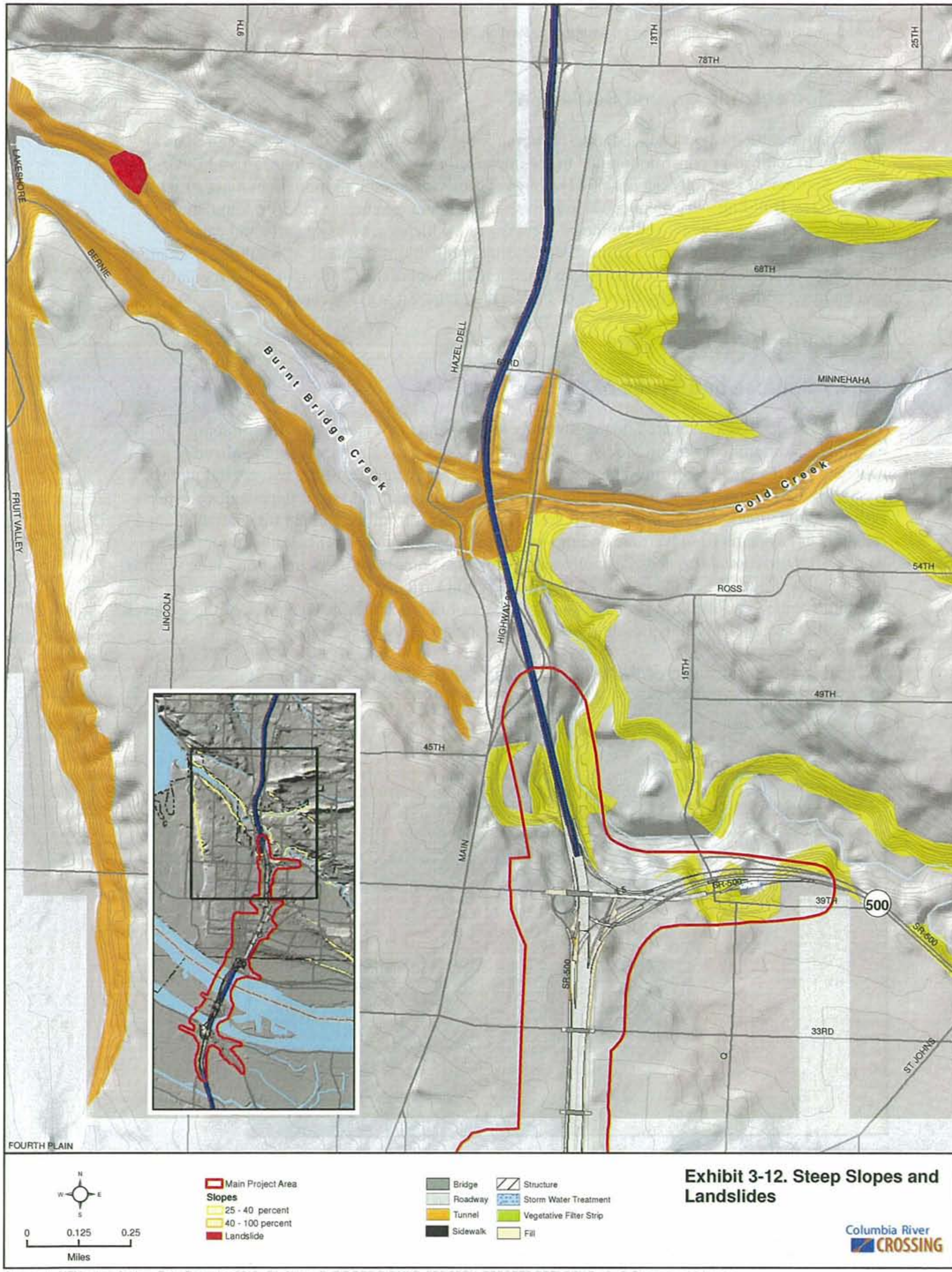


Exhibit 3-12. Steep Slopes and Landslides

3.9.3 Non-seismic Ground Settlement

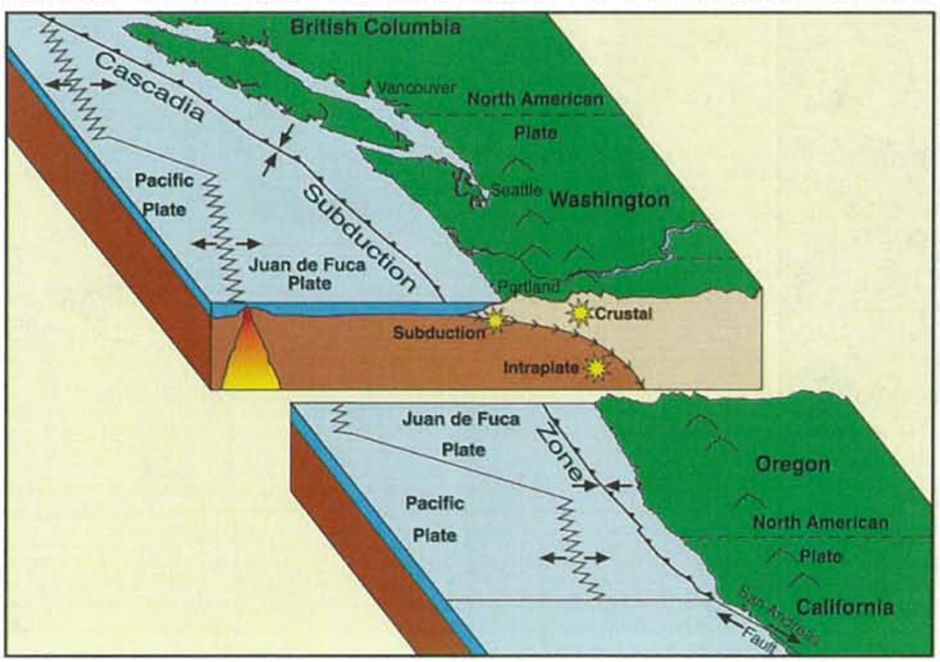
Non-seismic settlement or consolidation occurs in loose, soft soil material. The structure has the potential to settle after construction due to the introduction of added load (Johnson and DeGraff 1988). Settlement generally occurs slowly but over time can amount to more than most structures can tolerate. Building settlement could lead to structural damage such as cracked foundations, misaligned or cracked walls and windows. Settlement problems are site-specific and can generally be remedied through standard engineering applications. Settlement would be evaluated by site-specific geotechnical investigations conducted in accordance with applicable regulations and building codes set forth by the City of Portland and the City of Vancouver.

3.9.4 Earthquake Processes

3.9.4.1 Sources and Types of Earthquakes

The CRC project area is located in a regional tectonic regime that is capable of producing earthquakes of moment magnitude (M_w) 9 or greater. Exhibit 3-13 presents a generalized schematic of the Pacific Northwest tectonic regime. The convergence of the two crustal plates generates the regional tectonic regime that results in folding and faulting of rocks and volcanic activity in the vicinity of the project area. Earthquakes result from the sudden movement along a fault or fault systems from tectonic and/or volcanic forces. The movement along a fault is hampered by frictional resistance as potential energy is accumulated over time around the volume of the fault surface. When the potential energy overcomes frictional resistance the sudden release of energy generates seismic waves, heat and cracking of the rock. The propagation of these waves through the ground cause the ground motion felt during an earthquake.

Exhibit 3-13. Schematic of Plate Boundaries for the Pacific Northwest



Source: Barnett et al. 2009.

6090

In general, three relevant types of earthquake occur in the Pacific Northwest tectonic setting: 1) subduction zone earthquakes; 2) intraplate earthquakes; and 3) crustal earthquakes. All three types of earthquakes can cause damage to roadway and bridge structures by strong ground shaking and by the secondary effects such as ground surface ruptures, landslides, and liquefaction.

Seismicity in the Vancouver and Portland areas has historically produced earthquakes at magnitudes of M5.3 in 1877; M5.5 in 1962; and M5.6 during the Scotts Mills earthquake in 1993. Pratt et al. (2001) indicates that these late Pleistocene to Holocene faults may still be active, but suggest that other interpretations are possible. Several crustal faults are mapped by Beeson et al. (1991) and Madin (2004) to the southwest and by Phillips (1987) to the northeast of the project area. There are no known seismically active faults that cross the LPA (USGS 2006 and 2007).

The ability to estimate the occurrence and frequency of earthquakes is difficult because fault activity in the region is poorly understood. This is due to the general lack of surface expressions of the faults; faults are buried under hundreds of feet of recent alluvial deposits; and there is a limited recorded history of earthquakes in the area of only approximately 150 years. However, an estimate of the maximum plausible earthquake magnitude can be made based on several seismicity studies by Bott and Wong (1993), Mabey, Black, Madin, et al. (1993), Mabey, Madin, and Palmer (1994), Mabey, Madin, Youd, et al. (1997), Atwater and Hemphill-Haley (1997), Wong et al. (2000), Pratt et al. (2001), Palmer et al. (2004), USGS (2006 and 2008), which have been conducted in the region over the past 10 years.

Subduction Zone Earthquakes

Large subduction zone earthquakes result from the failure of the surface contact between the Juan de Fuca and North American convergent plates. The plate boundaries interact within the CSZ located off shore west of the Pacific coast line and extends from Northern California to Vancouver Island, Canada. The denser Juan de Fuca oceanic plate is subducted under the North American continental plate. Irregularities along the plate convergent boundaries cause stick-slip behavior.

An evaluation of subduction zone earthquake recurrence, based on the historical and geologic evidence (Atwater and Hemphill-Haley 1997, Wong et al. 2000, Nelsen et al. 1996), indicate that these earthquakes occur, ranging from 250 to 700 years for the past 7,000 years (Kelsey et al. 2005).

Bradley Lake on the southern Oregon coast has been shown by Kelsey et al. (2005) to produce reliable tsunami records. These records show that tsunamis occur about 3 to 4 times every 1,000 years from 4,600 to 2,800 years ago. This period was followed by 1,000 years with no tsunami and then by another 1,000 years with 4 tsunamis. Historical evidence of tsunami inundation in Japan, suggests that the last subduction zone earthquake occurred on January 26, 1700 (Mabey et al. 1993, Wong et al. 2000, Atwater et al. 2005, Nelsen et al. 1995,). The 1700 earthquake most likely ruptured along virtually the entire length of the CSZ for almost 1,000 miles and was approximately between M_w 8.7 and 9.2 (Atwater et al. 2005. Future CSZ earthquake ground displacement would occur within the subduction zone off the Pacific Coast.

An estimated maximum probable earthquake magnitude of M_w8 or greater could result from a subduction zone earthquake. The horizontal peak ground motion acceleration (PGA) during a CSZ earthquake at a distance of 90 kilometers (minimum distance to convergent plate boundary) is estimated to be approximately 0.15 gravity units (g) (top of Troutdale Formation) (Parsons

Brinkerhoff 2009, Gregor et al. 2002). The use of magnitude of the PGA is an important input parameter for earthquake engineering.

Intraplate Earthquakes

Intraplate earthquakes result from the breaking apart of the remains of the Juan de Fuca Plate as it subducts beneath the North America Plate. Intraplate fault displacement occurs at pre-existing zones of weakness typically called failed rifts. Failed rifts occur 25 to 37 miles deep (Wang and Clark 1999).

Significant intraplate earthquakes have occurred in the Pacific Northwest in 1949, 1965, and 2001. These M7.1, M6.5, and M6.8 earthquakes, respectively, have epicenters in the Puget Sound area approximately 200 kilometers from the CRC project area. However, some damage did occur in Portland during the 1949 event (Mabey et al. 1994). Wong (2005) indicates that based on a 150-year record, no intraplate earthquakes greater than M5.5 have occurred beneath northern Oregon or Southwestern Washington and the absence of earthquakes in this zone is likely a result of higher intraplate temperatures. However, a M4.6 intraplate earthquake occurred northwest of Corvallis, Oregon in 1963 (Barnett et al. 2009), smaller (<M3.0) intraplate earthquakes occur in the Portland area (Mabey et al. 1994), and the Nisqually earthquake of 2001 (M_w 6.8) was felt as far south as Salem, Oregon (Dewey et al. 2002). Mabey et al. (1993) and Barnett et al. (2009) suggest intraplate earthquakes epicenters of significant magnitude could occur near the project area.

Maximum plausible earthquake magnitudes for intraplate earthquakes may be as large as M7.5 (Mabey et al. 1993). Earthquake intensity and duration would be less severe than what is produced during subduction earthquakes. Barnett et al. (2009) suggest that on rock, peak ground motion accelerations are expected to be approximately 0.2g to 0.3g.

Crustal Earthquakes

Crustal earthquakes result from the rupture of shallow faults in the Earth's crust of depths up to approximately 15 miles below the ground surface. Several shallow crustal faults are mapped within the vicinity of the project area; however none in the main project area (Phillips 1987; Madin 1994 and 2004; Mabey, Madin, Youd, et al. 1993; Mabey, Madin, and Palmer 1994; Wong 2005; and Personius 2002 and 2003, Geomatrix Consultants 1995). The characteristic of these faults is not well understood since there are few surface features and little historical activity.

In Oregon, the East Bank Fault, Portland Hills Fault, Oatfield Fault are mapped southwest, the Grant Butte Fault is mapped southeast, and in Washington the Lacamas Lake Fault is mapped northeast of the project area (Phillips 1987; Beeson et al. 1991; Madin 1994; Madin 2004; Personius 2002 and 2003). The East Bank, Portland Hills, and Oatfield Faults included in Exhibit 3-3 are part of the Portland Hills Fault Zone (PHFZ) at a distance of 4, 7, and 10 kilometers, respectively, southwest of the project area. The Lacamas Lake fault is located approximately 11 kilometers northeast of the project area. The Grants Butte fault is located approximately 16 kilometers southeast of the project area.

Based on published information, the maximum plausible magnitude for local shallow crustal earthquakes is thought to be no greater than M6.5 (Mabey et al. 1993); however, Wong et al. (2000) indicate a M6.8 to M7.1 is also possible. Madin (1994) suggests that faulting in this region occurred primarily during the Pleistocene and that there has been no late Pleistocene or Holocene faulting within the project area. Mabey et al. (1993) indicate that the few moderate earthquakes that have originated near the project area during the brief recorded history have been crustal earthquakes. Exhibit 3-14 presents details on possible earthquake sources. The locations of local faults presented in Exhibit 3-14 are shown on Exhibit 3-3. The recurrence rate of maximum plausible magnitude crustal earthquakes within the project area is approximately 1,000 to 2,000 years (Bott and Wong 1993). Displacement at these faults may occur at the ground surface. The PGA is estimated to be approximately 0.3 to 0.43g (top of Troutdale) for the project during a PHFZ rupture (Parsons Brinkerhoff 2009, Wong et al. 2000).

Exhibit 3-14. Possible Earthquake Sources

Earthquake Source	Distance from CRC Project Area (km)[a,c]	Magnitude Max (M_w)[a]	Length (km)[a]	Dip[a,b,c]	Slip Rate (mm/yr)[c]	Most recent deformation[b,c] (Years ago)
Cascadia Subduction	100-200	9.0	1,100	9°-11°E	>5	300
Intraplate	40-60	7.5	~1,000	>9°E	>5	>150
Crustal						
Portland Hills Fault	6	6.6-7.1	49	70°SW	<0.2	<1.6Ma
East Bank Fault	4	6.8-7.1	29	70°NE	<0.2	<15 ka
Oatfield Fault	10	6.5-6.9	29	70°SW	<0.2	<1.6Ma
Lacamas Lake Fault	11	6.5-6.9	24	>75° SW	<0.2	<750ka
Grant Butte Fault	16	6.2-6.5	10	90°	<0.2	<750ka

a Wong et al 2000.
b Gregor et al. 2002.
c Personius 2002, information is approximate.
Km = kilometer
mm = millimeter
yr = year
Ma = Million years
Ka = Thousand years

3.9.4.2 Earthquake Effects

Effects from earthquakes result from: 1) ground motion, 2) soil liquefaction, 3) lateral spreading, 4) seismic-generated water waves, and 5) earthquake-induced landslides.

Ground Motion

Ground motion relates to the amount of shaking that occurs during an earthquake as soil particles move back and forth from a seismic wave. This movement is described as the particles change position or acceleration over time. Ground motion during an earthquake creates potential for building and bridge collapse as well as road failure. Certain soil types may amplify ground motion through low impedance and resonance effects from reflection and trapping of surface waves (Pratt et al. 2001). Severe ground motion disrupts building and bridge load balances, causing unequal weight distribution that can result in structure collapse.

The amount of ground motion can be estimated in the field through deterministic and probabilistic approaches. Limited ground response analyses were performed on Bent 1 and Bent 2 located along the Columbia River (Shannon & Wilson 2009). Ground motion parameters were developed for three design events of different recurrence intervals for the preliminary engineering (as required by ODOT and WSDOT). Based on a soft rock Uniform Hazard Spectra (UHS) designation (USGS 2002) the following events were evaluated 1) the 2,500 year upper level

Safety Evaluation Earthquake (SEE) 2) 1,000 year "No Collapse" event and 3) 500 year lower level Functional Evaluation Earthquake (FEE) "Serviceability" event.

Shannon & Wilson (2009) used probabilistic earthquake deaggregation results from the USGS Probabilistic Seismic Hazard Analysis (PSHA) to develop seismogenic-source-specific spectra and guide the selection and scaling of input time histories.

The data indicate that significant contributions to ground motion are from both shallow crustal sources and Cascadia Subduction Zone (CSZ) mega-thrust sources, where shallow crustal sources are the principle hazard contributors (Shannon & Wilson 2009).

The PGA on rock (top of Troutdale Formation) is estimated to be approximate: 1) 0.41g for the 2,500 year recurrence SEE event, 2) 0.274g for the 1,000 year recurrence "No Collapse" event, and 3) 0.196g for the 500 year recurrence, "Serviceability" or FEE event (Parsons Brinkerhoff 2009, Shannon & Wilson 2008).

Based on data collected for the LPA, the subsurface conditions for the project range from a AASHTO site class C (dense soils [360 to 760 meter per second]) to class E (soft soils [< 180 meter per second]) (Parsons Brinkerhoff 2009; Shannon & Wilson 2008).

Liquefaction and Settlement

Soil liquefaction occurs when ground shaking induces cyclic shear stresses that break grain-to-grain contact in saturated unconsolidated soils (Castro 1987). This causes the material to rapidly change its physical properties and behave more like a liquid than a solid. Liquefiable soils tend to be fairly young, loose granular soils (sand as opposed to clay) that are saturated with water (NRCS 2004). As rotating soil particles settle into open pore space, water in the pores is expelled and the pore-water pressure increases as shear strength is lost. The rapid increase in pore-water pressure reduces the effective stress to zero (Johnson and DeGraff 1988). Unsaturated soils do not liquefy, but may settle during an earthquake (Mabey et al. 1993). Consequently, as the soil material strength is lost structures such as roads, buildings, and bridges may be subjected to foundation settlement due to loss of effective stress. These structures may sink into the subsurface or collapse as a result of soil liquefaction. Liquefied soil can exert high pressure on retaining walls and cause them to tilt. The pressure on the wall and loss of soil strength can cause settlement of the wall and destroy the structure.

Liquefiable soils typically occur in saturated sediments where the groundwater table is no deeper than 30 feet (Mabey et al. 1993). The greatest thickness of liquefiable soils in the project area is encountered in the Quaternary alluvial unit (Qal). Catastrophic flood deposits (Qff and Qfc) are typically too dense to be considered liquefiable soils. Soil liquefaction hazard is greatest within mapped Qal areas from Columbia Boulevard in Oregon north to approximately Fourth Street, Burnt Bridge Creek, and Salmon Creek in Washington. Exhibit 3-15 presents the liquefaction susceptibility of the project area. Simplified procedures were used to assess liquefaction triggering during a seismic event. The results of the analysis indicate that all sites in the project area south of the Columbia River may experience liquefaction during a design earthquake event (Parsons Brinkerhoff 2009). Liquefaction effects are expected to extend to depths greater than 75 feet bgs and liquefaction induced settlement may occur up to 12 to 30 inches (Parsons Brinkerhoff 2009).

PRELIMINARY

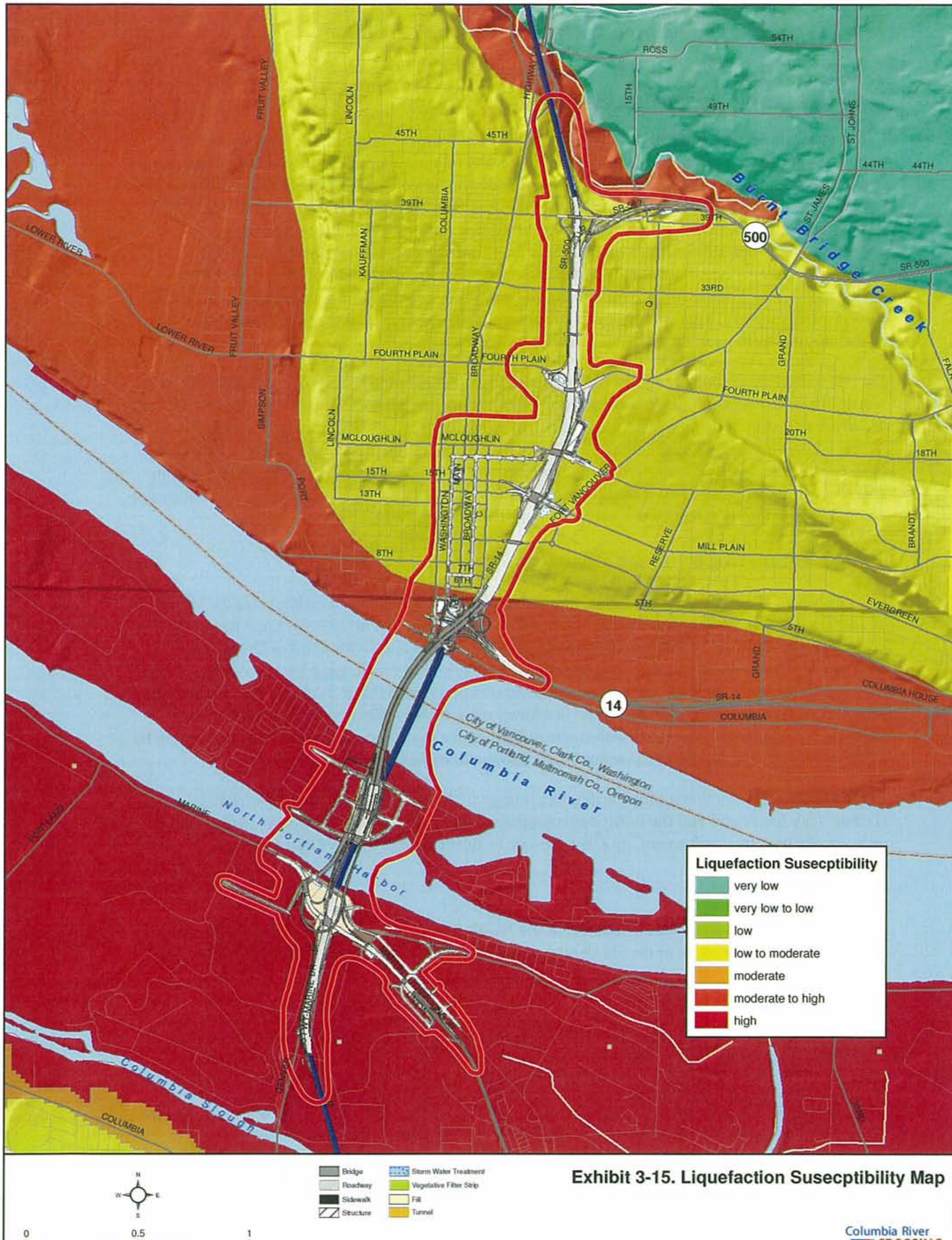


Exhibit 3-15. Liquefaction Susecptibility Map

Columbia River CROSSING

Liquefaction-Induced Lateral Spreading

Lateral spreading occurs as large, surficial blocks of soil moves horizontally in response to earthquake ground motion and as a result of increases in pore water pressure causing liquefaction in a subsurface layer. Ground displacement generally occurs on slopes of less than 3 degrees and moves toward unsupported banks such as a river or stream channels (Bartlett and Youd, 1992). Lateral spreading can compress or buckle building foundations, bridge footings, roadways, pipelines, and other utilities built on or across the failure (Youd 1993). Localized lateral spreading may also occur around in-water bridge piers where severe scour has created over-steepened slopes. Failure of these slopes during a seismic event will induce large lateral forces on in-water bridge piers. This is currently a problem for the existing in-water bridge piers and is a potential long-term problem for new in-water bridge piers.

Lateral spreading could potentially occur along the north and south banks of the Columbia River, North Portland Harbor, and Columbia Slough in Oregon; and Burnt Bridge Creek, Salmon Creek, the Mocks Bottom area in Washington, and near in-water piers. Possible liquefaction-induced lateral spreading may be as much as 30 to 60 inches of lateral displacement during a PHFZ or CSZ event (Parsons Brinkerhoff 2009). Displacement may occur between 5 and 10 feet within 250 feet of the Columbia River bank in the vicinity of Bent 1 of the existing bridge, and between 1 and 5 feet within 650 feet of the bank (Shannon & Wilson 2009).

3.9.4.3 Rating of Earthquake Hazards

The earthquake hazards discussed above have been given a quantitative rating scale by Mabey, et al. (1993), Mabey, Madin, and Palmer et al. (1994), and Mabey et al. (1997). Each hazard is given a rating of A to D (A for areas with the greatest hazard and D for areas with the least hazard). This rating is based on the greatest or least likelihood for damage by any combination of earthquake hazards. Relative earthquake hazards are shown in Exhibit 3-16 and are categorized according to the methodology described in Mabey et al. (1994). Relative earthquake hazard analysis for CRC was conducted with maps published for the Vancouver 1:24,000 quadrangle by Mabey et al. (1994) and for the Portland 1:24,000 quadrangle by Mabey et al. (1993).[5,6]

Exhibit 3-16 indicates that a high earthquake ratings of A and B were given to North Portland Harbor, Hayden Island and the north embankment of the Columbia River. A low earthquake rating was given to Vancouver City Center north to Burnt Bridge Creek Drainage.

3.9.5 Volcanoes

As the Juan De Fuca plate subducts beneath the North American crustal plate, a significant amount of water is brought to deeper depths of the upper mantle with the subducting slab. The

---

[5] An updated earthquake hazard map has been published for Clark County at a scale of 1:100,000 (Palmer 2004). The City of Vancouver uses this map for land use planning. However, the 2004 Clark County map was not used for this analysis. The 2004 Clark County Site Class map employs a different hazard evaluation method than the 1993 and 1994 maps. An updated map for the Portland area using hazard evaluation similar to the 2004 Clark County map has not been published. As a result a consistent comparison could not be made using these different map sets. In addition, the use of the 1993 and 1994 maps are more useful for analysis because the maps have a higher resolution.

[6] Cited maps should not be used to make construction design decisions for the CRC project area. Only a site-specific geotechnical investigation performed by a qualified geologist or engineer can adequately assess the potential for damage from soil liquefaction, ground motion amplification, or earthquake induced landslides. The 1993 and 1994 relative earthquake hazard maps are intended to provide a source of comparable information.

water lowers the melting temperature of the mantle rock, and the more buoyant magma above the slab rises upward. This produces a line of volcanoes that tend to parallel the oceanic trench at the subduction zone boundary known as the Cascade Mountain Range that stretches from northern California to British Columbia, Canada. Several of these volcanoes, Mount St. Helens, Mount Adams in Washington, and Mount Hood in Oregon, are located within 70 miles of the CRC project area (Exhibit 3-17). The Boring Lava Field volcanoes are a smaller series of volcanic eruptions including possibly up to 95 vents within 25 miles of Portland.

Volcanoes in the region pose a variety of hazards. Hazardous geologic events that nearby erupting volcanoes are capable of producing include: 1) ash fall 2) pyroclastic flows 3) lava flows, 4) debris avalanches, and 5) lahars. Volcanoes commonly repeat their past behavior. Thus, it is likely that the types, frequencies, and magnitudes of past activity will be repeated in the future (Scott et al. 1995).

3.9.5.1 Volcanic Hazards

Volcanic ash (tephra) consists of small pulverized pieces of rock and glass ejected during an eruption. Ash is hard, abrasive, and mildly corrosive. Ash has a low density and small particle size which gives ash the ability to spread over broad areas by wind. The ash begins to fall when the energy needed to keep the particles in the air diminishes. The size of ash particles that fall to the ground generally decreases exponentially with increasing distance from the volcanic vent in the prevailing wind direction (Wolfe and Pierson 1995; Scott et al. 1997). Tephra fragments larger than a few centimeters typically do not fall more than a few miles from the vent and are not likely to impact the project area.

Pyroclastic flows are avalanches of very hot mixtures of volcanic rock fragments and gases that descend a volcano's flanks at speeds of more than 200 miles per hour (Wolfe and Pierson 1995; Scott et al. 1995; Scott et al. 1997). Pyroclastic flows are generally denser than the surrounding air and typically follow topographic low areas like valley bottoms, but are also capable of overtopping ridges. Pyroclastic flows can travel several miles.

Lava flows are streams of molten rock that erupt from a volcanic vent. The lava typically follows topographic low areas and move slowly downslope. The distance a lava flow can travel depends on viscosity, volume, slope, and obstructions to the flow (Miller 1989). Because of their high viscosity, andesite, dacite and rhyolite lava typical of Cascade volcanoes, lava flows are typically from short, thick flows or domes close to the volcanic vent (Wolfe and Pierson 1995, Scott et al. 1995).

Debris avalanches are sudden and very rapid movement of a massive landslide as a result of volcanic activity. The magma beneath the volcano produces warm acidic ground water that circulates in cracks and porous zones inside volcanoes (Wolfe and Pierson 1995). The acidic water weakens the rock. Volcanic activities such as earthquakes or eruptions can trigger a catastrophic failure of large portions of the weak volcanic edifice and create chaotic mixtures of water, soil, and rock debris that move rapidly downslope away from the volcano (Scott et al. 1995; Myers and Brantley 1995; Miller 1989).

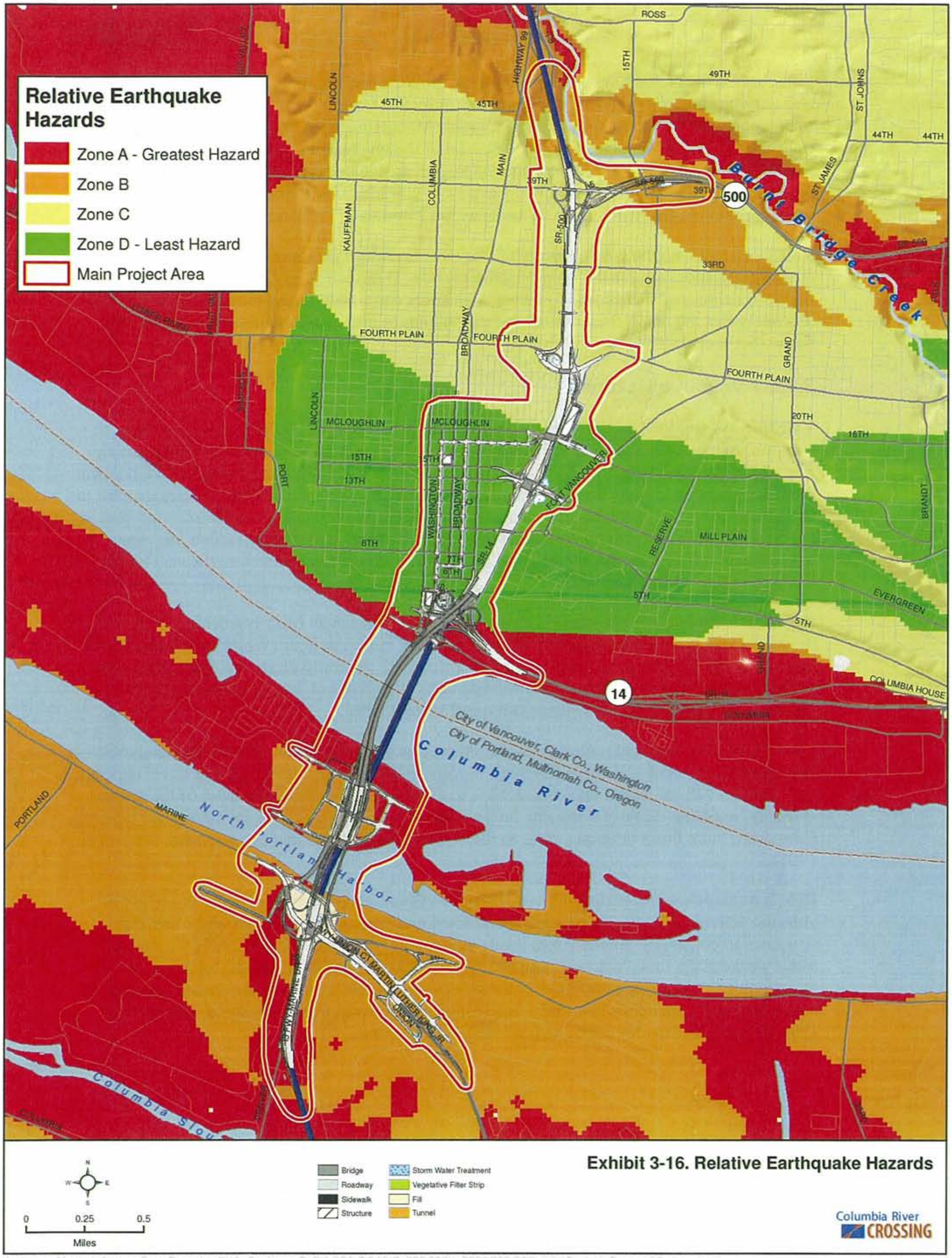


Exhibit 3-16. Relative Earthquake Hazards

Columbia River CROSSING

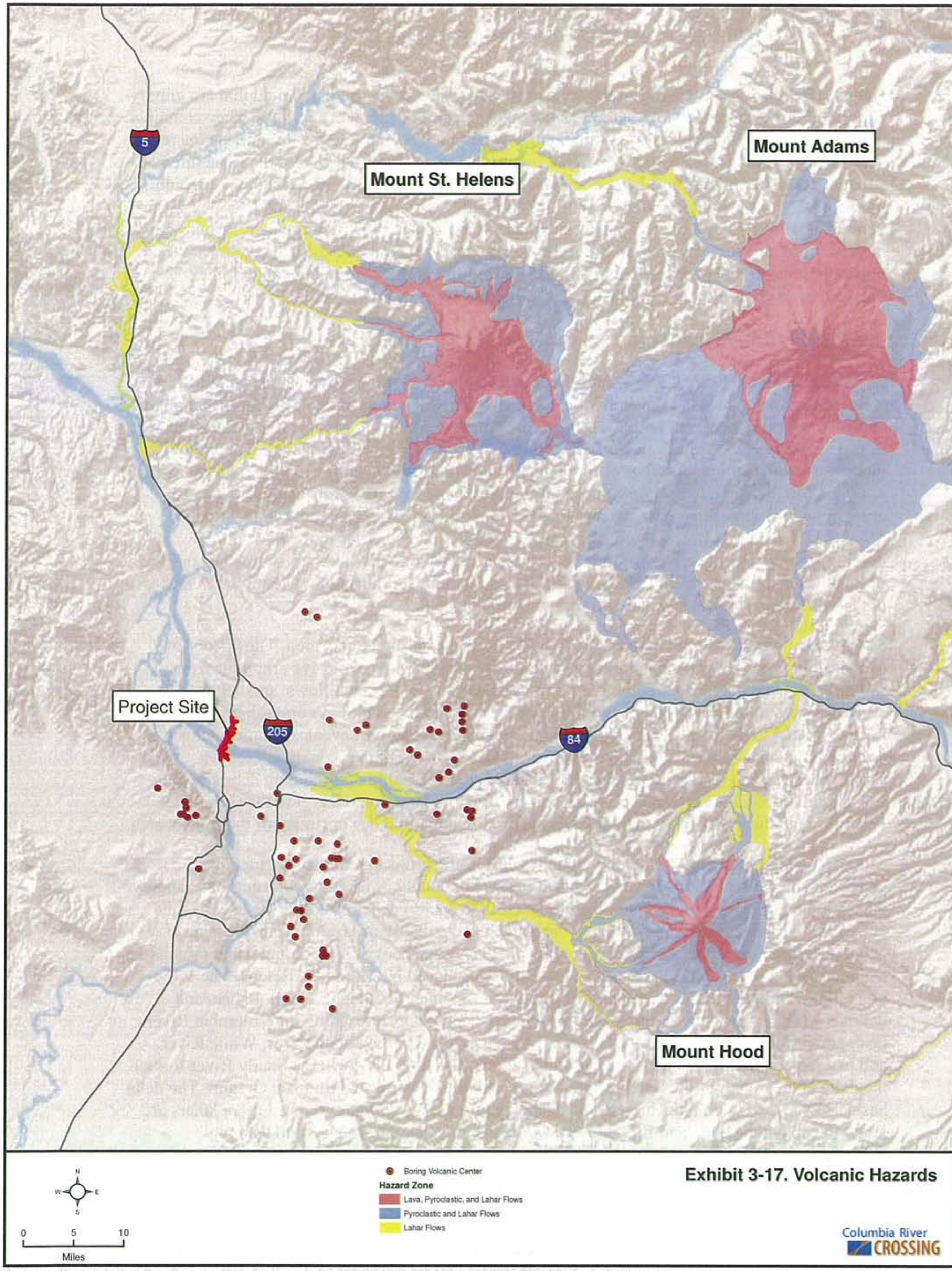


Exhibit 3-17. Volcanic Hazards

Lahars (Debris Flows or Mudflows) are mixtures of water, rock, sand, and mud that are gravity-controlled flows channeled into valleys as they move downhill (Scott et al. 1995). They contain a high concentration of rock debris giving them a consistency resembling freshly mixed concrete to very muddy water. The rock (60-90 percent by weight) to water ratio provides them the internal strength necessary to transport huge boulders, buildings, and bridges and exert extremely high impact forces against objects in their paths (Wolfe and Pierson 1995, Myers and Brantley 1995, Scott et al. 1995). They can travel between 20 and 40 miles per hour for more than 50 miles, and increase volume 3 to 5 times as they move downstream. Structural damage can result from the impact of large boulders or logs carried in the flows, from high drag and buoyancy forces imposed by the dense fluid, by abrasion, and by burial (Wolfe and Pierson 1995).

3.9.5.2 Nearby Volcanoes

Mount St. Helens is located approximately 46 miles northeast of the project area. Mount St. Helens is known to have had several large explosive eruptions in its past. The most recent notable explosive eruption occurred on May 18th, 1980. Volcanic activity at Mount St. Helens is capable of producing eruptions of ash (tephra), lava flows, pyroclastic flows, and lahars. The probability that ten or more centimeters (four or more inches) of tephra from a large eruption will fall as far as 60 km (40 mi) directly east of Mount St. Helens is 20 percent; the probability that such an eruption would deposit ten or more centimeters (four or more inches) 60 km (40 mi) west of Mount St. Helens is between 1 and 2 percent. Lava flows and pyroclastic flows would be confined to the general vicinity of the vent (Wolfe and Pierson 1995). Lahars would be confined to established drainages from the mountain. The southernmost drainage for Mount St. Helens is the Lewis River which is downstream from the project area.

Mount Adams is located approximately 70 miles northeast of the project area. The history of Mount Adams has shown a smaller range of eruptive styles. Large explosive eruptions from Mount Adams are rare. More commonly, Mount Adams generates lava flows, smaller ash eruptions (less than a few kilometers/miles extent), and lahars. Lava flows and ash eruptions have been restricted to the immediate vicinity of the mountain during past events. Mount Adams has erupted little during the past 10,000 years. Consequently much of the mountain has been subjected to erosion that has created steep, unstable slopes capable of producing debris flows (Scott et al. 1995). Lahars and debris flows from Mount Adams could travel to the Columbia River through the Wind and Klickitat Rivers approximately 60 miles upstream of the project area.

Mount Hood is located approximately 50 miles east of the project area. Mount Hood has produced volcanic eruptions for thousands of years, principally as lava, pyroclastic flows, and lahars, although numerous debris avalanches have also occurred. The eruptive history over the last 30,000 years has been dominated by the growth and collapse of lava domes which can generate pyroclastic flows and lahars (Scott et al. 1997). Episodes of ash column generation have been noted, but would have impacts similar to those produced by Mount St. Helens. The prevailing wind direction is to the east 70 percent of the time (Scott et al. 1997). Lahars and debris avalanches produced from Mount Hood have been mapped reaching the Columbia River upstream of the project. Numerous lahars have been mapped in the Sandy River, White River, and to a lesser extent Hood River. Lahars and sediment-rich floods down the Sandy River formed the delta at the mouth of the Sandy River in the Columbia River near Troutdale Oregon. The delta has narrowed the Columbia River and pushed it against the Washington shore. Future lahars are likely to expand the delta and further narrow the existing channel, which could lead to progressive bank erosion and inundation of land in Washington (Scott et al. 1997). A lahar from an eruption at Mount Hood would enter the Columbia River approximately 10 miles upstream from the project area (Exhibit 3-17).

Boring Volcanic Field consists of possibly up to 90 volcanic centers that occurred in the Portland-Vancouver metropolitan area from 2.7 million to less than 500,000 years ago (Evarts et al. 2009). Most of these were originally small cinder cones and some are low, broad lava shield volcanoes. All of the volcanic centers that have been identified are extinct, but the volcanic field may be quiescent. The most recent eruption at the eastern edge of the field is 57,000 years ago. However, the probability of an eruption is low and the occurrence would likely be preceded by earthquakes thus providing some advanced warning.

This page intentionally left blank.

4. Long-term Effects

Long-term effects are the future effects from the operation and maintenance of the No-Build Alternative or the LPA on geologic and groundwater resources, or future effects to the operation and maintenance to the No-Build Alternative or LPA from geologic hazards (e.g., steep slopes, earthquakes, soil liquefaction, and volcanoes). These potential effects (adverse or beneficial) are assessed qualitatively based on the project team's current understanding of the natural and built environment.[7] If the assessment concludes that a "significant" adverse effect is associated with the LPA, than a minimization, avoidance or mitigation strategy is proposed in Chapter 6.

4.1 Long-term Effects from Geologic Hazards

4.1.1 Soils Hazards

Soils susceptible to erosion, shrink-swell soils, and corrosive soils have been identified in the main project area. Soils with erosion hazard ratings of moderate to severe are located in the Burnt Bridge Creek drainage area along SR 500, near the I-5 and Mill Plain Boulevard Intersection, and south of Evergreen Boulevard on the east side of I-5. Adverse effects from soil erosion may include plugging of stormwater catch basins; deposition of soil and surface water on roadways; diminished surface water quality at Burnt Bridge Creek; and potential undermining of roadway and structures.

Soils with shrink-swell properties are also located in the Burnt Bridge Creek drainage area and at the eastern boundary of the main project area at the SR 14 interchange. Corrosive soils are present throughout the project area. Long-term physical and chemical interaction with shrink-swell and corrosive soils, respectively, may affect the longevity of roadway and below-grade structures.

4.1.1.1 No-Build Alternative

No potential long-term adverse effects to the No-Build Alternative from soil hazards are anticipated. Long-term adverse effects to Burnt Bridge Creek drainage, SR 500, and Mill Plain Boulevard are thought to be minimal due to developed vegetative cover, adequate stormwater management, and limited soil disturbing activities from operation and maintenance of the No-Build Alternative.

Effects on the integrity of roadways and built structures from shrink-swell and corrosive soils is thought to be minimal, because these elements have been built on engineered fill and periodic inspections and maintenance by WSDOT and ODOT.

[7] A significant adverse effect represent a substantial increase in project costs, a substantial delay in project schedule, long-term liability or harm, and/or a substantial diminishment to an environmental resource. As stated in 40 CFR 1502.2, "Effects shall be discussed in proportion to their significance," and "in a finding of no significant effect, there should be only enough discussion to show why more study is not warranted."

4.1.1.2 LPA

No long-term effects to the LPA from soil hazards are anticipated. The greatest potential for long-term effects from soil hazards is in the Burnt Bridge Creek area. Erosion will be minimized because the LPA will use vegetative plantings to stabilize soils, improve stormwater conveyance, and reduce topographic grades. In addition, the physical and chemical effects from shrink-swell and corrosive soils on structures are thought to be minimal because new roadways and structures will incorporate current material science into design and construction and structures will be built on structural fill.

The LPA would likely result in reduced long-term effects from soil hazards compared to the No-Build Alternative because of project improvements. However, LPA with highway phasing will likely not reduce the potential for long-term adverse effects from soil hazards to the Burnt Bridge Creek drainage area since construction would not extend to SR 500.

4.1.2 Steep Slopes and Landslides

Landslide hazard areas are typically defined as areas that, due to a combination of slope inclination, soil type, geologic structure and presence of water, are susceptible to failure and subsequent downhill movement. No active or historical landslides have been identified within the main project area. Steep slopes (slopes greater than 25%) that can contribute to slope failure have been identified near the SR 500 interchange. These slopes are associated with the Burnt Bridge Creek drainage area (Exhibit 3-12). However, these slopes only occupy a small portion of the main project area.

4.1.2.1 No-Build Alternative

No potential long-term adverse effects to the No-Build Alternative from steep slopes are anticipated. Steep slopes in the Burnt Bridge Creek drainage area are limited in their extent, and no current information suggests that significant mass movement is eminent. In addition each state DOT periodically inspects and evaluates steep slopes for warning signs of potential failure.

4.1.2.2 LPA

No potential long-term adverse effects to the LPA from steep slopes are anticipated. The LPA includes construction of the SR 500 and 39th Street interchange to connect eastbound and west bound traffic from SR 500 to I-5. This construction would require stabilization of steep slopes in the Burnt Bridge Creek drainage area that may employ retaining walls, embankments, slope grading, ground improvements, enhanced stormwater conveyance, and/or vegetative plantings.

The LPA would likely result in reduced long-term effects from slope failure (in terms of frequency and extent) compared to the No-Build Alternative because of improvements in design, construction, and stormwater conveyance systems. The No-Build Alternative would not include the future stabilization of existing steep slopes, which may have unforeseen long-term effects from slope failure.

4.1.3 Non-seismic Settling

Soil settling and consolidation can occur throughout the project area where compressible soils or non-structural fill exists. Settling around structures occurs as the load equilibrates to soil conditions over time. Settling can result in a variety of adverse effects such as cracks in roadways and compromised foundations.

4.1.3.1 No-Build Alternative

No potential adverse effects from the No-Build Alternative are anticipated. Settling of soil has predominantly occurred around existing roadways and structures. Settling has been observed at the former Hayden Island Landfill where construction debris has consolidated overtime resulting in cracks and depressions in the parking surfaces.

4.1.3.2 LPA

Potential long-term effects from settling around proposed roadway structures are thought to be significant if not correctly mitigated through geotechnical assessment. The greatest potential for settling is thought to be present on Hayden Island and the shoreline of the Columbia River where construction fill or dredge fill has been used to extend shorelines and fill depressions. Retained fill or cut and cover fill may also not be suitable for construction and result in long-term adverse effects from settling.

4.1.4 Earthquakes

The project area is located in a seismically active region capable of producing earthquakes up to M9 for Cascadian Subduction Zone (CSZ) mega-thrust event and/or M6.8 for a Portland Hills Fault Zone (PHFZ) seismic event. The greatest risk from earthquakes in the main project area is attributed to ground motion and liquefaction. The areas most susceptible to ground motion and liquefaction occur along the Columbia River, Hayden Island, and Burnt Bridge Creek (designated Hazard Zone A) due to soil characteristics, the presence of non-structural fill, and/or shallow water table. Adverse effects from earthquakes are significant if not mitigated correctly. Effects include impacts to public safety, structural damage, and economic disruption. Site-specific impacts are discussed in greater detail in the geotechnical data reports prepared by the project team to aid design. In addition, further geotechnical assessments are currently being conducted to fill data gaps on existing soil characteristics. Human activities and construction of any alternative would not affect magnitude or frequency of earthquakes in the project area.

4.1.4.1 No-Build Alternative

Long-term adverse effects from earthquakes would be significant for the No-Build Alternative. The No-Build Alternative would not include seismic upgrades to existing I-5 bridges. Construction codes used at the time of the original river-crossing bridge design contained no provisions for seismic construction. In addition bridge foundations were placed relatively shallow into unconsolidated sediment, which makes them vulnerable to ground motion.

Long-term adverse effects from liquefaction would be significant for the No-Build Alternative. The No-Build Alternative does not include ground improvements necessary to stabilize unconsolidated material or fill along the banks of the Columbia River on Hayden Island and around the Marine Drive interchange. Without ground improvements, existing soils and fill materials in these areas are susceptible to liquefaction during a major seismic event. Liquefaction could result in settlement and/or slope displacement of subsurface materials and deformation of ground improvements and roadway.

4.1.4.2 LPA

Long-term adverse effects from earthquakes would be significant for the LPA if not mitigated correctly. The design of the new bridge and new structures would be based on: new site specific geotechnical information; current understanding of earthquake science; and advances in earthquake engineering, material science, and construction techniques. The replacement bridges and related structures will be constructed to withstand the effects from projected ground motion during a major seismic event. This construction would include deeper foundations that anchor the main river crossing into the consolidated portion of the Troutdale Formation. In addition, seismic upgrades would be conducted on existing structures where applicable.

The LPA would include ground improvements to help withstand liquefaction from a major seismic event. Ground improvements may include the use of soil mixing, stone columns, jet grouting or other techniques to help stabilize soils that are susceptible to liquefaction. Ground improvements would be conducted along the banks of the Columbia River, Hayden Island at Tomahawk Island and Marine Drive, and Burnt Bridge Creek.

The potential for adverse effects from ground motion and liquefaction is significantly lower for the LPA compared to the No-Build Alternative due to improvements in design and construction.

4.1.5 Volcanoes

The project area is located in an active volcanic region capable of producing eruptions from Mount Hood, Mount St. Helens, and Mount Adams. Volcanoes in the region pose a variety of hazards including ash fall, pyroclastic flows, lava flows, debris avalanches, and lahars that have the potential to reach the project area. In addition volcanic activity would be linked to seismic affects. Construction or operation of any alternative would not affect volcanic activity in the project area.

4.1.5.1 No-Build Alternative

Long-term effects to the No-Build Alternative from volcanoes have the potential to be significant. Potential ash fall and lahars from Mount Hood have the potential to adversely affect the integrity of bridge structures and roadways. Lahars may rapidly add water volume and sediment to the Columbia River, which may cause severe scour to bridge pile caps and foundation. The No-Build Alternative would not include upgrades to existing structures and would be likely susceptible to the effects from a major volcanic event.

4.1.5.2 LPA

Long-term effects to the LPA from volcanoes have the potential to be significant. Potential ash fall and lahars from Mount Hood could adversely affect the integrity of bridge structures and roadways. Lahars may rapidly add water volume and sediment to the Columbia River, which may cause severe scour to bridge pile caps and foundation. However, these affects are thought to be reduced compared to the No-Build Alternative because of improvements to the structural stability of the LPA interchanges, and other noted project elements.

4.2 Long-term Effects to Resources

4.2.1 Geologic Resources

Geological resources such as fill, top soil, quarry rock, aggregate are present locally and may be used as a local resource for construction or processed to make concrete and asphalt. All earth and rock construction materials will be obtained from regulated and permitted operations.

4.2.1.1 No-Build Alternative

The No-Build Alternative includes no significant improvements to roadways and bridges in the project area. Demand for geologic resources would likely be limited to roadway, easement and bridge maintenance activities. Long-term beneficial effect on geologic resources from the No-Build Alternative would be represented as no additional strain on local surface mining resources. Counter to this beneficial effect is potential economic effects on the local mining and aggregate industries from unrealized income from project construction material needs.

4.2.1.2 LPA

The LPA includes construction of significant infrastructure to improve roadways, transit, and bridges. These improvements would use geologic resources for building materials during construction and maintenance. Long-term adverse effects can occur to geologic resources from the LPA if not mitigated correctly. These adverse effects would include environmental damage to natural areas and a commitment of geological resources to project construction. If properly mitigated these adverse effects are not thought to be significant because geologic resources would be obtained from state permitted operations. Beneficial effects from the LPA would be economic stimulus to local mining operations in Clark, Cowlitz, Skamania, and Multnomah counties due to demand for geologic resources.

4.2.2 Groundwater Resources

Hydrogeologic resources are utilized in the Washington and Oregon portions of the main project area. Groundwater is extracted for drinking water use in Vancouver, and is used to augment Portland drinking water. The Troutdale Aquifer System is a federally designated Sole Source Aquifer (SSA) because over 50 percent of the drinking water from the area is sourced from the TSSA and there are no alternative sources or combination of sources which could physically, legally, and economically supply all those who depend upon the aquifer system for drinking water. In addition, the City of Vancouver has designated a critical aquifer recharge area within the city limits. Two water stations (WS), WS-1 and WS-3, are just outside the main project area. Groundwater at these well-heads is treated for primary and/or secondary contaminants, such as microorganisms. Within the main project area groundwater quality and recharge are diminished by stormwater from PGIS infiltrating to groundwater and/or surface water. The aquifer also interacts with surface water of the Columbia River and Burnt Bridge Creek and provides a beneficial resource to plants, aquatic organisms and wildlife.

The Interstate 5 Columbia River Crossing August 2009 TSSA Technical Report provides information regarding the hydrogeologic conditions and beneficial use of the TSSA, proposed project construction activities, evaluates potential adverse effects to the TSSA as a result of project construction activities, and recommends mitigation measures to help ensure the TSSA is protected during project construction.

4.2.2.1 No-Build Alternative

The No-Build Alternative would maintain its current stormwater conveyance system with limited management and treatment. This would result in continued diminishment of the TSSA groundwater quality from PGIS stormwater. Diminishment of groundwater quality is thought to be localized to stormwater discharge areas; however, the degree of this impact is not well understood due to limited data. As such, adverse effects to groundwater quality from the No-Build Alternative are considered to be significant because of the economic importance of the aquifer.

4.2.2.2 LPA

The LPA would provide long-term management and treatment of stormwater generated from PGIS. Stormwater treatment and management facilities are planned throughout the project area. Specifically, stormwater will be collected and treated at sites near the SR 500 interchange, Fourth Plain, Mill Plain, SR 14, Hayden Island, and Delta Park. This would result in locally improved groundwater quality in the TSSA because stormwater will be treated resulting in infiltrated water with reduced contaminant load. In addition, recharge to the aquifer should increase due to better management controls of stormwater discharge rates and volumes into treatment facilities. Beneficial effects to groundwater quality from the LPA are considered significant relative to the No-Build Alternative.

The LPA would install an estimated 100 permanent structural piles below the water table into the top of the Troutdale Formation (greater than 100 feet deep) for construction of the Columbia River bridges, SR 14, and Mill Plain interchanges. The permanent piles and other related structures may have an effect on groundwater velocity and movement. Retaining walls constructed below the water table near SR 14, Hayden Island, and Delta Park may also alter the shallow groundwater flow direction depending on the depth of the walls and orientation to the direction of groundwater flow. The degree of these impacts, if any, are not well understood because of the complexities of this hydrogeologic system.

5. Temporary Effects

Temporary effects are potential short-term effects (3 to 5 years) to the No-Build Alternatives or the LPA from geologic hazards or effects from construction of the LPA to geologic resources. Because the timescale of short-term effects from construction is so small compared to geologic timescales, some effects from geologic hazards or to geologic resources are more appropriately addressed in Chapter 4, Long-term Effects. As such only potential effects relevant to a short timeframe are discussed below. These potential effects are assessed qualitatively based on the project teams' current understanding of the natural and built environment.

5.1 Temporary Effects from Geologic Hazards

5.1.1 Soils Hazards

Short-term effects from soil hazards pertain to erosion that would occur during construction activities that expose erosive soils to wind and stormwater. Construction activities would include, but are not limited to, excavation, fill, clearing, and grading. Limited construction activities are planned for the No-Build Alternative. It is estimated that the LPA will disturb approximately 415 acres of near surface soils as presented in table Exhibit 5-1. Temporary adverse effects from soil erosion may include plugging of stormwater catch basins; deposition of soil surface water on roadways; diminished surface water quality at Burnt Bridge Creek drainage area; and potential to undermining of roadway and structures.

5.1.1.1 No-Build Alternative

No short-term adverse effects from the No-Build Alternative to soil erosion are anticipated. Little to no soil disturbing activities that will expose soils will be conducted during the near term.

Exhibit 5-1. Summary of Ground Disturbance by Watershed

Watershed	Vegetated (acres)	Non-vegetated (acres)
Burnt Bridge Creek	0.1	55
Columbia River	0.6	240
Columbia Slough	0.2	105
Fairview Creek	1.3	10.5
Total	**2.2**	**410.5**

5.1.1.2 LPA

Short-term adverse effects from the LPA to soil erosion are anticipated. These effects can be significant if not correctly mitigated. Mitigation includes, but is not limited to, preparing and implementing stormwater pollution prevention plans and grading plans, hydroseeding, management of stockpiled fill, and other BMPs for erosion control. Short-term effects are most significant near the Columbia River, Burnt Bridge Creek, and Vanport wetlands, where surface water quality can be diminished.

It is anticipated that the LPA with highway phasing option are thought to have less of impact than the full build since the construction activities would be delayed.

5.2 Temporary Effects to Resources

5.2.1 Geologic Resources

Geologic resources such as aggregate, crushed rock, top soil and fill material may be used as raw materials for project construction. There are currently 33 permitted mines within 10 miles of the main project area. These mines are extracting sand and gravel aggregate, or extracting and crushing rock materials. These resources are not unique, but are limited locally. Short-term effects to resources include the expansion of new or existing mineral locations which may result in environmental damage and/or economic benefit.

5.2.1.1 No-Build Alternative

No short-term effects for the No-Build Alternatives are anticipated. The No-Build Alternative would not require any additional need for materials.

5.2.1.2 LPA

Short-term adverse effects on geologic resources from the LPA include use of existing local rock and aggregate resources; expansion of existing surface mines; and potential for opening of new surface mine sites. The demand for material suitable for the construction requirements of the project design could stress the local and regional resources. These potential adverse effects would be less significant for LPA with highway phasing than compared to the LPA.

5.2.2 Groundwater Resources

Short-term adverse effects on geologic resource from the LPA may also include the installation of up to 1,500 temporary in-water piles for work bridges (Exhibit 1-5). Installation of piles would be into relatively shallow, unconsolidated sediments, but may extend to the top of the Troutdale Formation. Pile installation may affect the movement of groundwater baseflow into the Columbia River and/or North Portland Harbor. However, the significance of these effects, if any, is not well understood.

6. Proposed Mitigation for Adverse Effects

This section describes measures that could be included with the LPA to prevent, minimize, or offset long-term and temporary effects to geology, soil, and groundwater resources, or the effects to structures and landforms from geologic hazards. Some of these measures may be included in the project design with the issuance of a Record of Decision (ROD) and will be further refined during preliminary and final engineering and the design phases of the project.

6.1 Geologic Hazards

The following measures were identified to address geologic hazards.

- Adequately assess existing geologic hazards such as, but not limited to, faults, ancestral landslides, steep cut slopes, and soil liquefaction during the preliminary engineering stage of the project. Site-specific assessments should include the use of geotechnical drilling, test pitting, material testing, geophysical techniques and/or inclinometers and monitoring wells installation and monitoring. Assessments will comply with:
    - WSDOT Geotechnical Design Manual, M46-03 (GDM)
    - ODOT Geotechnical Design Manual
- Avoid to the extent possible steep slopes identified in the Burnt Bridge Creek drainage area or employ engineering design to mitigate potential effects from steep slopes.
- Adequately assess the use of soil stabilization techniques used to minimize liquefaction of soils during the preliminary engineering stage of the project. Stabilization techniques include the use of compaction grouting, jet grouting or the use of stone columns.
- Design and implement seismic upgrades to existing and future structures. Upgrades must adhere to applicable Federal, State and County building codes or standards, and use elements that include the use of drilled shafts, driven piles, abutments and retaining walls. Structural designs will take into consideration stormwater infiltration or other future changed conditions near shallow footings, retaining walls and/or other structures that could increase the potential for soil liquefaction during a future seismic event. Structure designs will comply with and adhere to:
    - AASHTO LRFD Bridge Design Specifications
    - AASHTO Guide Specifications for LRFD Seismic Bridge Design
    - WSDOT Bridge Design Manual, LRFD M 23-50 (BDM)
    - ODOT Bridge Design and Drafting Manual (BDDM)
    - City of Vancouver Municipal Code (VMC) Chapter 20.740.130 Critical Areas Protection - Geologic Hazards Areas.
- Implement erosion control and stormwater pollution prevention plans (SWPPP) during construction. SWPPP will comply with and adhere to:

- WSDOT Standard Specifications for Road, Bridge and Municipal Construction M 41-10
- ODOT Erosion Control Manual
- City of Vancouver VMC Chapter 14.24, Erosion Control
- City of Vancouver VMC Chapter 14.25, Stormwater Control
- City of Vancouver VMC Chapter 14.26, Water Resource Protection
- COP Erosion and Sediment Control Manual

Inspection and observation monitoring and reporting would be conducted throughout the project to ensure the appropriate measures are being conducted.

6.2 Geologic and Groundwater Resources

The following measures were identified to address geologic hazards.

- Recycle or reuse to the extent practical aggregate, quarry rock, asphalt and concrete materials.
- Evaluate local geologic resources for future building materials.
- Stormwater treatment facilities would be located to the extent possible away from City of Vancouver well head protection zones for WS-1 and WS-3.
- Adhere to City of Vancouver VMC Chapter 14.24, Erosion Control, 14.25, Stormwater Control, and 14.26 Water Resources Protection.
- Implement avoidance and mitigation measures that will minimize adverse effects to the TSSA.

7. Permits and Approvals

This section provides a summary of potential permits and approvals needed for the LPA in regard to geologic hazards and/or geologic and groundwater resources. Permit and/or approvals may overlap between federal, state and local requirements.

7.1 Federal

Federal Highway Administration (FHWA) requires that pile and shafts be designed, constructed and inspected under federal guidelines. Publication Nos. FHWA-HI-97-013 and FHWA NHI-03-018.

FHWA requires that soils be mechanically stabilized under federal guidelines. Publication No. FHWA-SA-96-071.

The U.S. Army Corps of Engineers (USACE) requires a Section 404 Permit for any activities that place or remove fill in "waters of the U.S." Exact permit requirements would depend on circumstances and activity. This project would be analyzed under an individual permit.

The USACE requires a Joint Aquatic Resources Permit Application (JARPA) for Washington waters and a Joint Permit Application (JPA) for Oregon waters.

The U.S. Environmental Protection Agency (USEPA) requires information on the groundwater system underlying the proposed project, including information about the federally designated TSSA and about groundwater underlying the Oregon portion of the project area and an evaluation of the potential impacts of the project area on the groundwater resource.

7.2 State

The Oregon Department of State Lands (DSL) has jurisdiction over removal-fill activities in "waters of the state." A permit from DSL is required for removal or fill of over 50 cubic yards in the waters within the main project area.

The Oregon DSL would likely require an easement to place structure in the Columbia River. The Washington Department of Natural Resources would also likely require an easement to place structure in the Columbia River.

The Washington Department of Ecology (Ecology) and Oregon DSL require general construction stormwater permits. This permit is issued by the states based on federal guidance within the National Pollutant Discharge Elimination System under Section 402 of the Clean Water Act.

The Oregon Water Resources Department (OWRD) and the Washington Department of Ecology requires 'start cards' for geotechnical holes, monitoring wells, piezometer, and injection wells.

7.3 Local

The City of Vancouver requires a pre-application conference for all projects subject to Vancouver Municipal Code (VMC) Chapter 20.740 Critical Areas Protection, unless waived by the planning office.

The City of Portland requires that all projects conduct permit applications following City of Portland Code (CPC) Title 44.10.070 Permit Applications.

The City of Vancouver requires a permit for grading, cut, fill and stockpiling under VMC Chapter 20.210.090, Decision Making Procedures.

The City of Portland requires that grading, cut, fill and stockpiling under CPC Title 24.10 Grading Permit Fees and CPC Title 24.70 Clearing Grading and Erosion Control.

The City of Vancouver requires that construction must conform to VMC Chapter 20.740.130, Critical Areas Protection - Geologic Hazard Areas.

The City of Portland requires that seismic upgrades to existing buildings must conform to CPC Title 24.85 Building Regulations.

The City of Vancouver requires that construction must conform to VMC Chapter 20.740.120 Critical Areas Protection - Frequently Flooded Areas.

The City of Portland prohibits building in frequently flood areas or cause increased flood heights under CPC Title 24.50.

The City of Vancouver requires that erosion prevention and sediment control be conducted under (VMC) Chapter 14.24 Water and Sewers – Erosion Control.

The City of Portland requires that erosion prevention and sediment control be conducted under CPC Title 10 Erosion and Sediment Control Regulations.

The City of Vancouver requires that stormwater control be conducted under VMC Chapter 14.25 Water and Sewers – Stormwater Control.

The City of Portland requires that stormwater by controlled under CPC Title 17.38, Drainage and Water Quality.

The City of Vancouver requires that surface, storm, and groundwater resources be protected under VMC Chapter 14.26 Water and Sewers – Water Resources Protection.

The City of Portland requires that groundwater resources be protected under CPC Title 21.35, Well Head Protection.

The Multnomah County Drainage District manages the levee system in Peninsular Drainage Districts 1 and 2 which are separated by I-5 in the CRC project area. The drainage districts are a special purpose local government organized under Oregon Revised Statute (ORS) Chapter 547. The Multnomah County Drainage District provides for the uniform management of the entire levee-protected area from the railroad embankment adjacent to North Portland Road on the west, and eastward to the Sandy River. ORS Chapters 190 and 195 require that the drainage districts, state agencies, and the local governments in the area cooperate and coordinate their activities.

8. References

Allen, J.E., M. Burns, and S.C. Sargent. 1986. Cataclysms on the Columbia. Timber Press, Portland, Oregon.

Allen, J.E., S.F. Burns, and M. Burns. 2009. Cataclysms on the Columbia. Ooligan Press, Portland, Oregon.

Atwater, B.F., and E. Hemphill-Haley. 1997. Recurrence Intervals for great Earthquakes of the past 3,500 years at northeastern Willapa Bay, Washington. U.S. Geological Survey, Professional Paper 1576.

Atwater, B.F., M.R. Satoko, S. Kenji, T. Yoshinobu, U. Kazue, and D.K. Yamaguchi. 2005. The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America. U.S. Geological Survey, Professional Paper 1707.

Baldwin, Ewart. 1976. Geology of Oregon. Kendall Hunt Publishing Company, Dubuque, Iowa.

Bartlett, S.F., and T.L. Youd. 1992. Case Histories of Lateral Spreads Caused by the 1964 Alaska Earthquake in Case Studies of Liquefaction and Lifeline Performance During Past Earthquakes: National Center for Earthquake Engineering Research Technical Report NCEER-92-0002, v. 2, 127 p.

Beeson, M.H., T.L. Tolan, and I.P. Madin. 1991. Geologic Map of the Portland Quadrangle, Multnomah and Washington Counties, Oregon, and Clark County, Washington. Geologic Map Series 75. Oregon Department of Geology and Mineral Industries. Salem, Oregon. Scale 1:24,000.

Barnett, E.A., C.S. Weaver, K.L. Meagher, R.A. Haugerud, Z. Wang, I.P. Madin, Y. Wang, R.E. Wells, R.J. Blakely, D.B. Ballantyne, and M. Darienzo. 2009. Earthquake Hazards and Lifelines in the Interstate 5 Urban Corridor: Woodburn, Oregon, to Centralia, Washington. U.S. Geological Survey, Scientific Investigations Map 3027. Scale 1:150,000 [http://pubs.usgs.gov/sim/3027].

Bott, J.D.J., and I.G. Wong. 1993. Historical earthquakes in and around Portland, Oregon. Oregon Geology. V. 55, no. 5, P. 116-122.

Bretz, H.J., H.T. Smith, and G.E. Neff. 1956. Channeled Scablands of Washington: New data and interpretations. Geological Society of America. Bulletin. V. 67, no. 8. P. 957-1049.

Castro, G. 1987. "On the Behavior of Soils During Earthquakes-Liquefaction." Soil Dynamics and Liquefaction. Ed. by A.S. Cakmak. Developments in Geotechnical Engineering Vol. 42. Elsevier. New York, New York.

Collins, C.A., and T.M. Broad. 1993. Estimated average annual ground-water pumpage in the Portland Basin, Oregon and Washington. 1987-1988: U.S. Geological Survey Water-Resources Investigations Report 91-4018, 26.

COP (City of Portland). 2008. City of Portland Stormwater Management Manual, Revision 4. Prepared by the City of Portland, Oregon. August 1, 2008.

COP. 2010. Portland Water Bureau 2010 Drinking Water Quality Report.

COV (City of Vancouver) 2009. Available at: http://www.cityofvancouver.us/water.asp?menuid=10465&submenuid=17052&itemID=17060

Das, Braja M. 1983. Fundamentals of Soil Dynamics. Elsevier. New York, New York.

Dewey, J.W., M.G. Hopper, D.J. Wald, V. Quitoriano, and E.R. Adams. 2002. Intensity Distribution and Isoseismal Maps for the Nisqually, Washington, Earthquake of 28 February 2001. U.S. Geological Survey Open File Report 02-346.

EPA (United States Environmental Protection Agency). 2006. Final Support Documents for Sole Source Aquifer Designation of the Troutdale Aquifer System. Region 10, Seattle Washington. July 2006.

Evarts, R.C., R.M. Conrey, R.J. Fleck, and J.T. Hagstrum. 2009. The Boring Volcanic Field of the Portland-Vancouver area, Oregon and Washington: Tectonically anomalous forearc volcanism in an urban setting, in O'Conner, J.E., Dorsey, R.J., and Madin, I.P., Volcanoes to Vineyards: Geologic Field Trips through the Dynamic Landscape of the Pacific Northwest: The Geological Society of America Field Guide 15, 2009. p. 253-270.

FEI (Foundation Engineering Inc. 2010. I-5: Marine Drive – Victory Blvd. Section Final Geotechnical Data Report Multnomah County, Oregon. Prepared for David Evans and Associates. Portland, Oregon. January 13.

Geomatrix Consultants. 1995. Final Report: Seismic Design Mapping, State of Oregon. Prepared for Oregon Department of Transportation. Salem, Oregon. Personal Services Contract 11688. January 1995. Project No. 2442.

Gray, J.J., G.R. Allen, and G.S. Mack.1978. Rock and Mineral Resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon.

Gray & Osborne, Inc. 1996. Water System Comprehensive Plan. City of Vancouver. November 1996.

Green, G.L. 1983. Soil Survey of Multnomah County, Oregon. United States Department of Agriculture, Soil Conservation Service. U.S. Government Printing Office. p. 146.

Gregor, N.J., W.J. Silva, I.G. Wong, and R.R. Youngs. 2002. Ground-Motion Attenuation Relationships for Cascadia Subduction Zone Megathrust Earthquakes Based on a Stochastic Finite-Fault Model. Bulletin of the Seismological Society of America. Vol. 91 No. 5, 1923-1932, June 2002.

HDR Engineering, Inc. 2006. Draft Water System Comprehensive Plan – 2006. City of Vancouver, Washington. March 2006.

Hoiland, Richard. City of Vancouver personnel communication with Eric Roth, Parametrix, April 14, 2010.

Johnson, R.B., and J.V. DeGraff. 1988. Principles of Engineering Geology. John Wiley and Sons. New York, New York.

Johnson, C.N., S.P. Palmer, and J.L. Poelstra. 2005. Rock Aggregate Resources Lands Inventory Map for Clark County, Washington. Washington Division of Geology and Earth Resources. Resource Map 1. October 2005.

Kelsey, H. M., Nelson, A. R. Witter, R. C., and Hemphill-Haley, E. 2005, Tsu-nami history of an Oregon coastal lake reveals a 4,600 year record of great earthquakes on the Cascadia subduction zone, Geological Society of America Bulletin, 117, 1009-1032.

Mabey, M.A., G. Black, I.P. Madin, D. Meier, T.L. Youd, C. Jones, and B. Rice. 1997. Relative Earthquake Hazard Map for the Portland Metro Region, Clackamas, Multnomah and Washington Counties, Oregon. Oregon Department of Geology and Mineral Industries. Special Paper #3.

Mabey, M.A., I.P. Madin, and S.P. Palmer, S.P. 1994. Relative Earthquake Hazard Map for the Vancouver, Washington Urban Region. Washington Division of Geology and Earth Resources. Geologic Map GM-42.

Mabey, M.A., I.P. Madin, T.L. Youd, and C.F. Jones. 1993. Earthquake Hazard Maps of the Portland Quadrangle, Multnomah and Washington Counties, Oregon, and Clark County, Washington. Oregon Department of Geology and Mineral Industries Geologic. Map Series 79.

Madin, I.P. 1994. Geologic Map of the Damascus Quadrangle, Clackamas and Multnomah Counties, Oregon. Oregon Department of Geology and Mineral Industries Geologic. Map Series 60.

Madin, I.P. 2004. Preliminary Digital Geologic Compilation Map of the Portland Urban Area, Oregon: Oregon Department of Mineral Industries, Open File Report O-04-2.

McFarland, W.D. and D.S. Morgan. 1996. Description of the Groundwater Flow System in the Portland Basin, Oregon and Washington. U.S. Geological Survey Water Supply. Paper 2470-A.

McGee, D.A. 1972. Soil Survey of Clark County, Washington. United States Department of Agriculture, Soil Conservation Service. U.S. Government Printing Office. p. 71.

Merrick and Company. 2002. IR/LiDAR Project contour data derived from LiDAR points, as well as photogrammetric breaklines for Clark County.

Myers and Brantley. 1995. Volcano Hazards Fact Sheet: Hazardous Phenomena at Volcanoes. U.S. Geological Survey. Open-File Report 95-231.

Miller, D.C. 1989. Potential Hazards from Future Volcanic Eruptions in California: U.S. Geological Survey. Bulletin 1847, 17p.

Mineral Land Regulation and Reclamation Program (MLRR). 2009. List of Existing Mining Permits. Oregon Department of Geology and Mineral Industries. Excel Spreadsheet. Updated September 1, 2009.

Mundorff, M.J. 1964. Geology and Ground-Water Conditions of Clark County, Washington, With a Description of a Major Alluvial Aquifer along the Columbia River. U.S. Geological Survey. Paper 1600. Washington D.C.

Nelson, A., R., and S.F. Personius. 1996. Great-Earthquake Potential in Oregon and Washington--an Overview of Recent Coastal Geologic Studies and Their Bearing on Segmentation of Holocene Ruptures, Central Cascadia Subduction Zone: *in* Roger, A. M., Walsh, T. J., Kockelman, W. J., and Priest, G. R., eds., Assessing Earthquake Hazards and Reducing Risk in the Pacific Northwest, U.S. Geological Survey, Professional Paper 1560, p. 91-114.

Nelson, A. R., B.F. Atwater, P.T. Bobrowsky, L.A. Bradley, J.J. Claque, G.A. Carver, M.E. Darienzo, W.C. Grant, H.W. Drueger, R. Sparks, T.W. Stafford, Jr., and M. Stulver. 1995. Radiocarbon Evidence for Extensive Plate-Boundary Rupture About 300 Years Ago at the Cascadia Subduction Zone. Letters to Nature. v. 378, no. 23, p. 372-374.

NRCS (Natural Resources Conservation Service). 2004. Understanding Soil Risks and Hazards. Using Soil Survey to Identify Areas with Risks and Hazards to Human Life and Property. Edited by Gary Muckel. U.S. Department of Agriculture. Soil survey publication. Lincoln, Nebraska.

NRCS. 1972. Soil Survey of Clark County, Washington. Natural Resources Conservation Service.

Palmer, S.P., S.L. Magsino, J.L. Poelstra, and R.A. Niggemann. 2004. Alternative Liquefaction Susceptibility Map of Clark County. Washington Based on Swanson's Groundwater Model. State Department of Natural Resources, Division of Geology and Earth Resources. September 2004.

Parametrix, S.S. Papadopulos & Associates, Pacific Groundwater Group, and Keta. Waters. 2008. Vancouver Lake Lowlands Groundwater Model Summary Report. Prepared for Port of Vancouver and Clark Public Utilities February 2008.

PB (Parsons Brinckerhoff). 2009. Oregon Landslide Bridges & Walls. Columbia River Crossing. Multnomah County, Oregon, Task AE Draft Preliminary Geotechnical Report. March 16, 2009.

Personius, S.F., R.L. Dart, L.A. Bradley, and K.M. Haller. 2003. Map of Quaternary Faults and Folds in Oregon. U.S. Geological Survey. Open-File Report 03-095, v.1.1, Scale: 1:750,000.

Personius, S.F., compiler. 2002. Fault number 880, Lacamas Lake fault, in Quaternary fault and fold database of the United States. Accessed at: http//earthquakes.usgs.gov/regional/qfaults/ accessed December 2009.

Personius, S.F., compiler. 2002. Fault number 878, Grant Butte fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http//earthquakes.usgs.gov/regional/qfaults/ accessed December 2009.

Personius, S.F., compiler. 2002. Fault number 877, Portland Hills fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http//earthquakes.usgs.gov/regional/qfaults/ accessed December 2009.

Personius, S.F., compiler. 2002. Fault number 875, Oatfield fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http//earthquakes.usgs.gov/regional/qfaults/ accessed December 2009.

Personius, S.F., compiler. 2002. Fault number 876, East Bank fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http//earthquakes.usgs.gov/regional/qfaults/ accessed December 2009.

Phillips. W.M. 1987. Geologic map of the Vancouver Quadrangle, Washington and Oregon. Washington Division of Geology and Earth Resources. Open File Report 87-10.

Pratt, T.L., J. Odum, W. Stephenson, R. Williams, S. Dadisman, M. Holmes, and B. Haug. 2001. Late Pleistocene and Holocene Tectonics of the Portland Basin, Oregon and Washington, from High-Resolution Seismic Profiling. Bulletin of the Seismological Society of America. Vol. 4, No. 9.

Robinson, Noble and Carr, Inc. 1980. City of Vancouver, Ground Water Source and Use Study. Volumes I and II. July 1980.

Schlicker, H.G., and C.T. Finlayson. 1979. Geology and Geologic Hazards of Northwestern Clackamas County, Oregon. Oregon Department of Geology and Mineral Industries, Bulletin 99.

Scott, W.E., T.C. Pierson, S.P. Schilling, J.E. Costa, C.A. Gardner, J.W. Vallance, and J.J. Major. 1997. Volcano Hazards in the Mount Hood Region, Oregon. U.S. Geological Survey. Open File Report 97-89.

Scott, W.E., R.M. Iverson, J.W. Vallance, and W. Hildreth. 1995. Volcano Hazards in the Mount Adams Region, Washington. U.S. Geological Survey. Open-File Report 95-492.

Shannon & Wilson, Inc. 2008. Geotechnical Report Columbia River Crossing Project – Interstate 5. Preliminary Foundation Evaluation Main Span (In-Water Piers) Vancouver, WA and Portland, OR. August 2008.

Shannon & Wilson, Inc. 2009. Task AF (Phase A) Geotechnical Evaluations I-5, Columbia River Crossing (CRC) Project. February 2, 2009.

Singer, M.J., and D.N. Munns. 1999. Soils: An Introduction. Fourth Edition. Prentice-Hall. New York, New York.

Snyder, D.T. 2008. Estimated depth to ground water and configuration of the water table in the Portland, Oregon area. U.S. Geological Survey. Scientific Investigations Report 2008–5059, 40 p.

Snyder, D.T., D.S. Morgan, and T.S. McGrath. 1994. Estimation of Ground-water Recharge from Precipitation, runoff into Drywells, and On-site Waste-Disposal Systems in the Portland Basin, Oregon and Washington. U. S. Geological Survey. Water Resources Investigation Report 92-4010. Portland, Oregon.

Swanson, R.D., and I. Leschuk. 1991. Orchards Aquifer, Two-Dimensional Finite Difference Numerical Model. Intergovernmental Resources Center. November1991.

Swanson, R.D., J.B. McFarland, J.B. Gonthier, and J.M. Wilkinson. 1993. A description of hydrogeologic units in the Portland basin, Oregon and Washington. U.S. Geological Survey. Water Resources Investigative Report 90-4196.

Trimble, D.E. 1963. Geology of Portland, Oregon, and Adjacent Areas. U.S. Geological Survey. Bulletin 1119.

USGS (U.S. Geological Survey). 2002. National Seismic Hazard Maps. Available at http://eqhazmaps.usgs.gov. December 2009.

USGS. 2006. Quaternary Fault and Fold Database for the United States. Accessed November 2009. Available at http://earthquake.usgs.gov/regional/qfaults/or/index.php.

USGS. 2007. Quaternary Fault and Fold Data Base for the United States: Accessed August 2007. Available at http://earthquake.usgs.gov/regional/qfaults/or/index.php

Waitt, R.B. 1985. Case for periodic, colossal jokulhlaups from Pleistocene glacial Lake Missoula. Geological Society of America. Bulletin Vol. 96, No. 10.

Wang, Y.M., and J.L. Clark. 1999. Earthquake Damage in Oregon: Preliminary estimates of future earthquake losses. Oregon Department of Geology and Mineral Industries. Special Paper 29.

DGER (Washington Division of Geology and Earth Resources). 2008. Mine Permit Sites. Olympia, Washington.

WDH (Washington State Department of Health). 2009. Division of Environmental Health Office of Drinking Water. Accessed August 2007. Available at http://www4.doh.wa.gov/SentryInternet/SingleSystemViews/SamplesSingleSys.aspx

WSDOT (Washington State Department of Transportation). 2010. Highway Runoff Manual. Prepared by WSDOT Environmental and Engineering Programs. May 2010.

Wolfe, E.D., and T.C. Pierson. 1995. Volcanic-Hazard Zonation for Mount St. Helens, Washington. U. S. Geological Survey. Open-File Report 95-497.

Wong, I.G., W. Silva, J. Bott, D. Wright, P. Thomas, N. Gregor, S. Li M. Mabey, A. Sojourner, and Y. Wang. 2000. Earthquake Scenario and Probabilistic Ground Shaking Maps for the Portland, Oregon, Metropolitan Area. Oregon Department of Geology and Mineral Industries. Interpretive Map Series IMS-16.

Wong, I.G. 2005. Low Potential for Large Intraslab Earthquakes in the Central Cascadia Subduction Zone. Seismological Society of America. Bulletin. Vol. 95, No. 5, pp. 1880-1902, October 2005.

Youd, T.L. 1993. Liquefaction, Ground Failure and Consequent Damage During the 22 April 1991 Costa Rica Earthquake. Abridged from EERI Proceedings. U.S. Costa Rica Workshop. 1993.

INTERSTATE 5 COLUMBIA RIVER CROSSING

Ecosystems Technical Report for the Final Environmental Impact Statement

Columbia River CROSSING

May 2011

Title VI

The Columbia River Crossing project team ensures full compliance with Title VI of the Civil Rights Act of 1964 by prohibiting discrimination against any person on the basis of race, color, national origin or sex in the provision of benefits and services resulting from its federally assisted programs and activities. For questions regarding WSDOT's Title VI Program, you may contact the Department's Title VI Coordinator at (360) 705-7098. For questions regarding ODOT's Title VI Program, you may contact the Department's Civil Rights Office at (503) 986-4350.

Americans with Disabilities Act (ADA) Information

If you would like copies of this document in an alternative format, please call the Columbia River Crossing (CRC) project office at (360) 737-2726 or (503) 256-2726. Persons who are deaf or hard of hearing may contact the CRC project through the Telecommunications Relay Service by dialing 7-1-1.

¿Habla usted español? La informacion en esta publicación se puede traducir para usted. Para solicitar los servicios de traducción favor de llamar al (503) 731-4128.

This page intentionally left blank.

Cover Sheet

Interstate 5 Columbia River Crossing

Ecosystems Technical Report for the Final Environmental Impact Statement:

Submitted By:

Jennifer Lord

This page intentionally left blank.

TABLE OF CONTENTS

List of Exhibits

List of Appendices

ACRONYMS

Acronym	Description
μPa	1 micropascal
API	area of potential impact
BA	biological assessment
BES	City of Portland Bureau of Environmental Services
BGEPA	Bald and Golden Eagle Protection Act
BLM	Bureau of Land Management
BMP	best management practice
BNSF	Burlington Northern Santa Fe Railroad
BOD	biological oxygen demand
BPA	Bonneville Power Administration
CAO	critical areas ordinance
CD	collector-distributor
CIA	contributing impervious area
cfs	cubic feet per second
COD	chemical oxygen demand
COP	City of Portland
CR	Columbia River
CRC	Columbia River Crossing
CTR	Commute Trip Reduction (Washington)
C-TRAN	Clark County Public Transportation
dB	decibel
DDE	dichlorodiphenyldichloroethylene
DEIS	Draft Environmental Impact Statement
DEQ	Oregon Department of Environmental Quality
DOT	U.S. Department of Transportation
DPS	distinct population segment
DSL	Oregon Department of State Lands
ECO	Employee Commute Options (Oregon)
Ecology	Washington Department of Ecology
ESC	erosion and spill control
EFH	essential fish habitat
EIS	environmental impact statement
EPA	United States Environmental Protection Agency

ESA	Endangered Species Act
ESEE	economic, social, environmental, and energy
ESH	essential salmonid habitat
ESU	evolutionarily significant unit
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
fps	feet per second
FTA	Federal Transit Administration
FPC	Fish Passage Center
GIS	Geographic Information System
GMA	Growth Management Act
GMAV	Genus Mean Acute Values
HPA	hydraulic project approval
I-5	Interstate 5
InterCEP	Interstate Collaborative Environmental Process
LCR	Lower Columbia River
LPA	Locally Preferred Alternative
LRV	light rail vehicle
MAX	Metropolitan Area Express
MBTA	Migratory Bird Treaty Act
MCDD	Multnomah County Drainage District
Metro	Metropolitan Regional Government
MHCC	Mount Hood Community College
MMPA	Marine Mammal Protection Act
MSFCMA	Magnuson-Stevens Fisheries Conservation and Management Act
NAS	National Academy of Sciences
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Dishcharge Elimination System
NR	Natural Resource
NRCS	Natural Resources Conservation Service
NRMP	natural resource management plan
OAR	Oregon Administrative Rule
ODA	Oregon Department of Agriculture
ODFW	Oregon Department of Fish and Wildlife

ODOT	Oregon Department of Transportation
OHW	ordinary high water line
ORNHIC	Oregon Natural Heritage Information Center
ORS	Oregon Revised Statutes
OTC	Oregon Transportation Commission
PAH	polycyclic aromatic hydrocarbon
PCE	primary constituent element
PDX	Portland International Airport
PGIS	pollution-generating impervious surface
RM	river mile
RMS	root-mean-square
ROD	Record of Decision
RTC	Regional Transportation Council
sq. ft.	square feet
SEPA	State Environmental Policy Act
SMA	Shoreline Management Act
SOC	species of concern
SOI	species of interest
SPCC	spill prevention, control, and countermeasures
SPUI	single-point urban interchange
SWCD	East Multnomah Soil and Water Conservation District
TDM	transportation demand management
TriMet	Tri-County Metropolitan Transportation District
TSM	transportation system management
TMDL	total maximum daily load
TPH	total petroleum hydrocarbons
UCR	Upper Columbia River
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
UWR	Upper Willamette River
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDFW-PHS	Washington Department of Fish and Wildlife, Priority Habitats and Species
WDNR-NHP	Washington Department of Natural Resources, Natural Heritage Program
WNHP	Washington Natural Heritage Program
WNWCB	Washington Noxious Weed Control Board

WSDOT	Washington State Department of Transportation
WTC	Washington Transportation Commission

1. Summary

1.1 Introduction

For this report, ecosystem resources include fish, wildlife, and plants, and their habitats, within and around the Interstate 5 (I-5) Columbia River Crossing (CRC) project area. The key issues that are addressed in this report are listed below:

- The potential for impacts to special-status species.
- The potential for impacts to habitats that support fish, wildlife, and plants.
- The potential for impacts to protected habitats.
- The potential for impacts to other ecosystem resources, including migratory birds, marine mammals, rare plants, and noxious weeds.

Impacts and effects may be beneficial or adverse. This report addresses how each alternative may differ in its effect on ecosystems, as well as how regional conditions may be affected by the project overall.

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
#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 (DOT). 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

1.3.1 Aquatic Resources

Long-term impacts to ecosystem resources as a result of the CRC project are likely for aquatic resources, including federally listed fish species and riverine habitat in the Columbia River and North Portland Harbor. Long-term effects include those related to direct effects to species and habitat.

Indirect effects are those caused by the action and may occur later in time or are farther removed in distance, but are still reasonably foreseeable. Two elements of the CRC project are likely to result in indirect effects. Increases to impervious surface area within drainages, and the consequent increase in stormwater runoff volumes and pollutant loads, would cause ongoing effects to the project area water bodies. Long-term net benefits to water quality may result from project improvements to stormwater treatment in the project area. Increased capacity of the highway system and light rail transit network could potentially lead to changes in land use or traffic patterns for years to come.

1.3.1.1 Long-term Effects to Species and Habitat

Long-term effects to aquatic species could include increased risk of predation to juvenile salmonids due to in-water shading and flow refuge associated with bridge structures. Bridge piers constructed in the channel may provide refugia via shade and protection from the river current for piscivorous fish species that could feed on out-migrating juvenile salmonids, thereby impacting overall juvenile survival rates. Holding and rearing behavior of salmonids as they pass through the project could also be affected by these localized changes in habitat. See section 4.1.3.1 for a detailed discussion of predation risk.

Long-term effects to listed salmonids would be consistent with current conditions with respect to the presence of human-made structures in a highly modified urban setting; that is, the continued presence of bridge pier elements in the river and a major highway system over the river. Bridge piers in the river, particularly in near-shore and shallow-water areas, can have long-term impacts to aquatic habitat and channel dynamics as a result of sediment deposition and alteration of flow patterns. The project would have permanent impacts to shallow-water habitat (water less than 20 feet deep) in the Columbia River and North Portland Harbor, including the addition of in-water and overwater bridge elements and the removal of existing in-water and overwater structures. Permanent impacts to deep-water habitat in the Columbia River would include a net physical gain of habitat area (due to removal of existing bridge piers), and an increase in overwater coverage. See section 4.1 for a detailed discussion of effects to species and habitat.

Due to the depth of the water and active riverbed in the Columbia River, benthic organisms (e.g., aquatic macroinvertebrates) are not likely to be present at the majority of the pier construction locations. Two piers would be located in shallow water (20 feet or less)/near-shore areas, where habitat for benthic organisms would be displaced by the new structures.

1.3.1.2 Long-term Effects to Water Quality

Addition of impervious surface to a watershed has the potential to affect fish by altering water quality in the receiving water bodies. Stormwater runoff flows over the roadway, picking up contaminants from impervious surfaces and delivering them to the roadside drainage system and eventually to surface water bodies (Pacific EcoRisk 2007). Sources of these contaminants include vehicles, atmospheric deposition, roadway maintenance, and pavement wear (Pacific EcoRisk 2007). Contaminants that may be present in stormwater runoff associated with highways include suspended sediments, nutrients, polycyclic aromatic hydrocarbons (PAHs), oils and grease, antifreeze from leaks, cadmium and zinc from tire wear, and copper from wear and tear of brake pads, bearings, metal plating, and engine parts.

The CRC Project is a bi-state initiative and it is important to note that the implementation of water management objectives differ significantly between Oregon and Washington State. The primary differences involve how areas that require pollutant reduction are calculated. These differences, which are described in the following paragraphs, can have an impact of the sizes of water quality facility required, especially for projects like the CRC that involve significant areas of impervious pavement.

Oregon requires runoff from the entire contributing impervious area (CIA) be treated to reduce pollutants regardless of degree to which the surfaces would contribute pollutants to runoff. Using this approach, runoff from highways would be required to be treated in the same manner as runoff from bike-pedestrian paths. In contrast, Washington State focuses on requiring treatment for runoff from the pollutant-generating impervious surfaces (PGIS).

ODOT defines the CIA as consisting of all impervious surfaces within the strict project limits, plus impervious surface owned or operated by ODOT outside the project limits that drain to the project via direct flow or discrete conveyance. NMFS has expanded this definition to also include impervious areas that are not owned by ODOT but drain onto the project footprint.

WSDOT and Ecology define PGIS as surfaces that are considered a significant source of pollutants in stormwater runoff including:

- highways, ramps and non-vegetated shoulders;
- light rail tranist guideway subject to vehicular traffic;
- streets, alleys, and driveways; and
- bus layover facilities, surface parking lots, and the top floor of parking structures.

The following types of impervious area are considered non-PGIS:

- light rail tranist guideway not subject to vehicular traffic except the occasional use by emergency or maintenance vehicles (referred to as an exclusive guideway);
- light rail tranist stations; and
- bicycle and pedestrian paths.

The project CIA currently contains 256 acres of impervious surface and would add a net 42 acres, resulting in a post-project net total of 298 acres. The increase in CIA would likely have effects on stormwater runoff draining from the project area into all of the project area water bodies: the Columbia River, North Portland Harbor, Columbia Slough, and Burnt Bridge Creek. It would not be expected to have effects on Fairview Creek since all impervious surfaces would be treated onsite and impervious surface within the watershed would actually decrease by 0.5 acre as a result of the expansion of the Ruby Junction maintenance facility.

The project would install stormwater treatment facilities to treat or sequester pollutants and to provide flow control (where required) before runoff enters any surface water body. The completed project will provide treatment not only for the new and rebuilt impervious surface, but also for existing impervious surface that is not currently treated. The completed project would treat more than 8 times the amount of new PGIS. The CRC project occurs within several different state and local jurisdictions, each of which has different stormwater treatment standards. The CRC project team agreed to incorporate the most restrictive water quality requirements of all these standards, as embodied in the ODOT stormwater best management practices (BMP) selection tool (ODOT 2008). Furthermore, the conceptual stormwater management design provides treatment and infiltration of the entire project CIA, to the maximum extent possible, in response to the requirements of NMFS and DEQ for the CRC project. The extent of treatment would likely result in a net benefit to water quality and water quantity in the project area water bodies during the majority of storm events. See section 4.1.1 for a detailed discussion of stormwater treatment and effects to aquatic resources.

Pollutant loading within the project corridor would be expected to decline within the Columbia River and Burnt Bridge Creek compared to pollutant loads expected under the No-Build alternative because stormwater treatment would be provided where treatment would otherwise not exist. Pollutant loads would decline in the Columbia Slough watershed with the exception of dissolved copper. Pollutant loads of dissolved copper are projected to increase slightly (5-6 percent) in the Columbia Slough as a result of the LPA.

1.3.2 Terrestrial Resources

Potential long-term effects to peregrine falcon habitat may occur if the existing bridge is removed and structures that are currently used by this species are demolished. No other significant long-term impacts are anticipated to terrestrial resources. See Sections 4 and 5 for additional effects analysis.

1.3.3 Botanical Resources

No long-term effects are expected to botanical resources. Although trees and other vegetation may be removed within the project footprint for new permanent and temporary structures, revegetation with native plants to meet local criteria would occur within or adjacent to the project footprint. Noxious weeds would be removed in accordance with state transportation department policies.

1.3.4 Regional Resources

Long-term regional effects would be seen primarily in effects to listed fish and aquatic habitat, especially water quality. The Columbia River in the project area is a major waterway through which at least fourteen salmonid stocks, as well as lamprey, sturgeon, and other native fish, pass during various portions of their life cycles. Salmonids are present in the project area during adult migration upriver to spawn, juvenile outmigration, and rearing; therefore, impacts to these species at these life stages could have substantial implications for survival and reproduction of these populations of salmonids. However, long-term impacts from project activities are likely to be consistent with existing conditions for aquatic species (e.g., the presence of a major artificial structure in the mainstem of the river). Impacts of a large bridge structure in the mainstem river could be reduced to some extent, relative to existing conditions, by several design elements. For example, the new bridge would have fewer piers in shallow water habitat. In addition, water quality in the mainstem Columbia River and North Portland Harbor may be improved, at least in the immediate project area, through improvements to stormwater collection and treatment.

Long-term regional effects to terrestrial species and habitats would likely be consistent with existing conditions. Migratory birds would likely use the new bridge designs and the natural habitat in the project area for roosting, foraging, and potentially for nesting, similar to their use of the existing elements. Wildlife passage would be likely to remain limited in the project area due to the highly urbanized setting.

Regional traffic patterns would likely change as a result of improvements to the I-5 bridge crossing, potentially resulting in negative impacts to ecosystem resources in some areas and positive effects on water quality in other areas. These effects are addressed in the Indirect Effects Technical Report.

1.4 Temporary Effects

1.4.1 Aquatic Resources

Temporary effects to aquatic habitat and aquatic species are anticipated from in-water work. In-water work may include removing existing bridge piers, constructing new piers, and installing and removing temporary in-water work structures. In-water work is likely to include coffer dams, barges, drilling equipment, impact pile drivers, vibratory pile drivers, and other construction vehicles in and near the water. Construction activities may cause injury or death to aquatic species.

In-water work would likely cause localized increases in underwater noise, turbidity, artificial lighting, avian predation, hydraulic shadowing, and shading. Specific effects could include potential sub-lethal injury due to hydroacoustic impacts associated with pile driving and fish handling; increased risk of predation due to in-water shading during construction; and potential mortality associated with hydroacoustic impacts and fish handling. Effects to habitat include turbidity, loss of shallow-water habitat, and obstructions to migration.

Water quality could be adversely impacted by accidental contaminant spills (e.g., barge and heavy equipment fuel, oil), erosion, turbidity, and sediment. Current riparian vegetative structure provides negligible benefits for regulating water temperature in the Columbia River and North Portland Harbor. Only small amounts of riparian vegetation may be removed during the project and would not be expected to affect aquatic habitats. See Section 5 for additional effects analysis.

1.4.2 Terrestrial Resources

Temporary impacts to terrestrial resources, specifically to migratory birds and peregrine falcons, are likely to occur. Modifications to migratory bird habitats are likely because existing vegetation, as well as the bridge structures themselves (on which birds may roost or nest), are expected to be removed. Vegetation, including potential nesting habitat such as trees and shrubs, would be replanted and would replace the temporarily impacted habitat. Construction noise may also disturb or prevent nesting.

Temporary effects to terrestrial species are anticipated from construction noise and impacts to vegetation. Construction activity causing noise disturbance could result in reduced nesting success for migratory birds. Trees, shrubs, and other vegetation serving as cover, nesting, roosting, and perching habitat may be removed during construction. Such vegetation removal could also impact terrestrial wildlife using such habitat structure for cover, feeding, breeding, and dispersal. See Section 5 for additional effects analysis.

1.4.3 Botanical Resources

Temporary impacts to vegetation in the project area may result from grading, staging, realignment of the main bridge structure, and other project-related activities. Disturbed vegetated areas would be replanted according to site restoration plans. No effects to sensitive plant species are expected because no sensitive plants are known to occur within the project area. Noxious weeds would be removed in accordance with state transportation department policies.

1.5 Proposed Mitigation

Mitigation for impacts to aquatic, terrestrial, and botanical resources include BMPs, conservation measures, and avoidance and minimization measures.

The LPA would impact fish species by the presence of large piers in the river that could provide habitat for piscivorous fish, and that could alter stream flow. In addition, riparian fringe habitat may be altered. Mitigation measures to address these impacts include impact avoidance and impact minimization. Revegetation of riparian areas and limited use of riprap would be employed to limit negative long-term effects. Long-term impacts to terrestrial resources, such as migratory birds, are relatively minimal and would not require extensive mitigation. Refer to Section 6 for a more detailed discussion of proposed mitigation approaches.

During construction, the LPA would impact fish species through in-water work that could result in increased turbidity, hydroacoustic impacts, temporary localized dewatering, and potential contaminant spills. Mitigation measures to address these impacts include impact avoidance and impact minimization. Impact avoidance has been addressed through project design alternatives that were considered but not advanced due to impacts to ecosystem and other resources. Certain design alternatives have also been modified to reduce impacts to resources. Impact minimization would be addressed through implementing BMPs (e.g., sediment and erosion control, no-work zones, appropriate flagging and fencing), monitoring project activities, timing restrictions for in-water work to avoid impacts to fish runs, using cofferdams around select in-water work sites, and using bubble curtains around impact pile driving that may cause adverse impacts from noise.

The LPA would impact terrestrial resources, such as migratory birds and species of interest (SOI) (defined for the purposes of this document as species which are not protected by federal statute but which are locally rare or have special habitat requirements), through noise impacts and removal or degradation of habitat. Mitigation measures to address these impacts include impact avoidance and impact minimization. For example, to avoid direct impacts to active peregrine falcon and other migratory bird nests, demolition of existing structures would be scheduled outside of nesting seasons, and/or management plans would be developed to provide guidance on ways to avoid violation of the Migratory Bird Treaty Act (MBTA).

Stormwater collections and treatment would occur to treat for metals, biosolids, and other contaminants. Methods used would be more effective and efficient than current treatment, and should result in improved water quality in the project area.

2. Methods

2.1 Introduction

Methods used to collect data and analyze effects included:

- Collecting a list of federally listed species, potential species of interest[1] (SOI), and their habitats from local, state, and federal resource and management agencies.
- Determining species life history and habitat requirements.
- Conducting field surveys with accepted protocols during appropriate seasons.
- Examining existing Geographic Information System (GIS) data layers.
- Discussing potential impacts to resources with species experts, local resource managers, and agency biologists.

Refer also to the Ecosystems Methods and Data Report for additional details.

2.2 Project Area

The project area is defined as all areas that would be directly impacted by the project, including the footprint of the permanent and temporary structures, the widened highway segments, the new interchanges, city street realignments, associated road shoulder excavation and fill areas, stormwater facilities, wetland mitigation sites, and staging and access areas, including those in the Columbia River and North Portland Harbor where work would occur from barges and temporary structures.

Along the I-5 corridor, the project area extends 5 miles from north to south, beginning at the I-5/SR 500 interchange in Vancouver, Washington and extending to the I-5/Victory Boulevard in Portland, Oregon (Exhibit 2-1). At its northern end, the project area extends west into downtown Vancouver and east near Clark College to include high-capacity transit alignments, transit stations, park-and-ride locations, and city road improvements included as part of this project. Heading south along the existing overwater bridge alignments, the project area extends 0.25 mile on either side of the existing bridges to include the new river and harbor bridges, as well as the areas where construction and demolition activities would occur. Continuing south, the project extends east to include city road improvements along Victory Boulevard.

The project area also includes those portions of the Columbia River and North Portland Harbor that would be affected by underwater noise. In the Columbia River and North Portland Harbor, hydroacoustic impacts from impact pile driving are the farthest reaching extent of project aquatic impacts. Due to the curvature of the river and islands present, underwater noise from impact pile driving is expected to reach land before it reaches ambient levels. Noise from impact pile driving is not expected to extend beyond Sauvie Island, approximately 5.5 miles downstream and Lady Island, 12.5 miles upstream. This distance encompasses the Columbia River from approximately

[1] SOI are not a specific category of governmental or NGO-designated species, but are referred to here as those identified through tribal, local, state, and federal coordination as those species that are locally rare and have special habitat considerations.

river mile (RM) 101 to 118. Within North Portland Harbor, underwater noise is expected to extend 3.5 miles downstream and 1.9 miles upstream.

The project area includes potential staging and casting yards at the Port of Vancouver, Alcoa/Evergreen, Sundial, Red Lion at the Quay, and Thunderbird Hotel staging sites.

In downtown Portland, the project area includes the upper deck of the Steel Bridge where minor rail improvements would take place.

In Gresham, Oregon, the project area includes a 10.5-acre expansion of the Ruby Junction Maintenance Facility. This includes all associated cut and fill slopes and stormwater treatment facilities.

2.3 Effects Guidelines

Local, state, and federal agencies provide guidance in determining impacts to ecosystem resources. The impact assessment considered effects to species and habitats, taking into consideration federal and state protected status, impacts to species' ecology and critical life stages (e.g., breeding), primary constituent elements (PCEs) where applicable (e.g., critical habitat), and other relevant factors. The following factors were considered in determining the type and degree of impacts:

- Effects to listed species analyzed in Section 7 of the Endangered Species Act (ESA) consultations conducted with the United States Fish and Wildlife Service (USFWS) and NMFS; consultation has been completed with FHWA, FTA, ODOT, and WSDOT.
- Effects to Essential Fish Habitat (EFH) under the Magnuson-Stevens Fishery Conservation Management Act (MSFCMA).
- Effects to threatened or endangered species recovery potential as described in a USFWS or NMFS recovery plan, or other guidance if a recovery plan is not available.
- Extent of impacts to existing wildlife corridors (which could be either further degraded or improved by this project).
- Impacts to fish passage for all life stages of listed and non-listed native fish (e.g., physical barriers).
- Effects to high quality habitat, such as fragmentation, degradation, or impairment that would reduce its capacity to provide vital functions for species; "high quality" habitat is defined in Oregon Department of Fish and Wildlife's (ODFW) Habitat Mitigation Policy and Washington Department of Fish and Wildlife's (WDFW) Priority Habitats.
- Effects to migratory birds, as defined under the MBTA, such as take of active nests and/or eggs.
- Effects to marine mammals, as defined under the Marine Mammal Protection Act (MMPA), such as harassment or injury.
- Effects to species under state regulatory statutes governing "take," such as the Oregon and Washington statutory authorities protecting endangered, threatened, and sensitive species.
- Effects to state and locally protected habitats (e.g., impacts that would remove or degrade habitats to the point that they can no longer provide vital functions for the species dependent on these habitats).

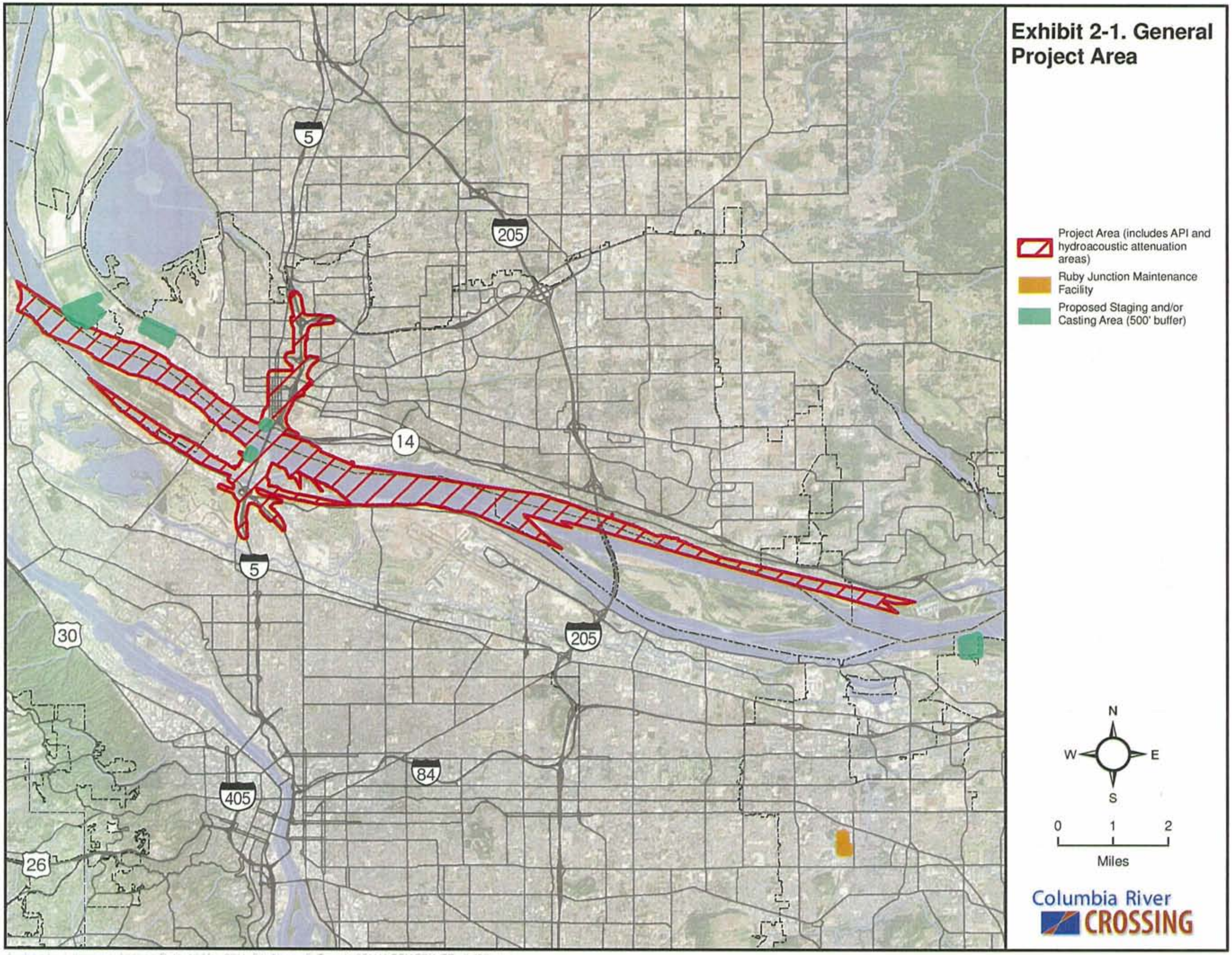


Exhibit 2-1. General Project Area

6155

2.4 Data Collection Methods

The project team conducted field reviews of SOI and aquatic, riparian, and terrestrial habitat features and conditions within the project area. Existing data, including previously prepared environmental reviews, were also gathered and incorporated into the analysis.

The following process was used to collect fish, wildlife, and botanical resource data:

1. Collected a list of potential SOI and their habitats. These data were obtained from the Oregon Natural Heritage Information Center (ORNHIC), USFWS, NMFS, WDFW, and the Washington Department of Natural Resources, Natural Heritage Program (WDNR-NHP).
   - Contacted federal, state, and local agencies, and local biologists and experts.
   - Examined studies, plans, and reports prepared by local, state, and federal agencies and private organizations for information on species and habitats that may occur within the project area. These studies included the ODOT Peregrine Falcon Management Plan 2002 through 2007, annual peregrine falcon monitoring reports for the Portland metropolitan area, and the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan.
2. Determined SOI habitat requirements.
   - Examined studies, plans, and reports and consulted with local biologists and federal, state, and local agencies.
   - Determined if critical habitat has been designated for listed species potentially found within the project area. Examined PCEs for species with designated critical habitat.
3. Determined potential habitat types and their associated species.
   - Obtained aerial photography to identify habitat types.
   - Obtained GIS maps of habitats, documented species locations, locally protected zones, critical habitats, and other ecological features. Such resource classifications include EFH (NMFS), regionally significant habitat (Metro)[2], essential salmonid habitat (ESH) (Oregon Department of State Lands [DSL]), priority habitats (WDFW), critical area ordinances (City of Vancouver) and environmental zones (City of Portland).
4. Conducted field reconnaissance in the appropriate season(s) to assess the presence of listed botanical species and all species' associated habitats within the project area and, if present, the role the habitats play in the species' life histories.
   - Ground-truthed habitat types and boundaries. Quantified habitat types within the project area based on GIS data.
   - Used Johnson and O'Neil's (2001) species/habitat matrix to determine the species most likely to be present in these habitats.

---

[2] Metro is the directly elected regional government that serves the residents of Clackamas, Multnomah and Washington counties, and the 25 cities in the Portland, Oregon metropolitan area.

- Determined SOI habitat use within the project area and identified wildlife passage opportunities.
- Conducted rare plant surveys using the intuitive controlled method (BLM 1998). Conducted noxious weed surveys and mapped results based on Oregon Department of Agriculture (ODA) and Washington Noxious Weed Control Board (WNWCB) status.
- Inspected bridges for bridge-nesting species and bats, and identified potential migratory bird habitat. Visual inspections for these species were conducted during nesting seasons.

5. Characterized aquatic and terrestrial habitats found during field surveys for features important to fish, wildlife, and plants. All species seen during field surveys were recorded.
   - Aquatic characteristics of interest included water quality, substrate composition, bank stability, channel condition, fish passage, bathymetric characteristics, and riparian conditions. Streams were evaluated for their potential to support fish and other aquatic resources. These characteristics were evaluated qualitatively (e.g., visual observation) during the field survey, and supported by technical reports from appropriate agencies (e.g., Ecology, DEQ, WDFW, ODFW).
   - Riparian corridors were surveyed for fish and wildlife habitat elements at the I-5 crossings of the Columbia River, North Portland Harbor, and Columbia Slough. Burnt Bridge Creek was surveyed where it runs parallel to I-5 at the northern boundary of the project area. Surveyed habitat elements include vegetation type and density, stream characteristics, and piers, footings, riprap, and other structures below the ordinary high water line (OHW).
   - Terrestrial characteristics of interest included opportunities for wildlife passage, habitat distribution, structure, and composition, and habitat fragmentation or connectivity.
6. Compiled lists and maps of observed SOI, habitats, protected habitats, rare plants, and noxious weeds.
7. Analyzed data to determine potential project impacts on ecosystem resources.
   - Used agency-approved documents to determine the potential impacts from proposed alternatives on ecosystem resources.
   - Determined potential impacts to listed species and designated critical habitat.
   - Identified other resources, such as SOI or protected habitats, which might be impacted.
   - Identified habitats that provide connectivity at a landscape scale.
8. Conducted windshield surveys for habitats classified as non-urban based on the Johnson and O'Neil's (2001) species/habitat matrix. Special consideration was given to habitats that provide connectivity within the project area. Used species/habitat matrix to determine the species most likely to be present in habitats identified from existing data.
9. Compiled a list of observed habitats and potential SOI, rare plants, and noxious weeds.
10. Analyzed data to determine the potential for indirect impacts to ecosystem resources.

- Determined potential indirect impacts to listed species and designated critical habitat.
- Identified other resources, such as SOI or protected habitats that might be indirectly impacted.
- Identified habitats that provide connectivity at a landscape scale.

2.5 Analysis Methods

Potential cumulative effects from this project are evaluated in the Cumulative Effects Technical Report. Please refer to this report for an evaluation of possible cumulative effects.

2.5.1 Aquatic Resource Impacts

The following process was used to determine short- and long-term operational impacts on aquatic resources:

- Evaluated impacts to fish passage by comparing structural designs of the various alternatives.
- Used maps of protected habitats to determine sensitive areas that may be impacted by the project and to quantify the impact area relative to existing habitat.
- Evaluated and quantified the potential for effects to critical habitat, suitable habitat, or "take" of listed fish.

2.5.2 Terrestrial Resource Impacts

The following process was used to determine short- and long-term operational impacts on terrestrial resources, including botanical resources:

- Evaluated and quantified the potential for destruction or adverse modification of critical habitat, suitable habitat, or "take" of listed wildlife and plants.
- Evaluated and quantified impacts to species and resources not listed under the ESA based on the amount of habitat modification, destruction, or increased levels of disturbance from project operation.
- Evaluated and quantified impacts to wildlife passage based on changes to existing wildlife corridors or fragmentation of existing habitat.
- Used maps of protected habitats to determine sensitive areas that may be impacted by the project and to quantify the impact area relative to undisturbed habitat.

2.5.3 Species of Interest Impacts

The following process was used to determine short- and long-term operational impacts on special-status species:

- Evaluated the potential for adverse effects to listed species, relative to their survival and recovery, under the federal ESA.
- Used maps of special-status species locations to determine habitats that may be impacted by the project and to quantify the impact area relative to undisturbed habitat.

In addition, local, state, and federal biologists were interviewed and beneficial impacts were identified and evaluated.

2.6 Mitigation Measures Approach

Bi-state coordination is occurring to best mitigate for impacts to ecosystem resources. The intent is to provide mitigation measures that are consistent with the mitigation policies of local, state, and federal governments. The mitigation measures approach was guided by the following actions:

- Avoiding impact through design modification or by not taking a certain action or parts of the action.
- Identifying and evaluating ways to minimize impacts to ecosystem resources.
- Researching and identifying BMPs to minimize and avoid impacts.
- Discussing BMPs and potential mitigation needs with local, state, and federal agencies.
- Rectifying temporary impacts by repairing, rehabilitating, or restoring the affected resource.
- Reducing or eliminating the impact over time by preservation and maintenance operations.
- Compensating for permanent impacts by replacing, enhancing, or providing substitute resources or environments. Compensation for unavoidable impacts is consistent with state and federal mitigation rules and guidance. Priority was placed on on-site compensatory mitigation first, but considers off-site mitigation options where appropriate. In choosing between mitigation options, the likelihood for success, ecological sustainability, practicability of long-term monitoring and maintenance, and relative costs is evaluated. The mitigation goal is to replace the lost or impaired ecosystem functions in accordance with applicable laws, regulations, and procedures.
- Short-term impacts to water quality would be addressed through a Stormwater Pollution Prevention Plan, which would include construction BMPs, such as appropriate measures to prevent accidental spills of chemicals and materials and ways to minimize vegetation removal and/or replant disturbed areas.
- Long-term impacts to water quality would be addressed through local, state, and federal requirements for the prevention of increases to pollutant loads and for standards and requirement for stormwater treatment.

Refer to the Wetlands Technical Report for further details on wetland compensatory mitigation needs and requirements.

2.7 Coordination

This technical report was developed in collaboration with federal, state, and local agencies, including the Environmental Protection Agency (EPA), USFWS, NMFS, ODFW, WDFW, DSL, Washington Department of Ecology (Ecology), the City of Vancouver, Metropolitan Regional Government (Metro), and the City of Portland. Regular meetings were held, beginning in 2005, with representatives from the federal and state environmental regulatory agencies (a group formed specifically to provide input on this project, and known as the Interstate Collaborative Environmental Process [InterCEP]).

Working groups for fisheries and water quality also met to discuss specific project elements. These meetings occurred between 2006 and 2010.

Native American tribes with resource interests relevant to this project also provided input and guidance in developing this report.

This page intentionally left blank.

3. Affected Environment

3.1 Introduction

The I-5 bridges connect two major metropolitan areas, and therefore the surrounding landscape is characterized by urban development interspersed with remnant natural habitat areas in the form of riparian buffers, open space and parks, and the mainstem Columbia River. All natural areas have been modified to suit the urban landscape and the needs of the urban population. Wildlife species that currently utilize the project area appear to have become relatively habituated to ambient levels of noise, light, and activities associated with large urban centers, at least for portions of their life cycles. City and county zoning and planning for habitat protection have maintained areas (albeit small and disjointed) of aquatic and riparian habitat that support listed and non-listed fish, sensitive reptiles and amphibians, mammals, and migratory birds.

3.2 Regional Conditions

Compared to historical conditions, the availability and quality of fish, wildlife, and plant habitat in the project area has been reduced by human settlement and development.

3.2.1 Regional Aquatic Conditions

The Columbia River and its tributaries are the dominant aquatic system in the Pacific Northwest. The Columbia River originates on the west slope of the Rocky Mountains in Canada and flows approximately 1,200 miles to the Pacific Ocean, draining an area of approximately 258,000 square miles. The ocean influence reaches 23 miles upstream from the river mouth in the form of salt water intrusion from the Columbia River estuary. Coastal tides influence the flow rate and river level up to Bonneville Dam at RM 146.1 (USACE 1989). Levees, built along the river between 1919 and 1921, and dams built between the 1930s and 1970s, have significantly altered hydrologic flow and reduced the abundance and quality of fish and wildlife habitat in the project area. The lower Columbia River is used for transport of commercial goods, irrigation, power generation, and recreation. The banks in many portions, particularly those in the urbanized area around the project area, have been armored for flood and erosion control. Channel dredging occurs periodically to ensure passage for commercial vessels.

Aquatic habitats in the project area, in general, support populations of native, non-native, and listed fish species in rivers, backwater areas, small creeks, ponds, and sloughs. Aquatic habitats have been subject to human modifications (e.g., dredging, filling, armoring) to accommodate commercial and residential development, and few (if any) of these habitats are in pristine condition. The North Portland Harbor connects to the mainstem Columbia River and shares many of the same attributes. Additional aquatic habitats of note in the project area include Burnt Bridge Creek in Washington, and the Columbia Slough and Fairview Creek in Oregon.

3.2.2 Regional Terrestrial Conditions

The region is classified within the western forest ecoregion (Omernik 1987), with elevations ranging from sea level to 11,240 feet. The Pacific Northwest temperate rainforest is one of the most productive forest regions in the world. Forest types of this ecoregion include old-growth conifer (e.g., Douglas-fir (*Pseudotsuga menziesii*), spruce (*Picea* sp.), hemlock), remnant hardwoods (e.g., Oregon oak woodlands), alpine communities (e.g., montane grasslands), and riparian, wetland, and aquatic systems. The project area was historically closed upland forest/woodland with patches of grassland savannah and prairie in lowland areas near water (e.g., present-day Hayden Island) (Hulse et al. 2002).

The suite of wildlife species originally inhabiting the project area and surrounding landscape in the Lower Columbia basin included at least 18 amphibian species (e.g., Pacific treefrog), 15 reptile species (e.g., western pond turtles), 154 bird species (woodpeckers, owls, songbirds, waterfowl), and 69 mammal species (e.g., elk, cougar, coyote, bobcat) (Hulse et al. 2002). The project area is located within the Pacific Flyway, the major north-south route for migratory birds that extends from Patagonia to Alaska. Migratory birds use the area for resting, feeding, and breeding. Species that once occurred in the area but have since been extirpated, largely due to human influence, include the grizzly bear (*Ursus arctos*), California condor (*Gymnogyps californianus*), and gray wolf (*Canis lupus*). Abundance and distribution of other species have sharply declined, some to the point of requiring legal protection (e.g., northern spotted owl [*Strix occidentalis*]). Other species have adapted to the conversion in land and habitat cover, persisting or even benefiting from the changes (e.g., raccoons [*Procyon lotor*], red-tailed hawks [*Buteo jamaicensis*]).

Native Americans lived in the region for 11,000 years before the arrival of Euro-American settlers. However, human populations were very low in the region prior to settlement (Hulse et al. 2002). As the region became settled by mineral and timber prospectors in the 1840s and 1850s, the area grew into a major West Coast port, and urban areas gradually displaced wildlife habitat. Current urbanized conditions have impacted habitat, making the project area unsuitable for historic population sizes of large mammals and many native amphibians, reptiles, birds, and other wildlife that were once common in the project area. Most of these native species still occur in the project vicinity but in reduced numbers.

Terrestrial wildlife species that currently occur in the project area—for example, bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons (*Falco peregrinus anatu)*—have adapted to some extent to the urban environment and are able to nest and forage in and near the project area. Large- and medium-sized mammals (e.g., ungulates, carnivores) may occasionally be seen near these urban environments, and some have adapted to living in developed urban areas (e.g., red fox [*Vulpes vulpes*], coyote [*Canis latrans*]). However, for the most part, these species no longer occur in the project area. Terrestrial habitat is limited to relatively small, patchy areas protected by city regulations (e.g., wetlands, forested park areas, open spaces, and riparian buffers) and currently support species with relatively small home ranges and restricted habitat requirements (e.g., turtles). Portions of the region adjacent to the project area (e.g., Forest Park, Vanport Wetlands, and the western end of Hayden Island) retain forested and wetland habitats capable of supporting native wildlife.

3.2.3 Regional Botanical Conditions

Due to the highly urbanized character of the project area, most natural habitat for native plants has been lost or highly degraded through land use conversion from natural to urban use. Remaining habitat for botanical resources, particularly for rare plants, is restricted to open space, wetlands, riparian buffers, and park lands managed under protective mandate. These habitats tend to be relatively small and isolated from each other, limiting the distribution of native plants. Non-native plants and noxious weeds are ubiquitous in the project area and further limit the ability of native plants to persist in most of the remaining suitable habitat.

3.3 Aquatic Resources

In this technical report, the term "aquatic resources" refers primarily to fish species and their habitat. Wetlands are discussed in the Wetlands and Waters Technical Report. Water quality is an important component of habitat for listed and non-listed aquatic (and terrestrial) species.

3.3.1 Summary of Aquatic Habitats

The project area contains the following water bodies: the Lower Columbia River, North Portland Harbor, Burnt Bridge Creek, Columbia Slough, and Fairview Creek. These are described individually in more detail below.

3.3.1.1 Columbia River and North Portland Harbor

The I-5 bridges are located at RM 106 of the Columbia River. The project area within the Columbia River extends from RM 101 to 118 (see description of the project area in section 2.2). The Columbia River within the project area is highly altered by human disturbance. Urban development extends up to the shoreline. There has been extensive removal of historic streamside forests and wetlands. Riparian areas have been further degraded by the construction of dikes and levees and by the placement of stream bank armoring. For several decades, industrial, residential, and upstream agricultural sources have contributed to water quality degradation in the river. Additionally, the river receives high levels of disturbance in the form of heavy barge traffic.

The twelve major dams located in the Columbia Basin are the dominant forces controlling flow in the project area. Bonneville Dam in particular influences flow in the project area, and all the dams buffer temporary hydrologic effects within the basin. Consequently, the Columbia River upstream of Bonneville Dam is a highly managed stream that resembles a series of slack-water lakes rather than its original free-flowing state. The major second factor regulating stream flow in the project area is tidal influence from the Pacific Ocean. Saltwater intrusion from the Pacific Ocean extends approximately 23 miles upstream from the river mouth at Astoria. Coastal tides influence the flow rate and river level up to Bonneville Dam at RM 146.1 (USACE 1989).

The Columbia River estuary is generally considered to be the portion of the Columbia River extending from the mouth to all tidally influenced areas (that is, to Bonneville Dam) (NMFS 2007). Therefore, the project area is part of the estuary.

The substrate of the river within the project area is predominantly composed of sand, with relatively small percentages of fine sediments and organic material (DEA 2006; NMFS 2002). A bathymetric study completed in 2006 found significant scouring on the upstream side of each bridge pier, and scour channels on the downstream side (DEA 2006). The scouring ranged from approximately 10 to 15 feet deep. Bedload transport patterns were evident in the form of sandwaves, a natural feature of the river bottom that indicates the influence of the currents and that continuously moves and shifts with the currents. The sandwaves observed in this study were especially distinct on the downstream side of the bridge. The sandwaves in the middle of the river were regular, while the sandwaves on the northern downstream side were larger and more irregular. The northern upstream side of the bridge was relatively smooth and had few to no sandwaves, while the southern upstream side had irregular sandwaves. Average river depth was approximately 27 feet (DEA 2006). Shallow-water habitat (defined as 20 feet deep or less) is present along both banks, but is more abundant along the Oregon bank (Exhibit 3-2).

Shallow and near-shore habitat is present in the project area on both the Oregon and Washington shores and is influenced by flow and sediment input from tributaries and the mainstem river, which eventually settles to form shoals and shallow flats. This shallow-water habitat is used extensively by juvenile and adult salmonids for migrating, feeding, and holding. Phytoplankton, microdetritus, and macroinvertebrates are present in shallow areas and serve as the prey base for salmonids and other native fish (USACE 2001). A recent study along Hayden Island documented suitable rearing habitat for naturally spawned juvenile Chinook salmon, and to a lesser extent, for naturally produced juvenile chum, coho, and steelhead in the vicinity of the project area (NOAA 2009).

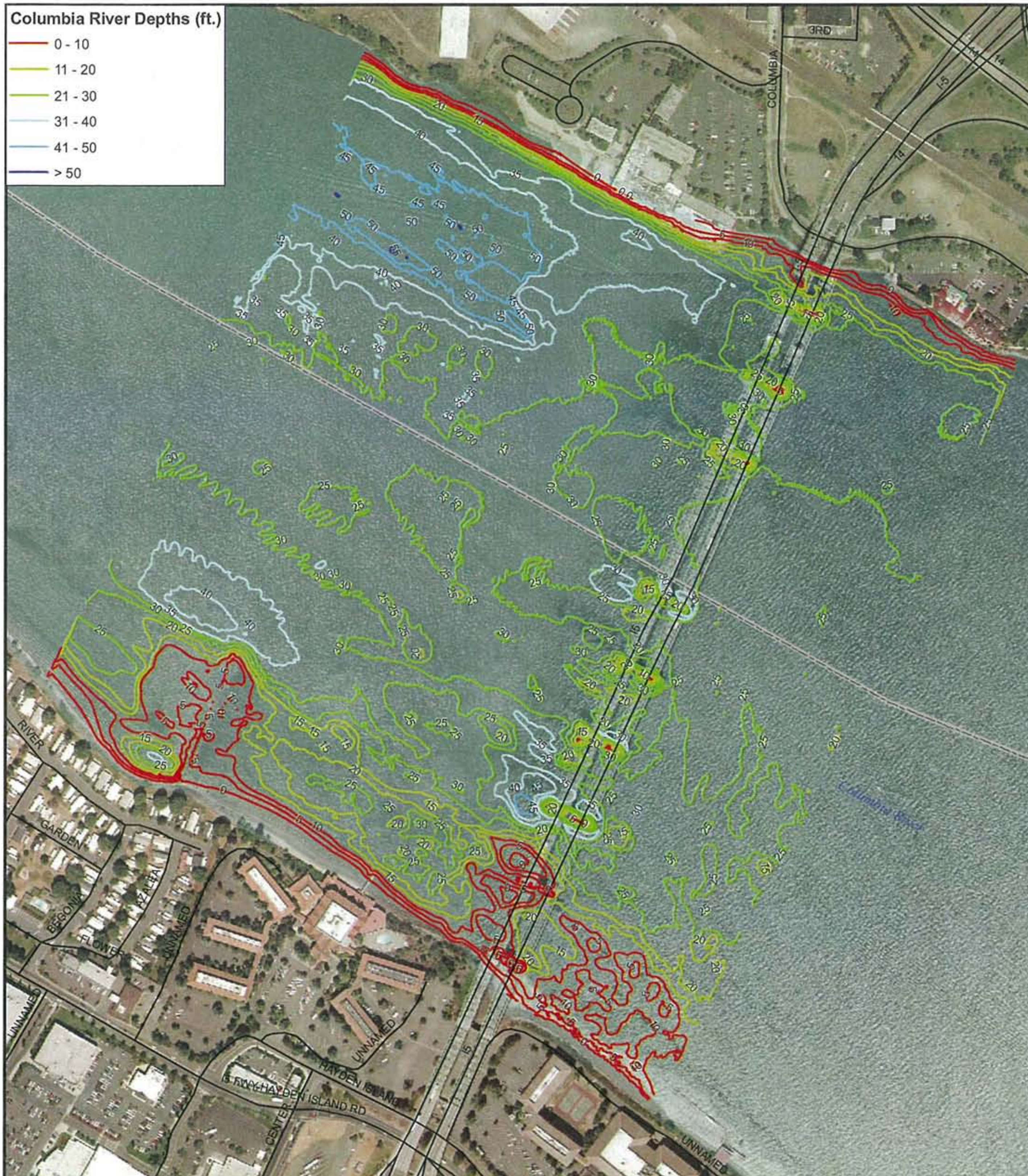
Hydrology has been significantly altered from historical conditions. Landform and bridge footings are the dominant and subdominant floodplain constrictions, respectively. Ten bridge footings are currently located below OHW. A flood control levee runs along the south bank of North Portland Harbor and forms a boundary between the adjacent neighborhoods and the harbor. Numerous upstream dams, shoreline levees, and channel dredging have restricted habitat-forming processes such as sediment transport and deposition, erosion, and natural flooding. Therefore, habitat complexity is reduced, and shallow-water habitat areas can no longer form. For this reason, these habitats are particularly lacking in the project area. Shoreline erosion rates are likely slower than they were historically due to flow regulation. The river channel is deeper and narrower than historical conditions.

Sand and gravel mining routinely occurs in several locations in the Columbia River portion of the project area. Multnomah County has issued seven permits for sand and gravel mining from September 2006 to May 2019 (Exhibit 3-1).

Exhibit 3-1. Multnomah County Sand and Gravel Permits

File Number	Name	TRS	Approximate River Mile	Tax Lot	Issued	Expires
SG-17209	Pacific Rock Products LLC	01N03E22	119	500	9/28/2006	9/27/2009
SG-16094	Columbia River Sand and Gravel, Inc.	02N01W24	102		8/1/2007	7/31/2010
SG-17111	Northwest Aggregates Co.	01N03E20A	117.5	100	7/1/2007	6/30/2010
SG-7174	Northwest Aggregates Co.	01N03E21	118	200,300	7/1/2007	6/30/2010
23300-SG	Morse Brothers, Inc.	01N03E23	120	100, 200, 300	12/15/2007	12/14/2010
24822-SG	Morse Brothers, Inc.	01N03E23C	120	100	2/19/2008	2/18/2011
25030-SG	Rose City Yacht Club, Inc.	01N01E01	109	100 & 200	6/1/2009	5/31/2019

Some high-quality backwater and side channel habitats have persisted along the Lower Columbia River banks and near undeveloped islands (USACE 2001) outside of the project area. These habitats contain high-quality wetlands and riparian vegetation, such as emergent plants and low herbaceous shrubs.



N W E S

0 260 520
Feet

Exhibit 3-2. Columbia River Water Depth Maps (CRD)

Columbia River CROSSING

Typical riparian vegetation in the project area is shown in Exhibit 3-3 and Exhibit 3-4. Exhibit 3-5 provides riparian vegetation area estimates for the Columbia River. Data were collected from the banks of the stream within 500 feet upstream and downstream of the bridge crossing (1,000 feet total). The riparian vegetation was visually surveyed.

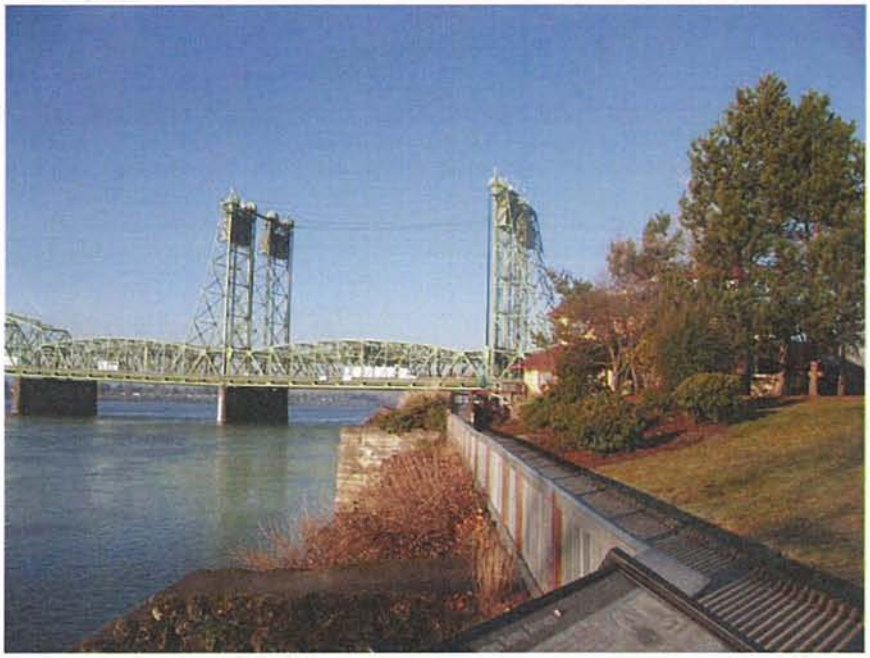


Exhibit 3-3. North Bank of Columbia River Looking Downstream Toward Existing I-5 Bridges

Exhibit 3-4. South Bank of Columbia River (foreground) Upstream and Downstream of Existing I-5 Bridges

Tree canopy in the project riparian areas is generally absent or sparse. Where present, typical canopy dominants include native willows (*Salix* spp.) and black cottonwood (*Populus balsamifera*) species and non-native species such as ailanthus (*Ailanthus altissima*). The understory is typically dominated by non-native species such as Himalayan blackberry (*Rubus armeniacus*) and ailanthus, and native species such as roses (*Rosa* sp.) and willows. Ground cover is typically dominated by non-natives such as English ivy (*Hedera helix*), reed canarygrass (*Phalaris arundinacea*) and Himalayan blackberry.

The riparian area within the project area is relatively degraded. As a result, shallow-water habitat has only sparse vegetative cover. Because riparian areas are limited in size and are unlikely to support productive vegetative communities in this urban setting, there is little potential for future large wood recruitment. Fish cover elements are generally sparse to absent in the project area, although some boulders and artificial structures are present.

Exhibit 3-5. Riparian Vegetation Cover Estimate in the Project Area for the Columbia River

	Vegetation Type and Density (% cover)			
	North Bank Upstream	North Bank Downstream	South Bank Upstream	South Bank Downstream
Canopy (> 15 ft high)				
Vegetation Type	None	Deciduous	Deciduous	None
Big trees (Trunk > 1 ft dbh)	Absent (0%)	Absent (0%)	Absent (0%)	Absent (0%)
Small trees (Trunk < 1 ft dbh)	Absent (0%)	Sparse (< 10%)	Sparse (< 10%)	Absent (0%)
Understory (1.5 to 15 ft high)				
Vegetation Type	Mixed	Mixed	Mixed	Mixed
Woody Shrubs & Saplings	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)
Non-Woody Herbs, Grasses & Forbs	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)
Invasive Species	Heavy (40-75%)	Heavy (40-75%)	Heavy (40-75%)	Heavy (40-75%)
Ground Cover (0.0 to 1.5 ft high)				
Vegetation Type	Mixed	Mixed	Deciduous	Mixed
Woody Shrubs & Saplings	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)
Non-Woody Herbs, Grasses & Forbs	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)	Sparse (< 10%)
Barren, Bare Dirt, or Duff	Heavy (40-75%)	Heavy (40-75%)	Heavy (40-75%)	Heavy (40-75%)
Invasive Species	Moderate (10-40%)	Moderate (10-40%)	Sparse (< 10%)	Moderate (10-40%)

Water temperatures of the Columbia River at Washougal, Washington range from approximately 6°C in early spring to approximately 22°C in late summer (USGS 2007). Temperatures in the project area are assumed to be similar to this sample site, which is 2 miles upstream of the confluence of the Columbia and Washougal Rivers. Desirable water temperatures for young salmonids during downstream migration range from 6.7 to 13.3°C. In freshwater, temperatures greater than 23°C are lethal for juvenile salmonids, and temperatures greater than 21°C are lethal for adult salmonids (USACE 2001).

As discussed in the Water Quality and Hydrology Technical Report, the Columbia River does not meet Oregon Department of Environmental Quality (DEQ) standards (and is 303(d) listed) for the following parameters: temperature, PCBs, PAHs, DDT metabolites (DDE), and arsenic (DEQ 2007). The DEQ does not differentiate between the North Portland Harbor and Columbia River when compiling the 303(d) list; therefore, these listings also apply to the North Portland Harbor. The Columbia River is not on Washington State's 303(d) list for any parameters (Ecology

2009a). In addition to the 303(d) listings, EPA has approved total maximum daily loads (TMDLs) for the Columbia River for dioxin and total dissolved gas (DEQ 1991, 2002).

As discussed in the Water Quality and Hydrology Technical Report, runoff from the I-5 bridges over Hayden Island discharges directly to the Columbia River through roadside grates located along the entire span. Runoff from the bridges is not treated prior to release to the river.

Refer to the Water Quality and Hydrology Technical Report for a description of the Columbia River floodplain, hydrology, and details on stormwater outfalls.

The North Portland Harbor is a large side channel of the Columbia River located along the southern banks of Hayden Island. The harbor branches off the Columbia River upstream (east) of the existing bridges and flows approximately 5 miles downstream (west) before rejoining the mainstem Columbia. I-5 crosses the North Portland Harbor at approximately RM 4, and this crossing is referred to as the North Portland Harbor bridges (Exhibit 3-6).

Exhibit 3-6. North Portland Harbor Bridges

The aquatic description of the Columbia River also applies to North Portland Harbor. Much of the fish cover provided in North Portland Harbor consists of permanently moored floating homes and boathouses. Landform, specifically levees, and bridge footings are the dominant and subdominant floodplain constrictions, respectively.

The substrate of the harbor within the project area is predominantly composed of sand, with relatively small percentages of fine sediments and organic material. A bathymetric study completed in 2006 (DEA 2006) found deep scouring near the ends of the downstream piers on the north bank of the slough, with scour holes approximately 8 to 10 feet deep. Scouring around the upstream piers was approximately 3 to 7 feet. Scouring was more pronounced around the northern piers than the southern piers. A particularly deep (approximately 21 feet) area on the south side of the channel, downstream of the existing bridge, is indicative of a fast-moving current through the harbor. The average depth of the harbor was approximately 14 feet (Exhibit

3-7). Shallow-water habitat (defined as 20 feet deep or less) is present throughout the project area in North Portland Harbor.

The Columbia River and North Portland Harbor provide holding, migration, and limited rearing habitat for Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), steelhead trout (*O. mykiss*), coho salmon (*O. kisutch*), and eulachon (*Thaleichthys pacificus*), as well as for species of concern (SOC) such as coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) and Pacific lamprey (*Entosphenus tridentatus*). Additional native fish that are known to occur in the Columbia River and North Portland Harbor include white sturgeon (*Acipenser transmontanus*), green sturgeon (*Acipenser medirostris*), suckers (*Catostomus* spp.), sticklebacks (*Gasterosteus* spp.), starry flounder (*Platichthys stellatus*), sculpin (*Cottus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), shiners (*Cyprinidae*), peamouth (*Mylocheilus caurinus*), and chiselmouth (*Acrocheilus alutaceus*).

Aquatic organisms that constitute the prey base for salmonids and other fish in the Lower Columbia River include invertebrates such as sand shrimp, mysids, crabs, zooplankton (e.g., daphnids, chironomid larvae), and floating insect larvae and adults. Benthic species present in the Columbia River and North Portland Harbor include mussels (e.g., *Anodonta* spp.). Native species share aquatic habitat with listed salmonids and other aquatic species; therefore, habitat description, habitat quality parameters, and project impacts described for listed aquatic species also apply to populations of non-listed native species that occur within the project area.

Pier # / Location	Min. Depth	Max. Depth	Average Depth
P-2	15	30	23
P-3	24	29	27
P-4	24	27	25
P-5	28	31	30
P-6	28	30	29
P-7	6	31	20
N. Portland Harbor	6	20	13

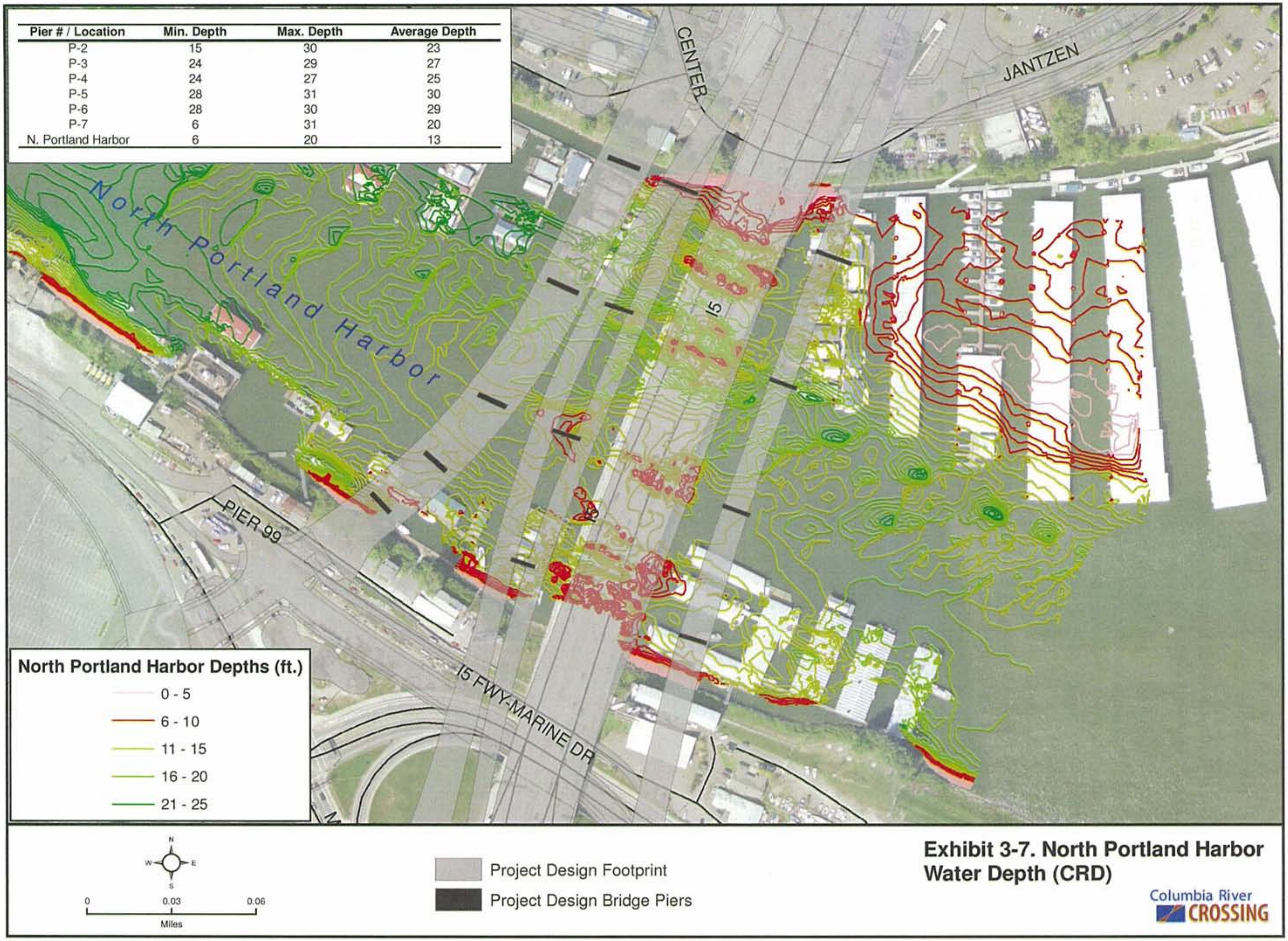


Exhibit 3-7. North Portland Harbor Water Depth (CRD)

Columbia River CROSSING

3.3.1.2 Columbia Slough

The Columbia Slough (also known as the Slough) is a slow-moving, low-gradient drainage canal running nearly 19 miles from Fairview Lake in the east to the Willamette River in the west. Running roughly parallel to the Columbia River, the Slough is a remnant of the historic system of lakes, wetlands, and channels that dominated the south floodplain of the river. Drainage and flood control in the Slough is provided via a system of dikes, pumps, weirs, and levees (CH2M Hill 2005). The Columbia Slough watershed drains approximately 37,741 acres of land in portions of Portland, Troutdale, Fairview, Gresham, Maywood Park, Wood Village, and Multnomah County (unincorporated areas). The Slough and surrounding area were historically used by Native Americans for fishing, hunting, and gathering food (COP 2009).

The Slough is divided into upper, middle, and lower reaches. The Upper and Middle Sloughs receive water inputs from Fairview Lake, groundwater, and stormwater from the Portland International Airport (PDX) and other industrial, commercial, and residential sites in the surrounding area. Water levels in the Upper and Middle Sloughs are managed to provide adequate flows for pollution reduction (e.g., during PDX de-icing/anti-icing events) and surface water withdrawals, flood control, and recreation (COP 2009). PDX is constructing new facilities to control releases of de-icing/anti-icing materials. Upgrades to the City of Portland sewer system were done in 2000 to control combined sewer overflows to the Slough.

The project area crosses the Lower Slough at RM 6.5 (CH2M HILL 2005) The predominant land use around the Slough in the project vicinity is light industrial, with some residential. The Lower Slough extends from the Peninsula Drainage Canal (which is the border between Peninsula Drainage District No. 1 and Multnomah County Drainage District No. 1) to the Willamette River. The Lower Slough connects to the Willamette River approximately 6.5 miles west of the project area, within a mile of the confluence of the Columbia and Willamette Rivers (COP 2009). The Lower Slough experiences from 1 to 3 feet of tidal fluctuation in water surface daily. Water levels are generally unmanaged in this portion of the Slough, but are affected by the management of the dams on the Columbia and Willamette Rivers. Water depth in the Lower Slough ranges from 2.0 to 4.5 feet NGVD. The slough is generally between 100 and 200 feet wide. The Lower Slough receives water inputs from combined sewer overflows, stormwater, Smith and Bybee Lakes, leachate from the St John's Landfill, and the Upper Columbia Slough (COP 2009).

The water column in the Columbia Slough often contains algal and aquatic macrophyte growth, especially in summer months when flow is low and temperatures are high. The Slough is a lentic (still water) system with low dissolved oxygen levels. However, the Slough provides habitat for many fish and wildlife species. As of 2004, 19 species of fish (including juvenile salmonids, lamprey, sculpins, threespine sticklebacks, and suckers), freshwater shrimp, and crawfish, had been identified in the Lower Slough. It provides some of the only remaining off-channel and refugia habitat in the Lower Willamette River area (COP 2009).

Anadromous fish can access the Lower Columbia Slough up to an impassable levee near NE 18th Avenue (RM 8.3). At Smith and Bybee Lakes, a water control structure allows fish passage. Recent genetic analyses of juvenile Chinook in the Slough show that juveniles originating from Middle and Upper Columbia River ESA-listed ESUs are present in the Slough from January to June (Teel et al. 2009). The Slough is accessible to and provides potentially suitable habitat for juveniles of most upper Columbia River and Willamette River salmonid runs. Juveniles are not likely to be present in the Slough during summer months (approximately June through September, depending on the year) as water temperatures are often too high to support juvenile salmonids (COP 2009).

Benthic habitat in the Lower Slough is dominated by sand, is extremely low in dissolved oxygen, and contains some toxic pollutants (COP 2009). Generally, the benthic community, including 36 taxa, increases in abundance from the Lower to the Upper Slough. This increase in species abundance is correlated to an increase in silt dominance, which increases with distance upstream in the Slough. Most of the species are adapted to low dissolved oxygen levels and still water conditions. The benthic community in the Columbia Slough appears to be similar in species richness and density to other similar aquatic habitats in the region (COP 2009).

Riparian habitat along the Slough has been significantly impacted by urban development along most portions of the Slough. Remaining areas of vegetation generally occur in a narrow band along Slough banks and are dominated by black cottonwood, Oregon ash (*Fraxinus latifolia*), willows, red osier dogwood (*Cornus sericea*), Himalayan blackberry, common snowberry (*Symphoricarpos albus*), and reed canarygrass. Both Himalayan blackberry and reed canarygrass are aggressive, non-native species. However, riparian areas in some portions along the Slough provide microclimate and shade, bank stabilization and sediment control, pollution control, streamflow moderation, organic matter input, large woody debris, and wildlife travel corridors.

Much of the Slough's wetland habitat has been filled, dredged, channelized, and/or degraded by current and past land uses. Remnant wetlands and restored wetlands do exist in the Slough watershed and provide habitat for wildlife, thermoregulation, nutrient removal, and other important ecosystem functions. The Oregon DEQ has listed irrigation, domestic and industrial water supply, livestock watering, anadromous fish passage, salmonid fish rearing, salmonid fish spawning, resident fish and aquatic life, wildlife use, hunting, fishing, boating, water contact recreation, aesthetic quality, and hydropower as beneficial uses of the Columbia Slough (Oregon Administrative Rules 340-041-0340, Table 340A; COP 2009).

Several restoration efforts are ongoing in the Columbia Slough area. The City of Portland's Watershed Revegetation Program and its community partners are conducting non-native species removal and native plantings in many areas along the Slough. The Multnomah County Drainage District (MCDD) now uses in-channel equipment to perform repairs and maintenance of channel and bank areas. Formerly, MCDD cleared vegetation to access these areas from the shore. Both vegetation enhancement and MCDD's alteration of maintenance practices have resulted in an increase in native plant diversity and cover in the Slough watershed. The City of Portland Bureau of Environmental Services (BES) has been involved in revegetation efforts in the Slough watershed since 1996 and has successfully re-established native vegetation along more than 40 miles of Slough streambank within the City of Portland (COP 2009).

3.3.1.3 Burnt Bridge Creek

Burnt Bridge Creek is a small perennial tributary to the Lower Columbia River. It originates near the Mill Plain suburb east of Vancouver, Washington and flows west (roughly paralleling SR 500 for approximately 5 miles) to its outlet at Vancouver Lake. The lake then drains into the Lower Columbia River via Lake River. I-5 crosses Burnt Bridge Creek at approximately RM 2.

Within and upstream of the project area (between Leverich Park and Fourth Plain Boulevard), canopy cover increases and many pools are present, providing good rearing and spawning habitat (WDFW 2007). Portions of the creek that are designated as riparian protection zone (e.g., within Leverich Park) tend to have retained characteristics of higher quality habitat, such as functioning pool and marsh habitat.

Within the project area, the stream passes through a valley constrained by surrounding land uses (primarily residential development). Stream slope is between 0 and 2 percent, but approximately 80 percent of the stream has a gradient of less than 0.1 percent (PBS 2003).

Burnt Bridge Creek enters the project area in Leverich Park, northeast of the I-5/SR 500 interchange. In the park area, the creek has substantial overhead cover from large-diameter trees and shrubs in some areas, and sparse cover by widely spaced large-diameter trees in areas maintained by park staff. In the more open areas within the park, the banks are highly eroded by regular visitor usage and mowing of herbaceous vegetation in the vicinity of the channel. Substrate within the park consists of fine sediments and gravels. Both riffles and pools are present within the park channel (WDFW/MHCC 1999).

Dominant tree species in this portion include natives such as Douglas-fir, black cottonwood, willow, and ash. The understory is dominated by non-native Himalayan blackberry and natives such as red alder (*Alnus rubra*), red osier dogwood, and beaked hazelnut (*Corylus cornuta*). Ground cover is typically dominated by non-native species such as Himalayan blackberry, reed canarygrass, and teasel (*Dipsacus sylvestris*). Riparian vegetation cover near Burnt Bridge Creek within the project area is summarized in Exhibit 3-8.

Exhibit 3-8. Riparian Vegetation Cover Estimate within the Project Area for Burnt Bridge Creek

	Vegetation Type and Density Left Bank (% cover)	Vegetation Type and Density Right Bank (% cover)
	Mixed	**Mixed**
Canopy (> 15 ft high)		
Big trees (Trunk > 1 ft dbh[a])	Moderate (10-40%)	Moderate (10-40%)
Small trees (Trunk < 1 ft dbh)	Moderate (10-40%)	Moderate (10-40%)
Understory (1.5 to 15 ft high)		
Woody Shrubs & Saplings	Very Heavy (> 75%)	Very Heavy (> 75%)
Non-Woody Herbs, Grasses & Forbs	Sparse (< 10%)	Heavy (40-75%)
Invasive Species	Very Heavy (> 75%)	Very Heavy (> 75%)
Ground Cover (0.0 to 1.5 ft high)		
Woody Shrubs & Saplings	Heavy (40-75%)	Heavy (40-75%)
Non-Woody Herbs, Grasses & Forbs	Sparse (< 10%)	Very Heavy (> 75%)
Barren, Bare Dirt, or Duff	Very Heavy (> 75%)	Very Heavy (> 75%)
Invasive Species	Absent (0%)	Absent (0%)

a Diameter at breast height.

From Leverich Park, the Burnt Bridge Creek channel passes under Leverich Park Way through a cement culvert and onto City of Vancouver property adjacent to I-5. The channel is armored for approximately 100 feet, after which it continues north, parallel to I-5 and Leverich Park Way, through a silt-dominated channel. The vegetation surrounding this portion of the channel is dominated by reed canarygrass with some overhanging Himalayan blackberry and red osier dogwood. Site observations indicate that the channel banks are undercut due to the growth habit of reed canarygrass and eroded due to the presence of nutria (*Myocastor coypus*).

Approximately 500 feet north of the cement culvert, Leverich Park Way bends to the west and the Burnt Bridge Creek channel passes under the roadway through a large corrugated metal pipe culvert. The channel continues north through a densely vegetated, privately owned area for about 200 feet. No permission to enter this area was granted during field visits to assess habitat and site characteristics. The channel then flows through a culvert under I-5, continuing north alongside a WSDOT wetland mitigation site to the west and Bonneville Power Administration (BPA) property and private land to the east. From the second culvert under Leverich Park Way to the point where Burnt Bridge Creek exits the project area, the channel is dominated by fine sediments

(PBS 2003) and has moderate to dense overhanging vegetation consisting of deciduous and coniferous tree and shrub species.

Between I-5 and Vancouver Lake, the creek is low gradient with moderate canopy cover, and contains marsh and pool features that provide good rearing habitat for juvenile salmonids.

Within the project area, Burnt Bridge Creek is on Ecology's 303(d) list for fecal coliform and temperature (DEQ 2007). Ecology has not approved any TMDLs for Burnt Bridge Creek (Ecology 2009b). Some stormwater runoff is routed to the creek through pipes and ditches, but most runoff is discharged into the ground through buried infiltration facilities. Three stormwater outfalls from I-5 discharge treated water into Burnt Bridge Creek: one on the east side of I-5 and two on the west side of I-5. Runoff from I-5 at the north of the SR 500 interchange area is routed to a retention pond east of I-5 and south of the Main Street interchange. Retained runoff usually evaporates or infiltrates, and releases to Burnt Bridge Creek only occur during peak runoff events. Runoff from SR 500 east of I-5 flows to a detention pond located at NE 15th Avenue before being released to Burnt Bridge Creek.

All freshwater life stages of coho, Chinook, and steelhead are potentially present in Burnt Bridge Creek (Weinheimer 2007 pers. comm.). Native resident fish including dace (Cyprinidae), threespine stickleback, redside shiners, suckers, sculpin, and lamprey are also present in the creek (PBS 2003).

3.3.1.4 Fairview Creek

Fairview Creek is a 5-mile urban stream whose headwaters consist of a wetland near Grant Butte in Gresham. The creek drains to Fairview Lake, a tributary to the eastern portion of the Columbia Slough. Historically, the creek had been a tributary of the Columbia River, but the water from the wetlands was diverted into an artificial channel that drained into the Columbia Slough. In 1960, water managers built a dam along Fairview Creek to create Fairview Lake for water storage and recreation. Fairview Creek has two named tributaries, No Name Creek and Clear Creek (COP 2009).

Fairview Creek receives stormwater runoff from Gresham, Wood Village, and Fairview, an area of about 6.5 square miles. Average flow in Fairview Creek at the USGS gauging station near Glisan Street, approximately 1.4 miles downstream of the Ruby Junction Operations Facility, was 6.39 cfs from 1992 to 1999 (Metro 2003). The 100-year floodplain for Fairview Creek is approximately 1,288 feet wide at its widest point, adjacent to the proposed maintenance facility expansion area (Metro 2003).

DEQ has placed Fairview Creek on its 303(d) list for *E. coli* (year-round) and fecal coliform (fall/winter/spring); it also has approved TMDLs for bacteria and spring/summer temperature (COP 2008a; DEQ 2009).

Excessive fine sediments have been shown to settle in the streambeds of Fairview Creek. This is caused by the erosion of upland areas and deposition of sediments by stormwater discharged to the creek. These sediments degrade native fish spawning areas and limit suitable habitat for benthic organisms (COP 2009).

Some stream restoration has occurred along Fairview Creek. The East Multnomah Soil and Water Conservation District (SWCD), Smith Presbyterian Church, ODFW, Fairview Village, and the City of Gresham have planted riparian areas, limited human access to sections of the stream, and installed large woody debris and boulders as in-stream habitat structures. The stream system also includes approximately 1 mile of undeveloped land, which includes parks and green spaces (Brick 2008 pers. comm.).

Fairview Creek between 185th and Marine Drive to Burnside Street has 21 stream crossings. All crossings between the Columbia Slough confluence and Glisan Street appear to be fish-passable, though some may be slightly undersized (Brick 2008 pers. comm.). Fairview Creek habitat upstream of Glisan Street was not assessed for this project.

Anadromous salmonids are not currently present in Fairview Creek. There is an impassable barrier between the lower and middle sections of the Columbia Slough located approximately at stream mile 8.3 (near NE 18th Avenue), approximately 10 miles downstream of Fairview Creek. At one time, Johnson Creek connected to the wetlands that serve as the headwaters of Fairview Creek. The two streams are not currently connected. However, it is possible that on rare occasions during extreme flood events, coho salmon or steelhead trout could enter Fairview Creek via Johnson Creek. These fish would most likely become trapped in the Fairview Creek system (Brick 2008 pers. comm.).

The creek may currently support resident fish species. Native cutthroat trout presence has been documented in only two of the remaining tributaries of the Columbia Slough: Fairview Creek and Osborn Creek (COP 2009).

3.3.2 Threatened, Endangered, and Proposed Species

"Listed" species refer to those with federal and/or state threatened, endangered, or proposed status. Data on listed species were obtained from NMFS, USFWS, ORNHIC, WDNR-NHP, and WDFW-PHS. The Columbia River and North Portland Harbor are known to support listed anadromous salmonids, including Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), steelhead trout (*O. mykiss*), and coho salmon (*O. kisutch*), as well as species of concern (SOC) such as Pacific lamprey (*Entosphenus tridentatus)*, river lamprey(*Lampetra ayresi*), coastal cutthroat trout, and the northern distinct population segment (DPS) of green sturgeon (*Acipenser medirostris*) (Exhibit 3-9). Habitat use for these species is primarily migration, holding, and rearing. Chum salmon are known to spawn in the Columbia River upstream of the project area, near the mouth of Camas Creek (FPC 2009) and a recent study showed that Hayden Island provides limited rearing habitat for chum in the project vicinity (NOAA 2009). The southern DPS of eulachon (*Thaleichthys pacificus)* occurs in the Columbia River during migration and spawning.

Bull trout (*Salvelinus confluentus*) are federally threatened and have been documented in the Lower Columbia River at very low abundance (Gray 2007). Bull trout use of the Lower Columbia may include overwintering and feeding; the Bull Trout Lower Columbia Recovery Team considers the mainstem Columbia River to contain core habitat necessary for full recovery of the species (USFWS 2002). Critical habitat has been proposed in the Columbia River within the project area.

NMFS has determined that the southern DPS of green sturgeon may occur in Washington coastal waters and below RM 35 of the Columbia River (74 FR 52299). Northern and southern DPSs were delineated in 2003; in 2006, the southern DPS was listed as threatened, while the northern DPS was classified as a SOC. Southern green sturgeon spawn in the Sacramento River, California, while northern green sturgeon spawn in the Klamath and Rogue Rivers in Oregon. Genetic and tagging data indicate that the stocks commingle in the Columbia River estuary during the summer as sub-adults and adults.

Steller sea lions are listed as threatened under the federal ESA as well as by both Oregon and Washington. California sea lions (*Zalophus californianus*) and harbor seals (*Phoca vitulina*) are not listed under the ESA, but like Steller sea lions, they are protected under the MMPA.

Pacific lamprey (*Entosphenus tridentatus*, formerly *Lampetra tridentata*) have significant cultural, spiritual, ceremonial, medicinal, subsistence, and ecological value for many Native American tribes in the Pacific Northwest (Archuleta 2005, CRITFC 2008). Lamprey play a key role in the aquatic and terrestrial food web and are an indicator species for anthropogenic impacts to ecological systems (Close et al. 2002). Pacific lampreys are thought to have been historically distributed wherever salmon and steelhead occurred (USFWS 2010). However, current data indicate that distribution and abundance of Pacific lamprey have been significantly reduced by the construction of dams, water diversions, and by degradation of spawning and rearing habitat (Quigley et al. 1996). Pacific lamprey are a federal Species of Concern. For a full discussion of Pacific lamprey in the project area, refer to Appendix A.

Exhibit 3-9. Protected Aquatic/Fish Species Potentially Occurring within the Project Area

ESU/DPS (Where Appropriate)[a] Species Common Name *Species Scientific Name*	Federal Status[b]	OR Status[c]	WA Status[d]	Critical Habitat Present	EFH Present in Project Area[e]	ESH Present in Project Area[f]	Presence Documented in Project Area[g]	Habitat Use within Project Area[h]
Lower Columbia River ESU **Chinook salmon** *Oncorhynchus tshawytscha*	LT	SC	SC	Yes	Yes	No	Yes	M/R/H
Upper Columbia River-Spring Run **Chinook salmon** *Oncorhynchus tshawytscha*	LE	N/A	SC	Yes	Yes	No	Yes	M/R/H
Snake River Fall-Run **Chinook salmon** *Oncorhynchus tshawytscha*	LT	LT	SC	Yes	Yes	No	Yes	M/R/H
Snake River Spring/Summer-Run **Chinook salmon** *Oncorhynchus tshawytscha*	LT	LT	SC	Yes	Yes	No	Yes	M/R/H
Lower Columbia River DPS **Steelhead trout** *Oncorhynchus mykiss*	LT	SC	SC	Yes	No	No	Yes	M/R/H
Middle Columbia River **Steelhead trout** *Oncorhynchus mykiss*	LT	SC	SC	Yes	No	No	Yes	M/R/H
Upper Columbia River **Steelhead trout** *Oncorhynchus mykiss*	LE	N/A	SC	Yes	No	No	Yes	M/R/H
Snake River Basin **Steelhead trout** *Oncorhynchus mykiss*	LT	SV	SC	Yes	No	No	Yes	M/R/H
Snake River **Sockeye salmon** *Oncorhynchus nerka*	LE	None	SC	Yes	No	No	Yes	M/R/H

ESU/DPS (Where Appropriate)[a] Species Common Name *Species Scientific Name*	Federal Status[b]	OR Status[c]	WA Status[d]	Critical Habitat Present	EFH Present in Project Area[e]	ESH Present in Project Area[f]	Presence Documented in Project Area[g]	Habitat Use within Project Area[h]
Lower Columbia River **Coho salmon** *Oncorhynchus kisutch*	LT	LE	None	N/A	Yes	No	Yes	M/R/H
Columbia River ESU **Chum salmon** *Oncorhynchus keta*	LT	SC	SC	Yes	No	No	Yes	M/R/H
Southwestern Washington/Columbia River **Coastal cutthroat trout** *Oncorhynchus clarki clarki*	SOC	SV	N/A	N/A	N/A	No	Yes	Unknown
Columbia River DPS **Bull trout** *Salvelinus confluentus*	LT	SC	SC	Yes	N/A	No	Yes	Unknown; potentially overwintering and feeding
Southern DPS **Eulachon** *Thaleichthys pacificus*	LT	None	SC	N/A	N/A	N/A	Yes	M,S
Pacific lamprey *Lampetra tridentata*	SOC	SV	None	N/A	N/A	N/A	Yes	Unknown
River lamprey *Lampetra ayresi*	SOC	None	SC	N/A	N/A	N/A	Unconfirmed	Unknown
Northern DPS **Green sturgeon** *Acipenser medirostris*	SOC	None	None	N/A	N/A	N/A	Yes	Unknown
Southern DPS **Green sturgeon** *Acipenser medirostris*	LT	None	None	No	N/A	N/A	Unlikely	Unknown
Steller sea lion *Eumetopias jubatus*	LT	LT	LT	No	N/A	N/A	Yes	Transiting, Foraging
California sea lion *Zalophus californianus*	Protected (MMPA)	None	None	N/A	N/A	N/A	Yes	Transiting, Foraging
Harbor seal (*Phoca vitulina*)	Protected (MMPA)	None	None	N/A	N/A	N/A	Yes	Transiting, Foraging

a ESU = Evolutionarily Significant Unit; DPS = Distinct Population Segment (USFWS 2008).

b Federal status: LT = Listed Threatened, LE = Listed Endangered, P = Proposed, C = Candidate, SOC = Species of Concern, N/A = Not Applicable (USFWS 2008).

c OR State status: LT = Listed Threatened, SC = Sensitive Critical, SV = Sensitive Vulnerable, None = No status designated, N/A = Not Applicable (Oregon Threatened and Endangered Species List).

d WA state status: SC=state candidate, N/A = Not Applicable (WDFW-PHS).

e EFH = Essential Fish Habitat, per the MSFCMA.

f ESH = Essential Salmonid Habitat, per DSL and ODFW.

g Source = StreamNet (2005).

h Habitat uses: S = Spawning, M/R/H = Migration/Limited Rearing/Holding (StreamNet 2005, NOAA 2009).

NMFS has designated critical habitat for several of the listed salmonid evolutionarily significant units (ESUs) (or DPS for steelhead) that occur in the Columbia River and North Portland Harbor. Chinook and coho salmon habitat is also managed under the MSFCMA. The MSFCMA requires cooperation among NMFS, the Regional Fishery Management Councils, fishing participants, federal and state agencies, and others in achieving the EFH goals of habitat protection, conservation, and enhancement. EFH comprises those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity, and includes the Columbia River and North Portland Harbor (NMFS 2008a). Of the fish species present in the project area, EFH applies only to Chinook and coho.

DSL, in coordination with other agencies, also designates ESH. ESH is defined as the habitat necessary to prevent the depletion of native salmon species during their life history stages of spawning and rearing (Oregon Administrative Rule [OAR] 141-102-0000). Aquatic habitats within the project area are not designated as ESH.

Formal consultation under Section 7 of the ESA to analyze effects to listed species and EFH has been completed. NMFS issued a Biological Opinion with a "not likely to jeopardize" determination for thirteen salmonid stocks, southern green sturgeon, eulachon, Steller sea lion, and relevant critical habitat on January 19, 2011. NMFS also concurred with the determination that the proposed action is "not likely to adversely affect" the southern resident killer whale (*Orcinus orca*). USFWS issued a concurrence letter for a "not likely to adversely affect" determination for bull trout and designated critical habitat on August 27, 2010.

3.3.2.1 Fish Passage

There are no known fish passage barriers within the project area. Barriers to fish passage are present on tributaries to the Columbia River along its entire length and dams are present on the river upstream of the project area. Off-channel habitat along the North Portland Harbor is extremely limited compared to likely historic conditions, and has been degraded along most of the North Portland Harbor. Levees act as fish passage barriers to historic off-channel habitat in both the Columbia River and North Portland Harbor. Insufficient passage facilities (e.g., undersized and failing culverts) are present in Burnt Bridge Creek downstream of the project area, but do not act as complete passage barriers, There are no known passage barriers in the Lower Columbia Slough within the project area. As noted above in section 3.3.1.4, fish passage barriers are present downstream of Fairview Creek in the Middle Columbia River Slough; however, none are present in the creek within the project area.

3.4 Terrestrial Resources

3.4.1 Summary of Terrestrial Resources

Two recently federally delisted species that may occur in or near the project area are bald eagles and peregrine falcons. Although both species have been delisted from the federal ESA, the bald eagle is still listed as threatened by Oregon and Washington, and both species' populations will be closely monitored in the near future. Bald eagles will continue to be protected by Washington and Oregon, as well as by the federal Bald and Golden Eagle Protection Act (BGEPA) and the MBTA. No known or potential bald eagle nesting or communal roosting areas exist within the project area. Bald eagles likely forage along the Columbia River and North Portland Harbor.

The peregrine falcon was federally delisted in August 1999, and was delisted by the State of Oregon in April 2007. The species is listed by the State of Washington as sensitive. Peregrine falcons are known to nest in the project area. In addition to being protected under state law, the peregrine falcon is protected by the MBTA. The State of Oregon has not prepared a conservation plan for the peregrine falcon, although their presence in the project area has been monitored since 2001 (Casey 2011).

Bridges are also home to other SOI, including bats and native birds such as swallows (also protected under the MBTA). Bats may use bridge structures for day roosts, and swallows may nest on bridge structures, particularly those over or adjacent to water.

Five terrestrial habitat types exist within the project area. These are described further in Section 3.4.2. Two of these habitat types, Westside Riparian Wetland and Herbaceous Wetlands, are priority habitats for the area (Johnson and O'Neil 2001). In addition to protecting species, local, state, and federal laws protect terrestrial habitats (Section 7).

The terrestrial habitats in the project area support rare species as well as more common native mammals, birds, amphibians, and reptiles, including but not limited to salamanders (e.g., *Batrachoseps* spp.), frogs (e.g., red-legged frogs [*Rana aurora*], tree frogs [*Hyla* spp.]), painted turtles (*Chrysemys picta*), pond turtles (*Emys marmorata*), ospreys (*Pandion haliaetus*), red-tailed hawks (*Buteo jamaicensis*), grebes (*Aechmophorus* spp.), finches (*Carpodacus* spp.), blackbirds (*Agelaius* spp.), geese (*Branta* spp.), native squirrels (*Sciurus* spp.), and raccoons (*Procyon lotor*). Many of these species are discussed under SOI (Section 4.3.4).

3.4.2 Habitat Occurrence

Habitat is the area where wildlife nest, feed, roost, and raise their young. The analysis in this document uses Johnson and O'Neil (2001) Habitat Types classification to classify the different habitats located within the project area (Exhibit 3-11).

- Open Water - Lakes, Rivers, and Streams
- Urban and Mixed Environs
- Westside Lowlands Conifer-Hardwood Forest
- Herbaceous Wetlands
- Westside Riparian – Wetlands

Exhibit 3-10 lists the acres of each Johnson and O'Neil habitat type occurring in the project area.

Exhibit 3-10. Acres of Habitat Classification within the Project Area[a]

Habitat Classification	Acres
Johnson and O'Neil classifications:	
Westside Lowland Conifer-Hardwood Forest	16.9
Lakes, Rivers, Ponds, and Reservoirs	1722.8
Herbaceous Wetlands	9.1
Westside Riparian – Wetlands	30
Urban and Mixed Environs	1179.8
Total:	**2958.6**

a Includes staging and casting areas, noise attenuation distances, and Ruby Junction (see areas shown on Exhibit 3-11).

Each of the five habitat types provide nesting, breeding, foraging, and/or dispersal habitat for migratory birds, small mammals, amphibians, reptiles, and other native species (Johnson and O'Neil 2001).

6180

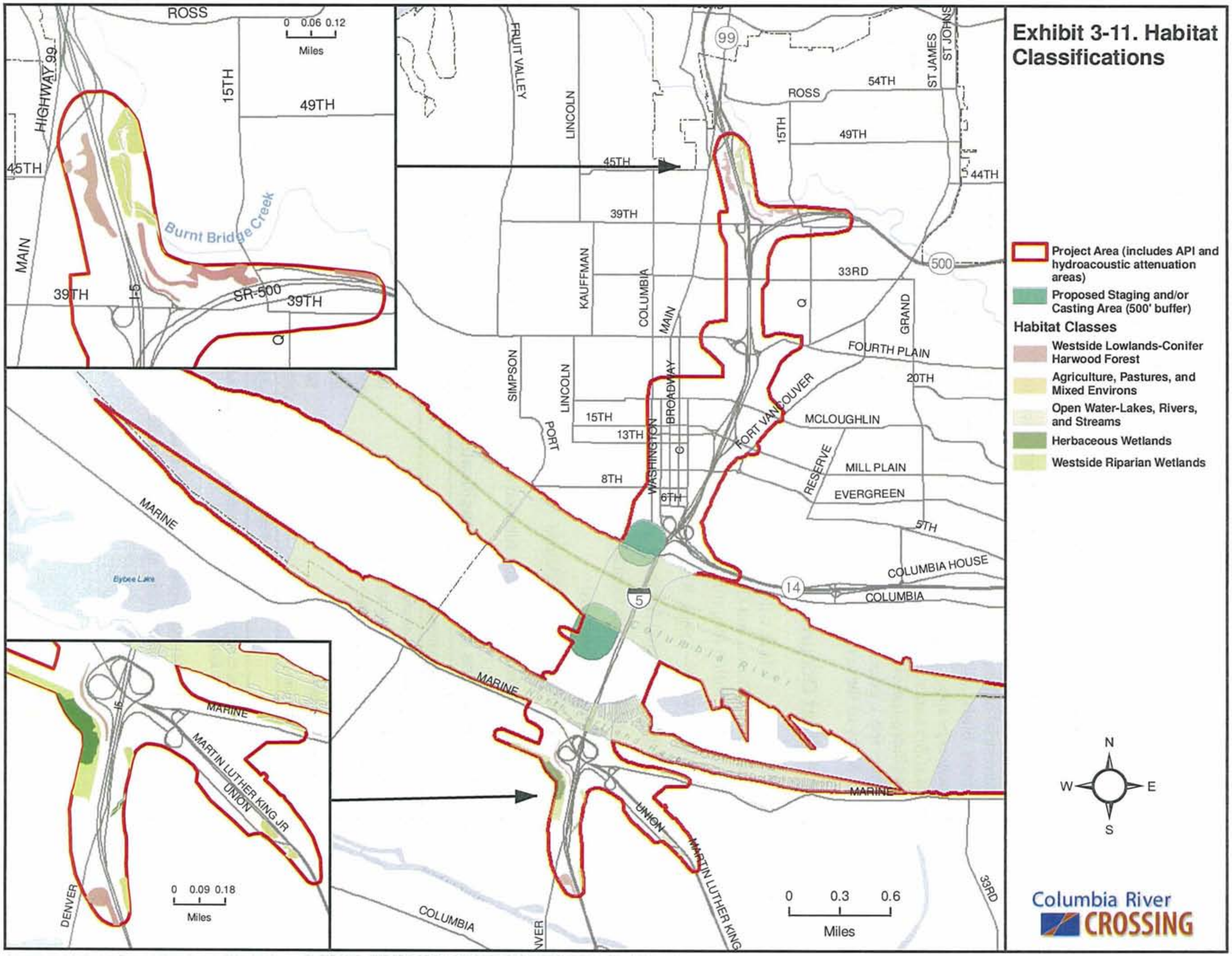


Exhibit 3-11. Habitat Classifications
Project Area (includes API and hydroacoustic attenuation areas)
Proposed Staging and/or Casting Area (500' buffer)
Habitat Classes
Westside Lowlands-Conifer Harwood Forest
Agriculture, Pastures, and Mixed Environs
Open Water-Lakes, Rivers, and Streams
Herbaceous Wetlands
Westside Riparian Wetlands
N
W
E
S
0 0.3 0.6
Miles
0 0.06 0.12
Miles
0 0.09 0.18
Miles
ROSS
HIGHWAY 99
15TH
49TH
45TH
Burnt Bridge Creek
MAIN
39TH
I-5
SR-500
Q
FRUIT VALLEY
LINCOLN
54TH
ST JAMES
ST JOHNS
44TH
33RD
KAUFFMAN
COLUMBIA
GRAND
FOURTH PLAIN
20TH
SIMPSON
PORT
13TH
8TH
WASHINGTON
BROADWAY
C
6TH
FORT VANCOUVER
MCLOUGHLIN
RESERVE
MILL PLAIN
EVERGREEN
5TH
COLUMBIA HOUSE
MARINE
Bybee Lake
Columbia River
MARTIN LUTHER KING JR
UNION
DENVER
MARTIN LUTHER KING
Columbia River CROSSING

3.4.2.1 Open Water – Lakes, Rivers, and Streams

This habitat includes all areas of open freshwater and shorelines, gravel bars, and sand bars associated with these habitats throughout the region (Johnson and O'Neil 2001). Species of interest associated with this habitat type include the bald eagle, peregrine falcon, osprey, geese and other waterfowl, migratory songbirds, Townsend's big-eared bat, purple martin, Pacific pond turtle, and northern painted turtle (Johnson and O'Neil 2001).

Within the project area, this habitat type includes the Columbia River and the North Portland Harbor.

3.4.2.2 Urban and Mixed Environs (High-density)

This habitat type consists of land containing built structures and impervious surfaces such as buildings, houses, parking lots, and roads. This habitat type is found throughout the project area and occurs within or adjacent to nearly every other habitat type. Land use types may include a mix of commercial, residential, and transportation developments. Many vegetative structural features typical of the historical vegetation have been removed. However, some remaining vegetative structures can provide habitat for nesting or roosting, and landscaping may provide foraging or nesting opportunities. High-density urban landscapes are covered with 60 to 100 percent impervious surfaces. Examples of SOI associated with this habitat type include the bald eagle, peregrine falcon, red-tailed hawk, migratory songbirds, kingfishers, and Townsend's big-eared bat (Johnson and O'Neil 2001).

These environs include core downtown areas, commercial areas, shopping malls, industrial areas, high-density housing, and transportation corridors such as I-5 (Johnson and O'Neil 2001).

3.4.2.3 Westside Lowlands Conifer – Hardwood Forest

This lowland to low montane upland forest occurs over most of western Washington, the Coast Range of Oregon, the western slopes of the Cascades in Oregon, and around the margins of the Willamette Valley. This forest is dominated by one or more of the following species: Western hemlock, Western red cedar, Douglas-fir, Sitka spruce *(Picea sitchensis)*, red alder, Port-Orford cedar, and bigleaf maple. This habitat type does not include dry Douglas-fir forests where western hemlock is not able to grow (Johnson and O'Neil 2001). Examples of SOI associated with this habitat type include the bald eagle, peregrine falcon, migratory songbirds, Townsend's big-eared bat, and, historically, the yellow-billed cuckoo and purple martin (Johnson and O'Neil 2001).

Only a small portion of the project area is composed of the Westside Lowlands Conifer-Hardwood Forest habitat type; this portion consists of very small, isolated patches surrounded by urban and mixed environs (e.g., Leverich Park).

3.4.2.4 Herbaceous Wetlands

This habitat type is composed of wet meadows, marshes, fens, and aquatic beds. These habitats are wetlands or riverine floodplains that are dominated by herbaceous vegetation. Common dominants include cattails, sedges, grasses, bulrushes, and various forbs. Aquatic rooted plants that extend to the surface or floating aquatic plants are also dominants (Johnson and O'Neil 2001). Examples of SOI associated with this habitat type include the bald eagle, peregrine falcon, Townsend's big-eared bat, purple martin, and painted turtle (Johnson and O'Neil 2001).

The Herbaceous Wetlands habitat type can be found at the Vanport Wetlands complex (located west of I-5 and south of Marine Drive), immediately surrounding the open water pond/wetland system east of I-5 Delta Park, and the closed slough east of I-5 along Whitaker Road. Please refer to the Wetlands and Waters Technical Report for more detailed information on wetlands in the project area.

3.4.2.5 Westside Riparian – Wetlands

This habitat includes all freshwater wetlands and riverine floodplains that are dominated by trees or shrubs at low elevations on the west side of the Cascades. Typical dominant species include Sitka spruce, Western red cedar, Western hemlock, red alder, black cottonwood, Oregon ash, willows, and spirea. Also included are all sphagnum bogs (forested, shrub, and herb-dominated) (Johnson and O'Neil 2001). SOI associated with this habitat type include the bald eagle, peregrine falcon, Townsend's big-eared bat, purple martin, willow flycatcher, migratory songbirds, pond turtles, and painted turtle (Johnson and O'Neil 2001).

The Westside Riparian – Wetlands habitat type is found scattered in small patches along the Columbia River and North Portland Harbor, and along the Oregon side of the Columbia River. This habitat type can also be found within the Vanport Wetlands complex. Very little riparian vegetation exists along the Columbia River. Human activities, urban development, and the absence of a riparian corridor cause the riparian area along the Columbia River to be highly disturbed. Please refer to the Wetlands and Waters Technical Report for more detailed information on wetlands in the project area.

3.5 Regional and Local Resource Protection

The project area is located within several governmental jurisdictions, and resource protection regulations vary with each jurisdiction. With the exception of Multnomah County, each of these jurisdictions has established habitat classifications that include lands within the project area. A summary of regional and local resource protection is found in Exhibit 3-12. Note that some of these areas overlap. For example, the open water habitat of the Columbia River is located within a Washington priority habitat, a Portland environmental zone (E-Zone), and a Goal 5 habitat for Metro. Refer to Section 7 for permits and approvals that may be associated with these resource protection areas.

Exhibit 3-12. Regional and Local Resource Protection in the Project Area[a]

Agency	Jurisdiction	Program	Habitat Protected	Acres in Project Area
WDFW	Washington State	Priority Habitats	Riparian, Urban Natural Open Space, Oak Woodland	2315.6
City of Vancouver	City of Vancouver	Critical Areas Protection Ordinance	Fish and wildlife habitat conservation areas, wetlands, frequently flooded areas, critical aquifer recharge areas, and geologic hazard areas	2375.4[b]
Clark County	Unincorporated areas of Clark County	Critical Areas Protection Ordinance	Riparian Priority Habitat, Other Priority Habitats and Species, and Locally Important Habitats and Species	See City of Vancouver acres above
City of Portland	City of Portland	Environmental Zones	Important natural resource areas	1977.9
Metro	Portland metropolitan area	Goal 5	Regionally significant fish and wildlife habitat; Riparian habitat; Upland habitat	5106.9

a Includes staging and casting areas, noise attenuation distances, and Ruby Junction (see areas shown on Exhibit 3-13, 3-14, and 3-16).

b City of Vancouver and Clark County critical lands are merged for mapping purposes; these figures represent critical areas for both City of Vancouver and Clark County.

3.5.1 Washington

3.5.1.1 Washington Department of Fish and Wildlife

WDFW is responsible for protecting fish and wildlife species. In order to address the protection of these habitats, WDFW publishes a Priority Habitats and Species List that identifies those habitats and species that should be a priority for management and conservation. This list is largely created to inform the management and conservation efforts of landowners, agencies, governments, and members of the public who, according to WDFW, "have a shared responsibility to protect and maintain these resources" (WDFW 2008).

Priority habitats are those habitats with "unique or significant value to a diverse assemblage of species," including but not limited to a "unique vegetation type or dominant plant species, a described successional stage, or a specific structural element." One or more of the following habitat characteristics are used by WDFW to identify a priority habitat:

- Comparatively high fish and wildlife density
- Comparatively high fish and wildlife species diversity
- Important fish and wildlife breeding habitat
- Important fish and wildlife seasonal ranges
- Important fish and wildlife movement corridors
- Limited availability
- High vulnerability to habitat alteration
- Unique or dependent species

Washington classifies 18 priority habitat types, three of which occur within the project area: Riparian, Urban Natural Open Space, and Oak Woodland. These are mapped in Exhibit 3-13 as riparian and non-riparian conservation areas. These priority habitats were not field-verified during the September 2005 surveys. See Exhibit 3-12 for a summary of acreage of this habitat type occurring in the project area.

3.5.1.2 City of Vancouver

As mandated by the Growth Management Act (GMA) (RCW 36.70A), the City of Vancouver designates and protects through ordinance ecologically sensitive and hazardous areas, termed here "critical areas," as well as their functions and values. Critical areas include wetlands, fish and wildlife habitat conservation areas, geologically hazardous areas, frequently flooded areas, and areas with critical effects on aquifers providing potable water.

Fish and wildlife habitat conservation areas include lakes, streams, rivers, naturally occurring ponds, riparian buffers, and any habitat that serves any life stage of state of federally designated endangered, threatened, or sensitive fish or wildlife species. These conservation areas can also include habitats of Local Importance—habitats that are not designated as Priority Habitat by WDFW but that serve a local importance as recognized by the City.

Frequently flooded areas have been identified as having special flood hazards by the Federal Insurance Administration and the Federal Emergency Management Agency (FEMA) in scientific and engineering reports entitled *The Flood Insurance Study for the City of Vancouver, Washington, Clark County* (1981) and *The Flood Insurance Study for Clark County, Washington*

(1991), respectively, and accompanying Flood Insurance Rate Maps, Flood Boundary-Floodway Maps, and any revisions thereto.

Geologic hazard areas include landslide, seismic, and erosion hazard areas. Landslide hazard areas include areas where slopes on the property are greater than 25 percent, and areas of historic or active landslides, potential instability, or older landslide debris. Seismic hazard areas include areas subject to liquefaction or dynamic, ground-shaking amplification, and fault rupture hazard areas as identified in previous scientific studies. Erosion hazard areas include areas of potential severe soil or bank erosion as determined by previous Natural Resources Conservation Service (NRCS) studies. Further details on geologic hazards are discussed in the Geology and Soils Technical Report.

The Critical Areas Ordinance (CAO) requires that development in these critical areas result in no net loss of function, including, but not limited to, water quality protection and enhancement, fish and wildlife habitat, and ground water recharge and discharge. This CAO is also intended to "protect residents from hazards and minimize risk of injury or property damage" (City of Vancouver, Municipal Code, Chapter 20.740).

A small portion of the project area is identified as Critical Sensitive Lands. Along the Columbia River in Washington, the riparian area is designated as a critical area (Exhibit 3-13). In addition, under Vancouver Municipal Code 14.26, (Water Resources Protection), the entire City is considered a critical area for the purpose of keeping the City's water resources from being contaminated. The City of Vancouver has jurisdiction over critical areas within the City boundaries. Clark County has jurisdiction over critical areas in the unincorporated area of the County. This discussion of critical areas refers to critical areas within the City of Vancouver. See Exhibit 3-12 for a summary of acreage of this habitat type occurring in the project area.

3.5.2 Oregon

3.5.2.1 City of Portland

The City of Portland applies two environmental overlay zones, protection and conservation, to sites throughout the city to protect natural resources. The Environmental Conservation and Protection zones (or E-Zones) are defined in Title 33, Planning and Zoning, Chapter 33.430 of the Municipal Code (City of Portland 2007). These E-Zones are in place to limit development in "resource areas" that contain significant resources and functional values (values provided by the resources) and the transition areas that buffer them from surrounding pressures. The transition area is defined as the first 25 feet from an E-Zone boundary.

Environmental protection zones provide the highest level of protection for resource areas deemed highly valuable through a detailed inventory and economic, social, environmental, and energy (ESEE) analysis. Development is largely prevented in these areas. Conservation areas are also considered valuable, but can be protected while allowing "environmentally sensitive urban development."

The application of the environmental zones is limited to areas that have undergone a thorough inventory of resources and functional value, in addition to an ESEE analysis. Environmental zoning applies to all development and site disturbance activities. The Columbia River, North Portland Harbor, and Columbia Slough are zoned for conservation (Exhibit 3-14). No lands are designated as a preservation zone. See Exhibit 3-12 for a summary of acreage of this habitat type occurring in the project area.

PRELIMINARY

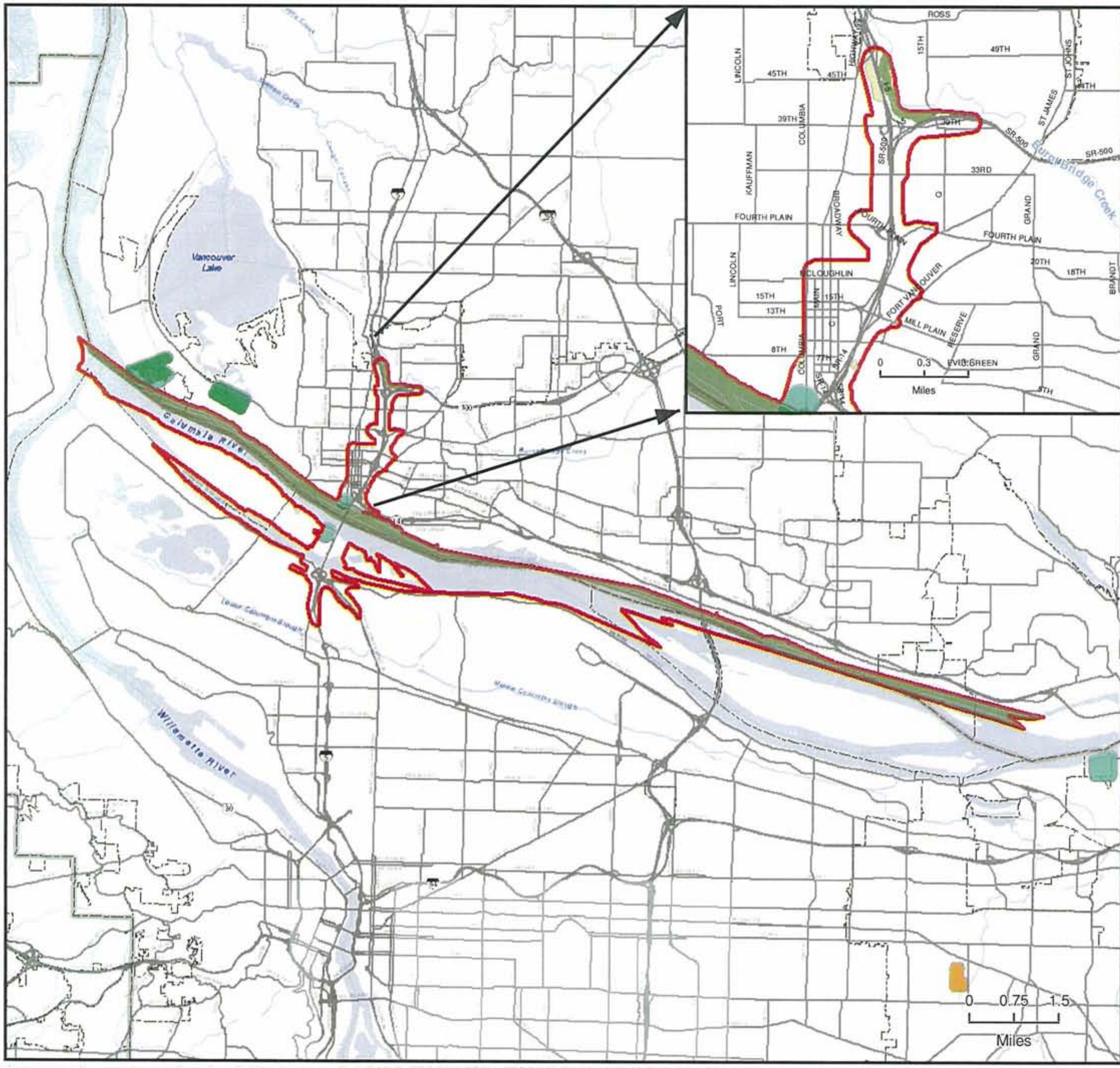


Exhibit 3-13. Washington Department of Fish and Wildlife Priority Habitat and Species Areas

Clark County

Columbia River CROSSING

PRELIMINARY

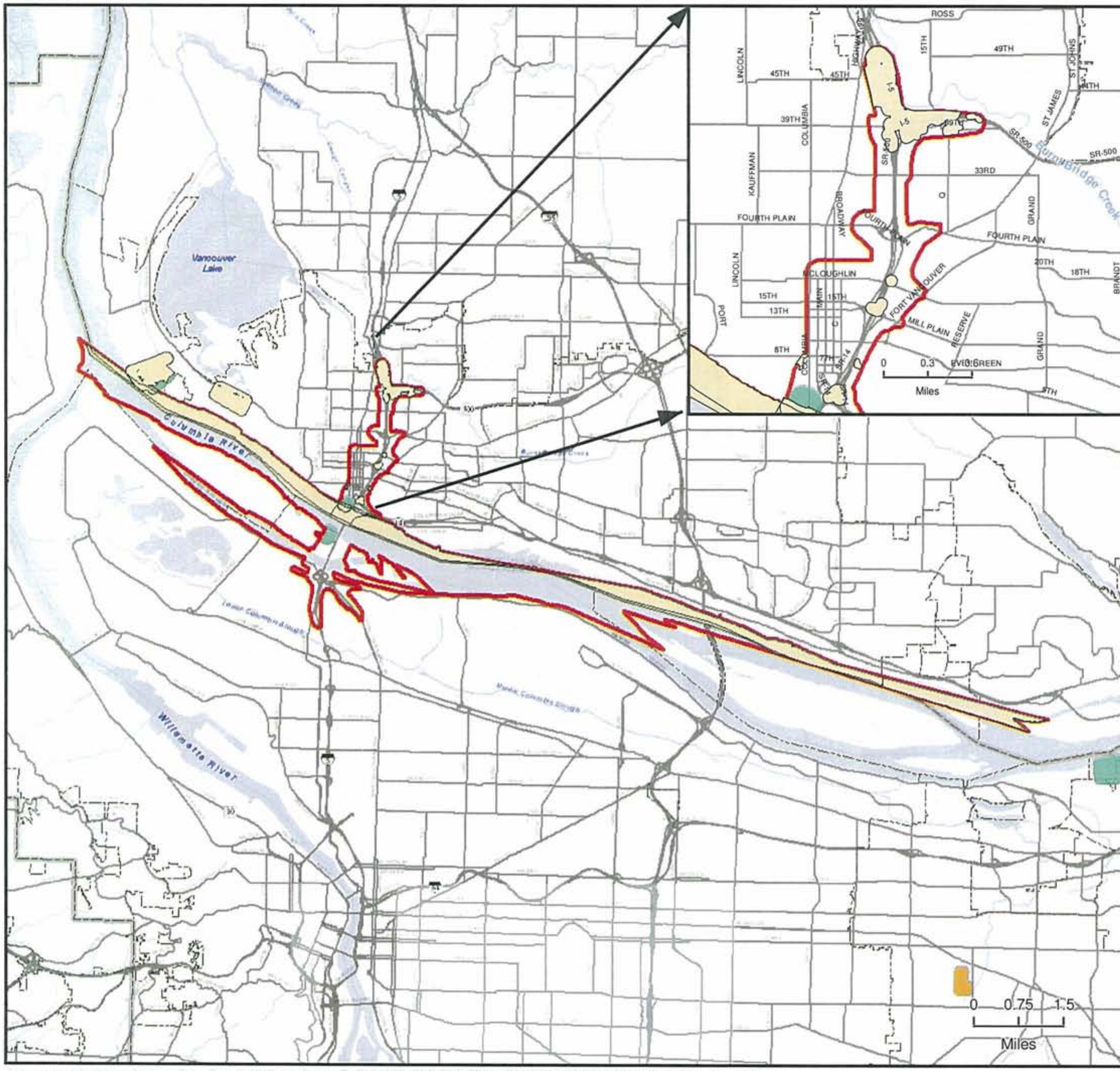


Exhibit 3-14. Critical Lands
Clark County

- Project Area (includes API and hydroacoustic attenuation areas)
- Ruby Junction Maintenance Facility
- Proposed Staging and/or Casting Area (500' buffer)
- Critical Lands (critical 1 areas)

N
W E
S

Columbia River CROSSING

3.5.2.2 Metro

Metro provides regional planning initiatives to meet the statewide planning Goal 5: Natural Resources, Scenic and Historic Areas, and Open Spaces. Metro's Nature in Neighborhood initiative is intended to meet Goal 5 requirements. Metro has no enforcement mechanism within local jurisdictions (such as the City of Portland and City of Gresham); therefore, the CRC project has used these habitat definitions to help assess habitat types and importance, rather than as an analysis of regulatory requirements. Exhibit 3-15 summarizes the acreage of each of these habitat types within the project area.

Exhibit 3-15. Summary of Metro Habitat Protections in the Project Area[a]

Metro Habitat Protections[6]	Acres in Project Area
Riparian Habitat Class I	4992.9
Riparian Habitat Class II	85.8
Riparian Habitat Class III	17.6
Upland Wildlife Habitat Class A	5.7
Upland Wildlife Habitat Class B	0.1
Upland Wildlife Habitat Class C	4.7
Total:	**5106.9**

a Includes staging and casting areas, noise attenuation distances, and Ruby Junction (see areas shown on Exhibit 3-16).

Metro adopted a methodology to inventory fish and wildlife habitat and conserve the most highly valued of this habitat. Metro established six classes of habitat inventory for "regionally significant habitat": Riparian Classes I, II, and III, and Upland Wildlife Classes A, B, and C. Highly ranked riparian and upland habitat are identified as "habitat conservation areas" in order to increase protection of these valuable areas from developmental pressures. Generally, these habitat conservation areas are selected based on two criteria: "habitat value or quality..., and urban development value." The regionally significant habitat classes are defined as follows on Metro's website (Metro 2007):

- Riparian class I is of the highest value and includes rivers, streams, wetlands, undeveloped floodplains, forested areas within 100 feet of streams or within 200 feet of streams in steep areas and unique, rare, or at-risk streamside habitats.
- Riparian class II is of moderate value and includes rivers, streams, areas within 50 feet of developed streams, areas with trees and other vegetation within 200 feet of streams, and portions of undeveloped floodplains. These areas provide fewer ecological values than class I areas but are still considered important for stream health.
- Riparian class III is of the lowest value and includes developed floodplains, grassy areas within 300 feet of streams, and small, forested areas that are farther away from streams but still influence them. Many Riparian class III areas are degraded due to development, but still provide some important ecological values and opportunities for restoration.

[6] "Impact Areas" include non-habitat areas within 150 feet of stream and wetlands, or within 25 feet of remaining habitat areas. In December 2004, the Metro Council approved a habitat protection concept that integrates urban development priorities and habitat values. Per this approval, development is allowed within the Impact Areas, and they are therefore not included in the table above as an indicator of sensitive habitat.

- Upland wildlife class A is of the highest value and includes very large forested areas and rare or at-risk upland habitats that are farther away from streams, lakes, or wetlands.
- Upland wildlife class B is of moderate value and includes medium-sized and large forested areas that are not rare or at-risk habitats, and non-forested habitat areas that allow wildlife to access water or move from one habitat area to another.
- Upland wildlife class C is of the lowest value and includes smaller forested areas, as well as smaller non-forested areas somewhat near, but no more than 300 feet from, streams and rivers that allow wildlife to move from one area to another.

Exhibit 3-16 summarizes habitats protected by the City of Portland (E-Zones) and Metro.

Riparian class III habitat has been designated on both sides of I-5 south of the Columbia River. In addition, the south bank of the Columbia River is designated Riparian class II.

On the west side of I-5, a portion of the Vanport Wetlands complex is designated as Riparian class I and Upland class A habitat. A small area on the southwest edge of the Marine Drive interchange is designated Riparian class I; and the southern bank of the North Portland Harbor is designated as Riparian class III.

On the east side of I-5, a pond/wetland system between I-5 and Delta Park is designated Riparian class I and class II, and Upland class B. A closed slough system between Delta Park and the Columbia Slough and parallel to I-5, is designated as Upland class C, Riparian classes I, II, and III. A portion of this designated habitat extends to the east side of I-5 as well.

Many of these areas designated as Wildlife Habitat (Upland and Riparian Corridors) are also designated by Metro as habitat conservation areas. Habitat conservation areas are subject to performance standards and BMPs (Metro 2005).

Metro habitat conservation areas are rated as of high, moderate, or low importance. Within the project area, the north shore of the North Portland Harbor is mapped as a low conservation importance area. Various portions of the closed slough system paralleling the east side of I-5 are identified as low and moderate conservation priorities. An open pond/wetland system between I-5 and Delta Park is mapped as a high conservation priority. An area on the southwest side of the Marine Drive interchange and the Vanport Wetlands complex is mapped as a moderate conservation priority.

Metro maps a number of these habitat conservation areas as habitat areas of concern and classifies them as Riparian class I. Within the project area, the southwest side of the Vanport Wetlands complex is designated by Metro as a habitat area of concern.

3.5.2.3 City of Gresham

The City of Gresham inventoried wetlands, riparian areas, and upland areas in the fall of 1987. The findings of this survey are summarized by the Inventory of Significant Natural Resources and Open Spaces that was adopted by the City of Gresham as an appendix to the Community Development Plan (City of Gresham 2005, 2006). This survey was oriented primarily toward wildlife habitat values of lowland and upland natural areas within the City of Gresham. The resource areas included in the inventory are significant wildlife habitats and noteworthy scenic features that perform a variety of useful natural functions, including retention of soils, pollution control, groundwater recharge, and flood control. Forty-five sites having potential significance as natural resource areas were identified within the City of Gresham and include wetlands, riparian corridors, upland areas, and greenways (City of Gresham 2005).

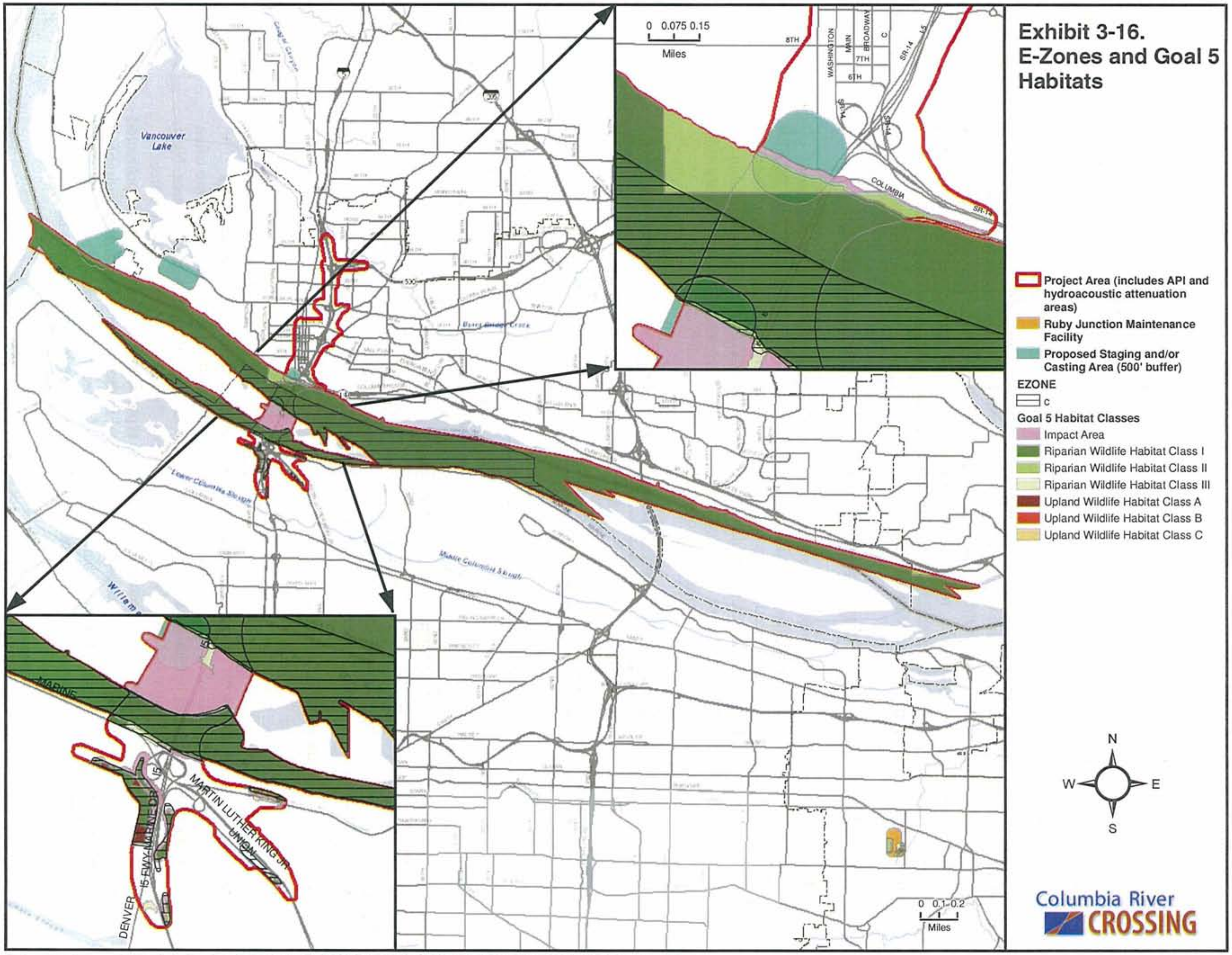


Exhibit 3-16.
E-Zones and Goal 5 Habitats
Project Area (includes API and hydroacoustic attenuation areas)
Ruby Junction Maintenance Facility
Proposed Staging and/or Casting Area (500' buffer)
EZONE
c
Goal 5 Habitat Classes
Impact Area
Riparian Wildlife Habitat Class I
Riparian Wildlife Habitat Class II
Riparian Wildlife Habitat Class III
Upland Wildlife Habitat Class A
Upland Wildlife Habitat Class B
Upland Wildlife Habitat Class C
N
W
E
S
Columbia River
CROSSING
Vancouver Lake
0 0.075 0.15
Miles
8TH
WASHINGTON
MAIN
BROADWAY
C
7TH
6TH
SR-14
I-5
COLUMBIA
MARINE
MARTIN LUTHER KING JR
UNION
I5-FWY
MARINE DR
DENVER
0 0.1 0.2
Miles

Among these sites, two sites along Fairview Creek were named as riparian resources: Fairview Creek at SE Burnside Street and Fairview Creek at SE Division Street (City of Gresham 2005). Both of these sites are within the 100-year floodplain of Fairview Creek and are in close proximity to the Ruby Junction Maintenance Facility. Three of the fourteen parcels that would be added to the facility during expansion are located within the floodplain.

According to City of Gresham code, within the floodplain overlay district of Fairview Creek, proposed developments need to comply with the guidelines and recommendations of the Fairview Creek master storm drain plan and would need to be accompanied by documentation prepared by a registered civil engineer demonstrating that the development would not result in an increase in floodplain area on other properties, reduce natural flood storage volumes, or result in an increase in erosive velocity of the stream that may cause channel scouring or reduced slope stability downstream of the development (City of Gresham 2009).

3.6 Threatened, Endangered, and Proposed Species

"Listed" species refer to those with federal and/or state threatened, endangered, or proposed status. Data on listed species were obtained from USFWS, ORNHIC, WDNR-NHP, and WDFW-PHS. The bald eagle is a state-listed species in Oregon and Washington (Exhibit 3-17). See Section 3.6.1 for a discussion of peregrine falcons, which have been delisted federally and in Oregon, but retain Sensitive status in Washington. See Section 3.3.2 for a discussion on aquatic species listed as threatened, endangered, or proposed.

Exhibit 3-17. Listed Wildlife Species Known to Occur Within the Project Area

Species Common Name Species Scientific Name[a]	Federal Status[b]	OR State Status[c]	WA State Status[d]	Critical Habitat Present	Habitat Present in Project Area[e]	Habitat Type
Bald eagle *Haliaeetus leucocephalus*	Delisted	LT	LT	N/A	Yes	Open water; Westside riparian wetlands
Steller sea lion *Eumetopias jubatus*	LT	LT	LT	No	Yes	Open water

a Source: ORNHIC (2003).

b Federal status: LT = Listed Threatened, LE = Listed Endangered, P = Proposed, C = Candidate, SOC = Species of Concern, N/A = Not Applicable (ORNHIC 2003; USFWS 2003).

c Oregon status: LT = Threatened, LE = Endangered, SC = Sensitive Critical, SV = Sensitive Vulnerable, SP = Sensitive Peripheral, SU = Sensitive Undetermined Status, N/A = Not Applicable (ORNHIC 2003; USFWS 2003).

d Washington status: LT = Listed Threatened, LE = Listed Endangered, C = Candidate, SS = State Sensitive (WDFW 2008).

e Source: Project Biologist Observations.

Bald eagles are associated with coastal environments, lakes, rivers, and marshes. They feed primarily on fish but also eat carrion, various water birds, and small mammals. Bald eagles typically nest in tall trees with strong branching structure near large water bodies. Nests are often constructed in the largest tree in a stand with an open view of the surrounding environment. Nest trees are usually near water and have large horizontal limbs. Snags and dead-topped live trees also provide perch and roost sites. Communal roost sites, typically located in treed areas protected from the wind and providing some thermal refugia, are used in the winter for resting. If suitable habitat is present, bald eagles may use urban environments for breeding, feeding, and roosting. In northwestern Oregon and southwestern Washington, the bald eagle breeding season lasts from

January 1 to August 31. Egg-laying takes place mid-February to April, hatching in late March to May, and fledging in late May to mid-August.

Based on a review of aerial and field photographs and topographic maps, viable bald eagle foraging and migration habitat exists within the project area. The Columbia River has sufficient fisheries resources to support bald eagles in the vicinity of the project area. No eagle nests or communal roosts were identified in the project area during the September 2005 field survey, nor during subsequent site visits. However, there are two known nesting sites on Hayden Island and one adjacent to the Columbia Slough, as well as three documented bald eagle nesting territories located within 1 mile of the project area near Vancouver Lake, Smith Lake, and the Columbia River (Isaacs and Anthony 2004, ORNHIC 2007). During limited field surveys in 2003, 2005, 2006, 2007, and 2008, no bald eagles were observed within the project area.

Steller sea lions are usually found in coastal waters near shore and in ocean waters over the continental shelf approximately 35 kilometers off shore, and seasonally up to several hundred kilometers off shore (NatureServe 2007). They feed opportunistically on fish (approximately 10-30 percent of which are salmon), lamprey, squid, and invertebrates (NOAA 2007). Steller sea lions use terrestrial rookeries and haul-out locations such as beaches, rocks, jetties, reefs, floating docks, and other structures for breeding, pupping, and resting. They occur year-round at the mouth of the Columbia River, and, in the past, were known to occasionally enter rivers in pursuit of prey. In recent years, adult and subadult male Steller sea lions have regularly been observed at Bonneville Dam, where they prey primarily on white sturgeon and Chinook salmon that congregate below the dam. In 2002, the United States Army Corps of Engineers (USACE) began monitoring seasonal presence, abundance, and predation activities of marine mammals in the Bonneville Dam tailrace (Tackley et al. 2008). Steller sea lions have been documented every year since 2003; the lowest abundance was two Steller sea lions in 2004, and the highest was 53 in 2010 (Stansell et al. 2010).

Steller sea lions use the Columbia River for travel, foraging, and resting as they move between haul-out sites and the dam. There are no known haul-out sites within the project area. The nearest known haul-out in the Columbia River is a rock formation (Phoca Rock) approximately 8 miles downstream of Bonneville Dam (approximately 32 miles upstream of the project area) (Tennis 2009 pers. comm.). Steller sea lions are also known to haul out on the south jetty at the mouth of the Columbia River, near Astoria, Oregon. There are no rookeries located in or near the project area. The nearest Steller sea lion rookery is on the southern Oregon coast at Orford Reef, approximately five miles northwest of Port Orford and more than 200 miles from the project area (NMFS 2008b).

3.6.1 Species of Interest

In addition to species protected by federal and state endangered species regulations, species of interest (SOI) (species which are defined as locally rare or with special habitat requirements) are associated with habitat types in the project area. These include migratory birds, marine mammals, certain terrestrial mammals (e.g., bats), and other species requiring special consideration for habitat and management, but which may not be protected under federal or state statutes. Migratory birds protected under the MBTA use habitat components (e.g., bridge structures, vegetation, riparian habitat) in the project area for nesting, roosting, foraging, and/or dispersing. Impacts to all migratory birds are considered in this report. Exhibit 3-18 lists examples of SOI that may occur in the project area. This list is not meant to be comprehensive but rather presents species groups that require special consideration in the course of the CRC project.

Exhibit 3-18. Examples of Species of Interest Associated with Habitat Types within the Project Area

	Federal Status[a]	OR State Status[b]	WA State Status[c]
Migratory Birds[d]			
Peregrine falcon *(Falco peregrinus anatum)*	Delisted	SV	S
Purple martin *(Progne subis)*	SOC	SC	C
Streaked horned lark (*Eremophila alpestris strigata*)	C	SC	LE
Osprey *(Pandion haliaetus)*	N/A	N/A	M
Barn owl *(Tyto alba)*	N/A	N/A	N/A
Belted kingfisher *(Ceryle alcyon)*	N/A	N/A	N/A
Cliff swallow *(Petrochelidon pyrrhonota)*	N/A	N/A	N/A
Barn swallow *(Hirundo rustica)*	N/A	N/A	N/A
Willow flycatcher (*Empidonax traillii*)	SOC	SU	N/A
Bullock's oriole (*Icterus bullockii*)	N/A	N/A	N/A
Yellow warbler (*Dendroica petechia*)	N/A	N/A	N/A
White-breasted nuthatch (*Sitta carolinensis*)	N/A	N/A	N/A
Great blue heron (*Ardea herodias*)	N/A	N/A	SM
Loons (*Gavia* spp.)	N/A	N/A	SS (*Gavia immer*)
Mergansers (*Mergus* spp.)	N/A	N/A	N/A
Geese *(Branta* spp.*)*	N/A	N/A	N/A
Grebes *(Aechmophorus* spp.*)*	N/A	N/A	N/A
Mammals			
Long-legged myotis *(Myotis volans)*	SOC	SU	M
Fringed myotis *(Myotis thysanodes)*	SOC	SV	M
Long-eared myotis *(Myotis evotis)*	SOC	SU	M
Townsend's big-eared bat *(Corynorhinus townsendii)*	SOC	SC	C
Silver-haired bat *(Lasionycteris noctivagans)*	SOC	SU	N/A
Harbor seal (*Phoca vitulina*)	N/A	N/A	M
California myotis *(Myotis californicus)*	N/A	N/A	N/A
Yuma myotis *(Myotis yumanensis)*	N/A	N/A	N/A
California sea lion (*Zalophus californianus*)	N/A[e]	N/A	N/A
Harbor seal (*Phoca vitulina*)	N/A[e]	N/A	N/A
Little brown myotis *(Myotis lucifugus)*	N/A	N/A	N/A
Big brown bat *(Eptesicus fuscus)*	N/A	N/A	N/A
Bushy-tailed woodrat *(Neotoma cinerea)*	N/A	N/A	N/A
Reptiles and Amphibians			
Western Pond turtle (*Emys marmorata*)	SOC	SC	LE
Painted turtles (*Chrysemys picta*)	N/A	SC	N/A
Northern red-legged frog (*Rana aurora aurora*)	SOC	SV/SU	N/A

a Federal status: C = Candidate, SOC = Species of Concern, N/A = Not Applicable (ORNHIC 2003; USFWS 2003).

b Oregon status: LT = Threatened, LE = Endangered, SC = Sensitive Critical, SV = Sensitive Vulnerable, SU = Sensitive Undetermined Status, N/A = Not Applicable (ORNHIC 2003; USFWS 2003).

c Washington status: LT = Listed Threatened, LE = Listed Endangered, C = Candidate, S = State Sensitive, M = State Monitor (WDFW 2008).

d All migratory birds are protected by the Migratory Bird Treaty Act.

e California sea lions and harbor seals are not federally listed; however, they are protected under the Marine Mammal Protection Act.

Peregrine falcon populations in Oregon and Washington include both resident and migratory populations. Peregrines adapt to a wide variety of nesting locations, including bridges. Their primary nesting locations are cliffs overlooking fairly open areas with ample food. Peregrines are known to feed on a wide variety of species, although birds are their primary food source. Rarely, peregrines feed on bats, squirrels, chipmunks, lizards, fish, and insects. Nests can be found near the coast, in marshes, in mountains, and in urban areas. Breeding occurs only if suitable nesting structures such as bridges, buildings, or cliffs are present (Johnson and O'Neil 2001). Adults remain close to the nest sites throughout the year. In the Portland area, courtship lasts from January to March, eggs are typically laid beginning in mid-March, and fledging occurs late May through late June or July (ODOT 2003).

Peregrine falcons are generally associated with open water, where they feed (Johnson and O'Neil 2001). The Columbia River and adjacent open areas provide sufficient resources to support peregrine falcons in and adjacent to the project area.

Monitoring conducted or funded by ODOT has documented peregrine falcons utilizing habitat in the project area every year since 2001 (Casey 2011).

Streaked horned larks occur adjacent to the project area. Habitat for this species includes bare ground or sparsely vegetated areas, even gravel roadsides. Streaked horned larks nest in grass seed fields, pastures, fallow fields and wetland mudflats. They may occur on any Columbia River beach, and on dredge deposition areas on islands or the mainland along the river.

Bridges within the project area were investigated for evidence of swallow or bat activity (roosting or nesting) in April 2007.,No signs of bat use were observed. Swallows commonly nest on bridges, and likely use the I-5 bridge for this purpose; two remnant mud structures were seen on the south side of the I-5 bridge. No occupied bird nests were found in the surveys. No birds protected under the MBTA were observed using any of the bridges for nesting within the project area.

Canada geese and swallows are known to nest on the concrete piers but are not known to nest on steel structure portions of the bridge.

3.6.2 Wildlife Passage

Due to the highly urbanized nature of the project area, suitable habitat for wildlife passage is fragmented and access to any habitat patches is restricted. I-5 and other arterial roads serve as passage barriers for SOI and urban wildlife. Underpasses, overpasses, and streams serve as potential corridors for crossing I-5. Due to extensive urbanization, the underpasses and overpasses are unsuitable and dangerous corridors for most terrestrial wildlife.

Species most likely to be moving through the project area and utilizing existing terrestrial and aquatic habitat, and which are therefore at risk of collisions with vehicles, are migratory birds (particularly waterfowl such as ducks and geese), and small mammals (e.g., raccoons, squirrels) (Hennings 2007 pers. comm.). A 2005 study of wildlife-vehicle collisions in northwestern Oregon, including the Portland area, did not identify any road kill "hotspots" in or near the project area (MBG 2005).

The Vanport Wetlands and Delta Park provide limited suitable habitat for small and medium-sized terrestrial species, and the habitats are fragmented by I-5. Throughout the remainder of the project area, wildlife corridors and passage opportunities are hindered by the density of urban structures and human disturbance.

Passage along the banks of the Columbia River and the North Portland Harbor is possible, although the riparian habitat quality is low and riparian vegetation that could provide cover is sparse. The river bank under the bridges primarily consists of riprap, and is poor habitat for wildlife passage. Potential wildlife habitat and passage corridors exist in some portions of the Delta Park area on the Oregon side of the Columbia River. The river itself is considered a wildlife corridor for waterfowl and some mammals that travel in water, such as river otters and beavers (Hennings 2007 pers. comm.). Areas where terrestrial wildlife could travel under the highway structures between the east and west sides of I-5 include the Victory Boulevard/Whitaker Road area, and the Marine Drive interchange (Thompson 2007 pers. comm.). However, the abundance of roads, traffic, and development makes passage quality marginal at best.

3.7 Botanical Resources

3.7.1 Summary

Listed plant species, including threatened, endangered, proposed, and candidate species, are not known to occur in the project area (ORNHIC 2005; WDNR-NHP 2005). Field visits were conducted on September 1 and September 16, 2005, to survey for potential habitat in the project area. Field surveys for special-status plants (i.e., those not listed but with state designations such as sensitive or vulnerable) occurred between May and September 2006. The surveys used the intuitive controlled method (BLM 1998). No listed plants were found (Parametrix 2005, 2006).

Wapato (*Sagittaria latifolia*) and cattail (*Typha latifolia*), herbaceous wetland plants with important cultural significance as traditional food, craft, and medicinal sources for several Native American tribes, occur in wetland areas in the project area, including Schmeer Slough (a J-shaped slough that extends under I-5 and adjacent to North Whitaker Road and Schmeer Road).

3.7.1.1 Rare Plants

Listed species that have historically occurred within the region include Willamette daisy (*Erigeron decumbens* var. *decumbens*), Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii*), Water howellia (*Howellia aquatilis*), Bradshaw's lomatium (*Lomatium bradshawii*), and Nelson's checker-mallow (*Sidalcea nelsoniana*) (USFWS 2006) (Exhibit 3-19). Willamette daisy and Kincaid's lupine occur in wet prairie, upland prairie, and oak/savannah habitats which were once widely distributed in western Oregon and Washington. Water howellia historically occurred in Multnomah County in small, vernal, freshwater wetlands or in former river oxbows; it is now thought to be extirpated in Oregon. This species occurs in limited distribution in Clark County, Pierce County, and Lincoln County in eastern Washington (WDNR-NHP 2005). Bradshaw's lomatium occurs in Clark County. Nelson's checker-mallow occurs in Oregon ash swales, meadows with wet depressions, or along streams. The species also grows in wetlands within remnant prairie grasslands. Bradshaw's lomatium primarily occurs in seasonally saturated or flooded prairies, adjacent to creeks and small rivers. Habitats associated with tall bugbane (*Cimicifuga elata*) and small-flowered trillium (*Trillium parviflorum*) were identified within the project area in Washington, although no instances of these species have been recorded there. Please refer to the Wetlands and Waters Technical Report for more detailed information on wetland plants in the project area.

Exhibit 3-19. Special-Status Plant Species Reported to Occur Within the Project Area

Species	Federal Status	OR Status	WA Status	Habitat Type	Suitable Habitat Present in Project Area[a]
Bristly sedge *Carex comosa*	N/A	N/A	Sensitive	Marshes, lake shores, wet meadows	No
Columbian watermeal *Wolffia columbiana*	N/A	N/A	Review Group 1	Freshwater lakes, ponds, slow-moving streams	No
Tall bugbane *Cimicifuga elata*	SC	C	Sensitive	Mixed coniferous-deciduous forest margins	No
Small-flowered trillium *Trillium parviflorum*	N/A	N/A	Sensitive	Moist, shady environments dominated by hardwoods	No

Source: ORNHIC 2005 and WDNR-NHP2005.

a Parametrix field surveys 2005 and 2006.

Habitat suitability for rare plants in the project area in Washington is extremely limited due to severe habitat fragmentation within an urban landscape, degradation by former and/or current land uses, and intense pressure from invasive plant species.

Within the Oregon portion of the project area, rare plant species are most likely to occur at the Vanport Wetlands, which are actively managed for wildlife habitat and wetland function by the Port of Portland. The Vanport Wetlands were not surveyed for rare plants because it was determined that no direct impacts to the site would occur.

3.7.1.2 Noxious Weeds

Small amounts of noxious weeds are found in the project area within most vegetated areas that are not regularly maintained. These include vegetated areas within Washington and Oregon DOT rights-of-way that are infrequently mowed and/or controlled with herbicide applications. Twelve noxious weeds listed by the ODA Noxious Weed Control Program were identified within the project area in Oregon. Fourteen noxious weeds identified by the Washington Department of Agriculture Washington Noxious Weed Control Board (WNWCB) were found within the project area in Washington (Exhibit 3-20). During the preliminary noxious weed survey, no Class A noxious weeds (i.e., those requiring eradication) were identified within the project area.

Exhibit 3-20. Noxious Weed Species Occurring within the Project Area

Botanical Name	Common Name	ODA Status	WNWCB Status
Agropyron repens	Quackgrass	B	N/A
Centaurea pratensis	Meadow knapweed	B	B
Cirsium arvense	Canada thistle	B	C
Cirsium vulgare	Bull thistle	B	C
Clematis vitalba	Old man's beard	B	C
Conium maculatum	Poison hemlock	B	C
Convolvulus arvensis	Field bindweed	B	C
Cytisus scoparius	Scotch broom	B	B
Daucus carota	Wild carrot	N/A	B
Geranium robertianum	Herb-Robert's	N/A	B
Hedera helix	English ivy	B	C

Botanical Name	Common Name	ODA Status	WNWCB Status
Hypericum perforatum	St. John's wort	B	C
Phalaris arundinacea	Reed canarygrass	N/A	C
Polygonum cuspidatum	Japanese knotweed	B	B
Rubus discolor	Himalayan blackberry	B	N/A
Verbascum thapsis	Common mullein	N/A	M

Notes:

ODA Key: A = Non-native species of economic importance with a limited distribution or not known to occur in the state; B = Non-native species of economic importance established only in some regions; T = Target A or B Designated weed for which a statewide management plan will be developed and implemented.

WNWCB Key: Class A = Non-native species with a limited distribution in the state – eradication required by state law; Class B = Established only in some regions – control required by state law in regions where the species is unrecorded or with limited distribution; Class C = Widely established in the state or of interest to agriculture – placed on the weed list so that local control is possible; M (Monitor) = Species being monitored for location, spread, and invasiveness.

N/A: Not Applicable indicates that the species does not have a listing status by either ODA or WNWCB.

3.8 Conclusions

3.8.1 Aquatic Resources

The existing I-5 bridges are located at RM 106 of the Columbia River. The Columbia River within the project area is highly altered by human disturbance. Urbanization extends up to the shoreline. There has been extensive removal of historic streamside forests and wetlands. Riparian areas have been further degraded by the construction of dikes and levees and the placement of streambank armoring. The existing bridge structures discharge highway runoff into the river. For several decades, industrial, residential, and upstream agricultural sources have contributed to significant water quality degradation in the river. The river also receives high levels of disturbance in the form of heavy barge traffic.

The twelve major dams located in the Columbia Basin are the dominant forces controlling river flow in the vicinity of the project area. Consequently, the Columbia River upstream of the project area is a highly managed waterway that in some sections (e.g., the reservoirs immediately above the major dams) resembles a series of slack-water lakes rather than its original free-flowing state, although the river is free-flowing in the immediate vicinity of the project area. The Columbia River is also tidally influenced by the Pacific Ocean, which affects flow and stage up to Bonneville Dam above the project area.

Due to the urbanization, industrial use, presence of existing structures, flow control, and channelization of the Columbia River within the vicinity of the project area, the riparian habitat quality within the project area is poor, providing little opportunity for large wood recruitment, nutrient cycling from litter fall, and general fish cover. Several listed fish species occur in the project area, primarily within the Columbia River. Listed fish species include Chinook salmon, steelhead trout, sockeye salmon, coho salmon, chum salmon, green sturgeon, and eulachon. Steller sea lions, California sea lions, and harbor seals also occur in the project area. Water quality is limited in the Columbia River by elevated temperatures, PCBs, PAHs, DDT metabolites (DDE), arsenic, and dissolved copper.

3.8.2 Terrestrial Resources

There are no federally listed terrestrial species that are likely to occur within the project area. One state-listed species, the bald eagle, may use the project area for foraging. Bald eagles are not known to nest within the project area. The existing I-5 bridge provides potential habitat for bats and swallows. The peregrine falcon, an Oregon and Washington state sensitive species, is known to occur in the project area and would likely be affected by project activities.

The five habitat types identified in the project area (Johnson and O'Neil 2001) are found throughout the region. Priority habitats for this area include the Westside Riparian Wetlands and Herbaceous Wetlands. Metro habitat classification in the project area include riparian and upland wildlife habitat. These habitat types may support SOI such as pond turtles, migratory birds, and small mammals (e.g., bats).

3.8.3 Botanical Resources

No listed plants are documented within the project area. Suitable habitat for rare plants is extremely limited in the project area. The Vanport Wetlands contains the most functional habitat in the project area and is the most likely site for listed species to occur; direct impacts to this habitat are not expected to occur. Noxious weeds are present throughout the project area, although no Class A noxious weeds were detected.

This page intentionally left blank.

4. Long-term Effects

This section describes the long-term effects the LPA Option A ("LPA") full build would have to aquatic, terrestrial, and botanical resources. Unless stated otherwise, the LPA with highway phasing options would have the same impacts to aquatic, terrestrial, and botanical resources as the corresponding LPA full build options. Similarly, whether Option A or Option B would be built, the impacts to aquatic, terrestrial, and botanical resources are expected to be the same, except where noted.

The LPA with highway phasing option includes the same bridge pier design as the full LPA options, but because there would be 10.7 fewer acres of impervious surface than the full build, the highway phasing option has slightly fewer stormwater impacts to the Columbia Slough and to Burnt Bridge Creek. The effects analysis for all other long-term impacts remains the same under highway phasing. See sections 4.1.1.4 and 4.1.1.5 for discussions of differences in stormwater effects under the highway phasing option.

4.1 Effects to Aquatic Resources

4.1.1 Stormwater Effects to Water Quality and Water Quantity

Stormwater runoff from highways has elevated levels of contaminants. The project would replace and create impervious surfaces. However, improvements to stormwater treatment within the project CIA, including the I-5 and North Portland Harbor bridges, are anticipated to reduce stormwater pollutant loads discharged to Columbia Slough, Columbia River, North Portland Harbor, and Burnt Bridge Creek.

Besides an existing infiltration pond in the Burnt Bridge Creek drainage, existing water quality facilities would be replaced with stormwater treatment that would meet the project's stormwater management requirements. The majority of new stormwater facilities within the project corridor would provide enhanced treatment.

Much of the current stormwater runoff generated by the existing highway corridor is not treated in accordance with current stormwater treatment standards for new construction. At present, only 21 acres out of the 256 acres of existing impervious area receives treatment via infiltration. Post-project impervious surfaces within the project CIA would be treated in accordance with current stormwater treatment standards before being discharged to project area receiving waters. However, at this time, no options have been identified to treat runoff from about 7 acres of new and resurfaced I-5 impervious surface immediately north of Victory Boulevard within the Columbia Slough watershed and 1 acre comprising the eastbound lanes of SR 14 within the Columbia River watershed in Washington.

Exhibit 4-1 presents an overall summary of the anticipated impact of the project on impervious area and proposed treatment or infiltration. The project currently contains 256 acres of impervious area and would add a net 42 acres, resulting in a post-project net total of 298 acres. The addition of 42 acres may reduce natural infiltration rates and increase stormwater pollutants loads of suspended sediments, nutrients, PAHs, oils and grease, antifreeze from leaks, cadmium and zinc from tire wear, and copper from wear and tear from brake pads, bearings, metal plating, and engine parts. However, untreated impervious surface would be reduced by 228 acres.

The stormwater drainage areas used in these calculations do not include staging areas outside the project footprint or casting yards that might be required for fabricating bridge elements.

Exhibit 4-1. Summary of Changes in Impervious Area and Stormwater Treatment across the Entire Project Corridor

	Area (acres)			
	Infiltrated	Treated	Untreated	Total
Existing PGIS	20.5	0.0	218.6	239.1
Existing Non-PGIS	0.0	0.0	17.1	17.1
Existing CIA	**20.5**	**0.0**	**235.7**	**256.2**
Post-project PGIS				
Existing PGIS retained as-is	15.0	14.1	0.0	29.1
New, rebuilt, or resurfaced PGIS	91.8	137.8	8.1	237.7
Post-project Non-PGIS	4.7	26.2	0.0	30.9
Post-project CIA	**111.5**	**178.1**	**8.1**	**297.7**
Net change in CIA	**91.0**	178.1	-227.6	41.5

Traffic models projected to the year 2030 indicate that the project would substantially improve traffic congestion within the project corridor. Decreasing traffic congestion on the I-5 and North Portland Harbor bridges and associated roadways would decrease idling and brake pad wear and may consequently reduce the amount of copper and other traffic-related pollutants currently carried by corridor runoff. However, quantifying the effect of reduced traffic congestion on pollutant loads is not feasible.

Therefore, in comparison to the No-Build Alternative, the LPA would have an overall beneficial effect on stormwater generation and treatment in the long-term due to increased stormwater treatment and decreased traffic congestion.

4.1.1.1 General Effects of Stormwater on Fish

In general, addition of impervious surface to a watershed has the potential to affect fish by altering water quality in the receiving water bodies. Stormwater runoff flows over the roadway, picking up contaminants from impervious surfaces and delivering them to the roadside drainage system and eventually to surface water bodies (Pacific EcoRisk 2007). Sources of these contaminants include vehicles, atmospheric deposition, roadway maintenance, and pavement wear (Pacific EcoRisk 2007).

The addition of impervious surface increases the level of vehicle-generated pollutants deposited on the roadway and delivered to surface waters. Common pollutants present in stormwater runoff include total suspended solids, nutrients, oil and grease, other fluids associated with automobiles, PAHs, agricultural chemicals used in highway maintenance, total zinc, dissolved zinc, total copper, dissolved copper, and other metals (NMFS 2008c). These pollutants are known to be toxic to fish (Everhart et al. 1953; Sprague 1968; Hecht et al. 2007; Sandahl et al. 2007; Johnson et al. 2009; Scholtz et al. 2003) and have potential adverse effects on salmon and steelhead, even at ambient levels (Loge et al. 2006, Hecht et al. 2007, Johnson et al. 2007, Sandahl et al. 2007, Spromberg and Meador 2006, all cited in NMFS 2008c). These contaminants are persistent in the aquatic environment, traveling long distances in solution or adsorbed onto suspended sediments. Alternatively, they may also persist in streambed substrates, mobilizing during high-flow events (Anderson et al. 1996, Alpers et al. 2000a, 2000b, all cited in NMFS 2008c). Some of these pollutants may also persist in the tissues of juvenile salmonids, resulting in long-term interference with important life functions such as olfaction, immune response, growth, smoltification, hormonal regulation, reproduction, cellular function, and physical development (Fresh et al. 2005, Hecht et al. 2007, LCREP 2007 all cited in NMFS 2008c). The addition of impervious surface may also increase the levels of contamination in surface waters, degrading water quality and causing further harm to fish.

The following sections provide more detail about the types of contaminants found in stormwater runoff and their likely effects on fish.

Contaminant Levels and Effects on Fish

There have been no comprehensive studies performed about the types and concentrations of pollutants found in stormwater runoff emanating from the project area. However, Herrera (2007) prepared a white paper on the types and concentrations of contaminants found in untreated runoff in western Washington, an area with climate and traffic volumes comparable to the project area. No such study exists in Oregon, and therefore, this study represents the most comprehensive review of the characteristics of stormwater runoff applicable to the CRC project area. The study reported that typical contaminants found in stormwater runoff included total suspended solids (TSS), metals, nutrients, and organic compounds. Additionally, stormwater runoff had levels of oxygen demand corresponding to detectable levels of these pollutants.

Geosyntec (2008) performed a comprehensive study of contaminant concentrations in treated stormwater runoff in western Washington. The results of both studies are presented in the subsections below in order to characterize the likely pollutant levels in stormwater runoff in the CRC project area and the risk that fish are exposed to toxic levels of contaminants in the CRC project area.

Total Suspended Solids

TSS has the potential to harm fish by causing gill tissue damage, physiological stress, altered behavior, and degradation of aquatic habitat (Pacific EcoRisk 2007). The level of effect generally depends on the characteristics of the particles, with hard angular particles causing more damage than softer, smoother ones. Given the short-term duration of most precipitation events, exposure of individual fish to such effects would be likely to be limited in space and time (Pacific EcoRisk 2007). However, chronically high levels of TSS may cause long-term degradation of habitat (such as spawning redds) or may reduce the productivity of the benthic communities that make up the food web of numerous fish species.

Herrera (2007) reported mean TSS concentration levels of 93 mg/L in untreated runoff in western Washington, with maximum concentrations of 900 mg/L. Stormwater treatment BMPs reduced TSS levels significantly such that post-treatment median concentration ranged from 6 to 20.5 mg/L (Geosyntec 2008).

There are several criteria for levels of TSS likely to harm aquatic organisms or habitats. Neither Oregon nor Washington offer numeric guidance for TSS. However, EPA guidance classifies impairment to aquatic habitat or organisms as follows:

- < 10 mg/L – Impairment is improbable
- < 100 mg/L – Potential impairment
- > 100 mg/L – Impairment probable.

The National Academy of Sciences (NAS) (1973) offers the following:

- < 25 mg/L – High level of protection to aquatic community
- 25–80 mg/L – Moderate level of protection
- 80–400 mg/L – Low level of protection
- > 400 mg/L – Very low level of protection

In the absence of site-specific data about ambient turbidity levels in the receiving water body, the timing and duration of TSS concentrations, and the characteristics of the suspended particles, it is difficult to draw a clear line between TSS concentrations and harm to fish. However, the data show that stormwater treatment facilities significantly reduce TSS concentrations, and, in comparison to the NAS standard, potentially reduce to levels that offer a high level of protection to the aquatic community. In comparison to the EPA threshold, stormwater runoff treatment may reduce TSS concentrations to the low end of the potential impairment standard (Pacific EcoRisk 2007).

Section 5.2.9.4 provides a more detailed review of the effects of suspended sediment on fish.

Metals

The main sources of metals in stormwater runoff include friction in engine and suspension systems, attrition of brake pads and tires, and rust and corrosion of automobile body parts. Other sources include guardrail plating, vehicle emissions, impurities in de-icing compounds, and atmospheric deposition (Herrera 2007). Metals may occur as particulates or dissolved ions (Pacific EcoRisk 2007). Metals in highway runoff are often correlated with levels of suspended sediments because they either occur as particulates or are bound to the surfaces of other solids. Zinc, copper, and chromium show a particularly high correlation with TSS concentrations (Herrera 2007). In general, factors that affect levels of solids in the water column will also affect the levels of metals; however, due to the varied behavior of metals under different environmental conditions, this relationship is very complex (Pacific EcoRisk 2007).

Herrera (2007) reported the following metals in untreated stormwater runoff: antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, vanadium, and zinc. About half of these (arsenic, antimony, barium, cobalt, molybdenum, nickel, and vanadium) occurred at levels well below any known thresholds for toxicity to aquatic organisms, and therefore, the authors deemed that these metals were not pollutants of concern for fish. Thus, only cadmium, chromium, copper, lead, mercury, and zinc will be addressed further in this discussion.

Cadmium: Herrera (2007) reported median concentrations of 1.2 μg/L in untreated stormwater runoff, with maximum concentrations of 2.80 μg/L. Treated stormwater runoff contained much lower concentrations, with median concentrations ranging from 0.05 to 0.20 μg/L (Geosyntec 2008). Median cadmium levels in treated stormwater were well below freshwater acute criteria. They were also below chronic water quality criteria and EPA Genus Mean Acute Values (GMAVs), that is, values specific to fish genera *Oncorhynchus* and *Salvelinus*. However, some of the upper 95th percentile values for treated stormwater exceeded freshwater acute and chronic criteria, indicating that, despite undergoing treatment, stormwater runoff may still contain cadmium at levels that could potentially harm fish (Pacific EcoRisk 2007).

Studies have indicated that chronic levels of cadmium at 0.5 μg/L for 30 days may have sublethal effects on bull trout, including interference with prey selection and prey capture efficiency (Riddell et al. 2005, cited in Pacific EcoRisk 2007). However, this concentration would not likely persist in highway runoff for such an extended period of time (Pacific EcoRisk 2007).

Chromium: Herrera (2007) reported median concentrations of 12.7 µg/L of total chromium in untreated highway runoff, with maximum concentrations of 17.9 µg/L. No data were presented for treated highway runoff (Geosyntec 2008). These values were well below the GMAV Cr (III) and Cr (IV) values for *Oncorhynchus* and *Salvelinus*, which ranged from 9,669 to 69,000 µg/L. The values were also well below the chronic and acute freshwater criteria for Cr (III) (64.4 to 628.6 µg/L), indicating that stormwater runoff does not contain Cr (III) at levels likely to harm salmonids (Pacific EcoRisk 2007).

Measured maximum values of total chromium did, however, exceed the freshwater acute (15 µg/L) and chronic criteria (10 µg/L) for Cr (IV). The measured median concentration is within the acute criterion, but exceeds the chronic criterion. This indicates that while typical chromium levels in untreated stormwater effluent may not cause direct injury or mortality to salmonids, there may be toxic effects on food chain organisms (Pacific EcoRisk 2007).

There were no direct data measuring chromium concentrations in treated runoff. However, it is presumed that levels in treated runoff would be much less than for untreated runoff. While it is reasonable to assume that chromium concentrations in treated runoff would be below levels likely to directly harm salmonids, it is uncertain as to whether concentrations are toxic to food chain organisms (Pacific EcoRisk 2007).

Copper: Herrera (2007) reported median concentrations of 5.18 µg/L for dissolved copper and 24.4 µg/L for total copper in untreated stormwater runoff in western Washington. Median concentrations of dissolved copper in treated effluent ranged from 4.4 to 10 µg/L (Geosyntec 2008). Regardless of whether the samples originated from treated or untreated stormwater, concentrations were in exceedance of freshwater acute criteria, but were below GMAVs for salmon and bull trout (Pacific EcoRisk 2007).

Although dissolved copper concentrations in stormwater runoff may not typically occur at levels likely to cause lethal toxicity to salmonids, sub-lethal toxicity is of great concern. Salmonids may avoid waters with copper concentrations at 2.3 µg/L (Sprague 1964). Dissolved copper is known to interfere with olfaction in fish, even at very low levels. Reduced olfactory ability interferes with important life functions, such as prey location, predator avoidance, mate recognition, contaminant avoidance, and migration. Baldwin et al. (2003) observed that an increase of 2.3 µg/L above background levels reduced olfactory response in salmonids by 25 percent. Sandahl et al. (2007) observed 50 percent reduction in olfactory response and 40 percent reduction in predator avoidance when dissolved copper levels were 2.0 µg/L above background levels of 0.3 µg/L.

The above data indicate that stormwater runoff contains dissolved copper at levels that may cause sublethal effects in salmonids. However, it is important to note that site-specific conditions, such as the presence of dissolved organic carbon, can reduce the bioavailability of dissolved copper and mitigate for the negative effect on olfaction (Pacific EcoRisk 2007). Therefore, even though a given highway system may discharge dissolved copper at these levels, it is not possible to definitively conclude that this causes harm to fish in every setting (Pacific EcoRisk 2007).

Lead: Herrera (2007) reported median and maximum dissolved lead concentrations at 3.2 µg/L in untreated runoff. BMPs markedly reduced dissolved lead concentrations; median post-treatment concentrations ranged from 0.1 to 2.2 µg/L. Regardless of treatment, dissolved lead levels in runoff were well below acute criteria (16.3 µg/L), indicating that stormwater runoff does not contain dissolved lead at levels likely to kill fish or prey organisms. In some cases, median concentrations for treated runoff exceeded chronic freshwater criteria (0.64 µg/L). However, the authors note that exposure to chronic levels of dissolved lead is unlikely due to the short duration of most runoff events (Pacific EcoRisk 2007).

Lead is also under investigation as a potential endocrine disruptor in fish. Isidori et al. (2007, cited in Pacific EcoRisk 2007) found potential estrogen receptor sensitivity at lead concentrations as low as 0.0004 µg/L. There are no data, however, that provide a direct evidence of actual endocrine disruption in fish at such low levels. The issue warrants more study (Pacific EcoRisk 2007).

Mercury: Herrera (2007) reported median concentrations of 0.02 µg/L for total mercury in untreated stormwater runoff in western Washington. There were no data for mercury concentrations typically found in treated stormwater (Pacific EcoRisk 2007). Total mercury concentrations were well below acute criteria and GMAVs for Hg (II) and were also below acute criteria for total mercury. These values indicate that mercury concentrations in stormwater runoff do not pose a risk to fish or their prey (Pacific EcoRisk 2007). Total mercury did, however, exceed chronic criteria, but Pacific EcoRisk (2007) concludes that chronic exposure to elevated levels of mercury is unlikely.

Organic mercury is of particular concern to fish due to its propensity to bioaccumulate in the aquatic environment. Pacific EcoRisk (2007) caution that it is impossible to extrapolate organic mercury levels or bioaccumulation rates from existing highway runoff sampling data. Nevertheless, the authors note that organic mercury is still an issue for fish, in particular where runoff flows into lentic systems that accumulate organic mercury.

Zinc: Herrera (2007) reported median dissolved zinc concentrations of 39 µg/L in untreated stormwater (with maximum concentrations of 394 µg/L). In the same study, median total zinc concentrations in untreated stormwater measured 116 µg/L (with maximum concentrations of 394 µg/L). Treated stormwater showed somewhat reduced levels of dissolved zinc, with median concentrations ranging from 7.5 to 41 µg/L (Geosyntec 2008). All of the dissolved zinc levels, whether for treated or untreated stormwater, were well below GMAVs for salmon and steelhead (931.3 µg/L) and bull trout (2,100 µg/L). However, some dissolved zinc concentrations exceeded acute freshwater quality criteria (40 µg/L) and chronic freshwater criteria (36.5 µg/L), indicating that direct lethal effects to fish and their prey species may occur after exposure to stormwater runoff, even after it has undergone water quality treatment (Pacific EcoRisk 2007). As with dissolved copper, it is important to note that site-specific conditions may reduce bioavailability of dissolved zinc and mitigate for its toxicity in fish-bearing waters.

Dissolved zinc may also have sublethal effects on salmonids. Sprague (1968) reported that salmonids may avoid waters with zinc concentrations of 5.6 µg/L above background levels of 3 to 13 µg/L. Geosyntec (2008) reported that dissolved zinc concentrations in both treated and untreated stormwater exceeded these levels.

Nutrients

Nutrients are chemicals that promote growth in organisms. Nutrients are of concern to fish in that they may cause excessive algal growth in fish-bearing waters, which may in turn reduce dissolved oxygen available to fish or may outcompete food organisms for space in streambed substrate (Pacific EcoRisk 2007). Nutrient levels are not necessarily correlated with traffic levels and may be more closely tied to other land use practices (Pacific EcoRisk 2007). Chief sources of nutrients in highway runoff include atmospheric deposition, vehicle exhaust, and fertilizer applications on the adjacent right-of-way (Herrera 2007). The nutrients of highest concern include nitrogen (in the form of ammonia and nitrate/nitrite) and phosphorous (in the form of orthophosphate and total phosphorous).

Ammonia: Herrera (2007) reported that untreated runoff contained median ammonia concentrations of 1.84 µg/L, with maximum concentrations of 2.66 µg/L. Geosyntec (2008) reported median ammonia concentrations in treated runoff at significantly lower levels, ranging from 0.03 to 0.08 μg/L. In surface waters, ammonia toxicity is highly variable, depending on ambient pH values; therefore, there is no one numeric acute toxicity criterion for ammonia. Acute toxicity is instead determined by using a complex numeric formula based on ambient pH. Using median highway runoff pH values (Herrera 2007), Pacific EcoRisk (2007) estimates acute toxicity for western Washington waters at 31.26 μg/L. In this case, ammonia found in both treated and untreated runoff is well below the estimated acute toxicity standards, indicating that ammonia levels in highway runoff do not occur at levels likely to kill salmonids.

Stormwater runoff may contain ammonia at levels that could cause sublethal effects to fish. Wicks et al. (2002, as cited in Pacific EcoRisk 2007) found that ammonia at concentrations of 0.02 to 0.08 μg/L may reduce the ability of coho to maintain their highest levels of swimming speed, potentially interfering with upstream migration.

Nitrate/Nitrite: Herrera (2007) reported that untreated runoff contained median nitrate/nitrite concentrations of 1.54 μg/L, with maximum concentrations of 2.99 μg/L. In the Geosyntec (2008) study, median concentrations of nitrate/nitrite in treated stormwater ranged from 0.20 to 0.70 μg/L. Both treated and untreated stormwater runoff has concentrations well below the 96-hour acute toxicity standard of nitrate to salmonids (ranging from 994 to 2342 mg/L). Additionally, levels were well below the 96-hour acute toxicity standard for nitrite (ranging from 110 to 1,700 mg/L). These data indicate that stormwater runoff is not a significant source of nitrate/nitrite in surface water bodies, at least not at levels that are likely to harm fish.

Phosphorus: Herrera (2007) reported that untreated runoff contained median orthophosphate concentrations of 0.10 mg/L, with maximum concentrations of 0.42 mg/L. The same study reported median total phosphorus levels of 0.19 mg/L, with maximum concentrations of 0.57 mg/L. The Geosyntec (2008) study noted that treated stormwater runoff contained median concentrations of 0.04 to 0.26 mg/L. There are no toxicity-based water quality criteria for phosphorus; however, a Pacific EcoRisk (2007) review of the scientific literature concluded that 96-hour exposure to 90 to 1,875 mg/L of di-ammonium phosphate may cause acute harm to certain species of fish (including coho, Chinook, and trout). Given that these standards far exceed levels typically found in both treated and untreated runoff, stormwater does not appear to be a significant source of phosphorus to surface water bodies.

Petroleum Hydrocarbons

This category of pollutants includes vehicle emissions from fuels, such as oil and grease, total petroleum hydrocarbons (TPH), and PAHs. Sources of PAHs include asphalt sealing, vehicle emissions, oils, and atmospheric deposition (Herrera 2007). These contaminants correlate closely with traffic volumes. Additionally, these contaminants have a high affinity for particulates, and therefore they are highly correlated with concentrations of suspended solids. PAHs in streambed sediments have been shown to cause adverse impacts to benthic invertebrates, with potential implications to the prey base of fish (Pacific EcoRisk 2007).

Petroleum hydrocarbons include a large subset of compounds, generally occurring as mixtures of many different chemicals. Accordingly, petroleum hydrocarbons are evaluated in broad groupings such as oil and grease, total PAHs (the sum of numerous individual PAHs), and TPH (the sum of individual petroleum hydrocarbons) (Pacific EcoRisk 2007).

Pacific EcoRisk (2007) examined the Herrera (2007) data regarding PAH concentrations in untreated stormwater runoff and concluded that concentrations of individual PAHs were well below freshwater acute values. This indicates that PAHs from stormwater runoff do not occur at levels that are toxic to fish or their prey base, even when the runoff is untreated. (No data were presented for treated runoff). For total PAH, the study concluded that median concentrations were well below freshwater acute values, but maximum concentrations were high enough to warrant concern and continued monitoring.

Other studies demonstrate that PAH may cause toxicity in fish embryo-larval life stages (Incardona et al. 2004; Incardona et al. 2005; Incardona et al. 2006, all cited in Pacific EcoRisk 2007); however, no study presents the concentration levels at which this toxicity may occur. Pacific EcoRisk (2007) posits that this type of toxicity may occur at lower levels than the acute toxicity criteria presented above, and therefore this issue warrants further study.

PCBs

PCB use has been banned in the United States since the 1970s (Herrera 2007). However, these compounds are highly persistent, and PCB residues still occur throughout the aquatic environment. PCBs are of particular concern for their propensity to bioaccumulate in fish (Yonge et al. 2002, as cited in Herrera 2007). Sources include atmospheric deposition, pesticides, and herbicides. Few data are available for PCBs concentrations in stormwater runoff. However, they have not been detected in stormwater runoff in western Washington (Zawlocki 1981 as cited in Herrera 2007). Pacific EcoRisk (2007) posits that PCBs are not believed to be a contaminant of concern in highway runoff in western Washington.

Oxygen Demand

Herrera (2007) reported that biological oxygen demand (BOD) median concentrations in untreated runoff were 40.3 mg/L, with maximum concentrations of 71.0 mg/L. For chemical oxygen demand (COD), median concentrations in untreated runoff were 106 mg/L, with maximum levels of 1,377 mg/L.

The State of Washington water quality standards mandate that if a stream has an ambient DO below the water quality criteria, then anthropogenic oxygen demand cannot lower the dissolved oxygen levels by more than 0.2 mg/L. Additionally, the State of Washington offers dissolved oxygen levels necessary for sustaining various salmonid life stages in freshwater, ranging from 6.5 to 9.5 mg/L. Site-specific conditions, such as water flow, turbulence, and ambient temperature, influence the degree to which stormwater runoff with high BOD or COD would result in reduced dissolved oxygen levels in a given surface water body. It is likely that mixing and turbulence in a stream would mitigate the effect of stormwater discharge with high oxygen demand, such that effects would be limited in spatial extent and duration. Nevertheless, Pacific EcoRisk (2007) posits that levels of BOD and COD found in stormwater runoff have the potential to reduce dissolved oxygen in surface water bodies, particularly in warm or lentic water bodies, although it is not possible to predict to what extent. Addition of impervious surface increases the level of vehicle-generated pollutants deposited on the roadway and delivered to surface waters. These pollutants include total suspended solids, nutrients, oil and grease, other fluids associated with automobiles, PAHs, total zinc, dissolved zinc, total copper, dissolved copper, and other metals. These pollutants are known to be toxic to fish (Everhart et al. 1953; Sprague 1968; Hecht et al. 2007; Sandahl et al. 2007; Johnson et al. 2009).

Dissolved copper is of particular concern because it interferes with navigation in fish. Additionally, exposure to dissolved copper, even at extremely low concentrations, causes disruption of the chemical cues that allow juvenile salmonids to avoid predation. These behavioral effects may occur after even brief exposures to low concentrations of dissolved copper; various studies have documented effects at concentrations of 2 μg/L (Baldwin et al. 2003;

Sandahl et al. 2007) to 5 µg/L (Hecht et al. 2007). Depending on the exposure concentration and dose period, effects can persist for several weeks.

Factors Affecting Toxicity of Pollutants in Stormwater Runoff

Although stormwater runoff certainly contains contaminants that are known to be toxic to fish, it is difficult to predict what specific concentration levels are likely to cause harm. Water quality criteria are nearly always based on laboratory studies that used purified water to avoid confounding influences from other waterborne contaminants. Accordingly, these results may not reflect site-specific field conditions. Ambient water quality conditions may influence the bioavailability of contaminants, either increasing or decreasing the ability of the contaminant to enter fish tissues. A contaminant concentration that is toxic in one setting may not be toxic in another, depending on the site-specific factors that determine the bioavailability of the contaminant. Similarly, toxicity levels in actual water bodies may be much less than that encountered in a laboratory setting (Pacific EcoRisk 2007).

Suspended solids may bind to chemical contaminants in the water column, reducing their bioavailability to fish. Suspended clay particles have a high capacity for binding, with particular affinity for metals and polar organics (Li et al. 2004, Roberts et al. 2007; Sheng et al. 2002; all cited in Pacific EcoRisk 2007). Thus, presence of clay in the water column may reduce the toxicity of contaminants to fish. On the other hand, silica-based particles (such as sand) have little affinity for such contaminants, and therefore their presence in the water column is not likely to reduce toxicity of chemicals in the water column (Cary et al. 1987, cited in Pacific EcoRisk 2007).

Dissolved organic carbon may have a similar effect, binding to both metals and organics and reducing the potential toxicity of both to aquatic organisms (Newman and Jagoe 1994, cited in Pacific EcoRisk 2007).

Water hardness (particularly concentrations of calcium and magnesium) has an antagonistic relationship with metals, potentially hindering with the uptake of metals into gill tissue (Hollis et al. 2000, cited in Pacific EcoRisk 2007). Interestingly, water hardness does not appear to significantly limit the uptake of copper into fish olfactory tissues (McIntyre et al. 2007, cited in Pacific EcoRisk 2007). On the other hand, water hardness my increase the bioavailability of some PAHs and PCBs (Akkanen and Kukkonen 2001, cited in Pacific EcoRisk 2007).

The pH of water may affect the ionic charge of waterborne contaminants. In general, conditions that promote the ionic form of a contaminant will reduce the contaminant's bioavailability and its toxicity to fish.

Water Quantity

New impervious surface also may also alter water quantity in the receiving water body. In general, addition of impervious surface to a watershed increases the amount of runoff entering surface waters. This may cause changes in stream dynamics, including higher peak flow, reduced peak-flow duration, and more rapid fluctuations in the stream hydrograph. These changes may in turn lead to scour, potentially resulting in impacts to water quality and degradation of stream bed habitat. Increasing the amount of impervious surface also decreases infiltration to groundwater, potentially reducing base flows in streams and decreasing the amount of water available during summer months.

4.1.1.2 General Effects to Aquatic Resources in the CRC Project Area

The project would install numerous stormwater treatment facilities to provide flow control where required and to sequester pollutants before runoff enters any surface water body. It is important to note that even treated stormwater contains some level of pollutants. Most treatment facilities are not 100 percent efficient, and although they greatly reduce pollutant levels, they do not completely eliminate discharges of pollutants to receiving water bodies. Flow-through facilities, in particular, would discharge pollutants during most events. Certain kinds of infiltration facilities have outfalls that discharge untreated stormwater to surface water bodies during events that exceed their design storm.

Treatment would comply with current WSDOT, ODOT, Ecology, and DEQ standards, as well as standards for the cities of Portland and Vancouver (for portions of the project along city-managed roads), before being discharged to project area water bodies. This may result in a net benefit to water quality and water quantity in the project area water bodies during the majority of storm events. Flow control would be provided for runoff discharged to Burnt Bridge and Fairview Creeks; however, flow control is not required for discharges to Columbia Slough, North Portland Harbor or Columbia River.

During events that exceed the design storm for each jurisdiction, stormwater will likely overwhelm treatment facilities, resulting in a release of undertreated or untreated stormwater into project area water bodies. Following these events, fish may be exposed to elevated levels of contaminants. However, the elevated contaminant levels would likely be concentrated around stormwater facility outfalls, would only occur infrequently following large storm events, would be diluted due to the storm event, and would occur only within the first few hours after a storm event when the greatest quantities of contaminants are mobilized from impervious surface into receiving waters (Lee et al. 2004).

The following sections outline the effects to fish species as they occur in each of the project area receiving water bodies.

4.1.1.3 Stormwater Impacts to the Columbia River and North Portland Harbor

Exhibit 4-2 summarizes the treatment scenario for the impervious area within the project corridor that drains to the Columbia River South watershed in Oregon. The project would create approximately 52.8 acres of new, rebuilt, and resurfaced PGIS for LPA Option A and 53.2 acres for Option B. Runoff from 2.2 acres of the existing North Portland Harbor Bridge and 7.6 acres of non-PGIS would be treated prior to being released to North Portland Harbor or the Columbia River. Currently, there are no water quality facilities for runoff from the project footprint in this watershed.

Exhibit 4-2. Summary of Changes to Impervious Area and Stormwater Treatment–Columbia River South (Oregon) Watershed

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS	0.0	0.0	59.4	59.4
Existing Non-PGIS	0.0	0.0	3.0	3.0
Existing CIA	**0.0**	**0.0**	**62.4**	**62.4**
Post-project PGIS				
Existing PGIS retained as-is	0.0	2.2	0.0	2.2
New, rebuilt, or resurfaced PGIS	0.0	52.8	0.0	52.8

	Area (acres)			
	Infiltrated	Treated	Untreated	Total
Post-project Non-PGIS	0.0	7.6	0.0	7.6
Post-project CIA	**0.0**	**62.6**	**0.0**	**62.6**
Net change in CIA	**0.0**	**62.6**	**-62.4**	**0.2**

Exhibit 4-3 summarizes the treatment scenario for impervious area that drains to the Columbia River North watershed in Washington. The CIA in this watershed would be increased by approximately 21.1 acres, most of which may be attributed to the reconfigured interchanges and increased number and length of merge lanes for I-5. The project would create approximately 97.8 acres of new and rebuilt PGIS and 13.3 acres of new and rebuilt non-PGIS. In addition, 15.0 acres of existing PGIS, mostly on I-5, would be resurfaced. Water quality facilities are proposed for approximately 134.7 acres of PGIS and 18.3 acres of non-PGIS. In contrast, runoff from only 3.0 acres of PGIS is currently treated.

Exhibit 4-3. Summary of Changes to Impervious Area and Stormwater Treatment – Columbia River North (Washington) Watershed

	Area (acres)			
	Infiltrated	Treated	Untreated	Total
Existing PGIS	3.0	0.0	117.7	120.7
Existing Non-PGIS	0.0	0.0	12.2	12.2
Existing CIA	**3.0**	**0.0**	**129.9**	**132.9**
Post-project PGIS				
Existing PGIS retained as-is	13.1	9.8	0.0	22.9
New, rebuilt, or resurfaced PGIS	71.3	40.5	1.0	112.8
Post-project Non-PGIS	4.0	14.3	0.0	18.3
Post-project CIA	**88.4**	**64.6**	**1.0**	**154.0**
Net change in CIA	**85.4**	**64.6**	**-128.9**	**21.1**

It is difficult to quantify exactly to what extent the treatment scenario would affect water quality in the Columbia River and North Portland Harbor. However, given that the LPA would decrease untreated impervious area by 191 acres in the Columbia River watershed, pollutant loads are anticipated to decrease and the exposure level of fish to these pollutants would likely be lower than current conditions.

Only during events exceeding the design storm would the project likely discharge untreated runoff into the receiving water bodies, potentially resulting in exposure of fish to waterborne pollutants. These watersheds fall under the jurisdiction of the City of Portland, ODOT, and Ecology. For the City of Portland, the design storm is 90 percent of the average annual runoff volume, meaning that, on average, 10 percent of the annual runoff volume would discharge untreated into the receiving water bodies. For ODOT, the design storm is 85 percent of the average annual discharge, meaning that approximately 15 percent of the annual runoff would discharge untreated. In Washington, the design storm is 91 percent of the average annual runoff volume, meaning that 9 percent of the average annual runoff volume would discharge untreated.

Exhibit 4-4 outlines the number of times that a precipitation event typically exceeds the design storms used in areas that drain to the Columbia River and North Portland Harbor. It also illustrates the percent chance that such events will occur in a given month. Events that exceed the design storm are very likely to occur from September through February, but are also possible during other months. Exceedances are unlikely in July and August. In any case, given the large volume of water in the Columbia River and North Portland Harbor, dilution levels are expected to be very high, and pollutant levels would likely dissipate to background levels within a short distance of the outfalls.

Exhibit 4-4. Frequency and Probability of Design-Storm Event Exceedance for a Given Month (Columbia River and North Portland Harbor)

	City of Portland		Ecology		ODOT	
Month	No. Events	Probability of Exceedance	No. Events	Probability of Exceedance	No. Events	Probability of Exceedance
Jan	12	14%	19	23%	30	36%
Feb	9	11%	13	16%	22	27%
Mar	1	1%	4	5%	10	12%
Apr	1	1%	1	1%	1	1%
May	0	0%	2	2%	2	2%
Jun	3	4%	4	5%	6	7%
Jul	0	0%	0	0%	0	0%
Aug	0	0%	1	1%	2	2%
Sep	4	5%	7	8%	9	11%
Oct	4	5%	8	10%	11	13%
Nov	18	22%	25	30%	44	53%
Dec	24	29%	44	53%	60	72%

Traffic models projected to 2030 predict that the project would substantially decrease overall traffic congestion on the new bridges and the roadways that contribute runoff to the Columbia River and North Portland Harbor. Idling and brake pad wear, which contribute to the amount of oil, grease, copper, and other pollutants released, would be expected to decrease with congestion relief, as would the amount of pollutants transported to the Columbia River and North Portland Harbor. This may further decrease exposure of fish to pollutants.

Numerous fish species are present in the Columbia River and North Portland Harbor. The following are a subset of species that may be exposed to water quality effects:

- Adult and juvenile Lower Columbia River (LCR) coho; Columbia River (CR) chum; Snake River (SR) sockeye; Lower Columbia River, Middle Columbia River (MCR), Upper Columbia River (UCR), and Snake River steelhead; and Lower Columbia River, Upper Columbia River (Spring-run), Snake River (Fall-run), Snake River (Spring/Summer-run) Chinook salmon;
- Adult and subadult bull trout;
- Adult and subadult green sturgeon;
- All life stages of white sturgeon;
- All life stages of eulachon;
- Adult and juvenile lamprey; and
- Native resident fish, such as sculpins, suckers, threespine sticklebacks, starry flounder, peamouth, and chiselmouth.

These species could be exposed to increased levels of pollutants during the overlap of: 1) when the species are present in the project area and, 2) any event that exceeds the design storm of the treatment facilities (Exhibit 4-4). However, exposure would likely be less than it is currently due to the high level of treatment provided.

USFWS and NMFS have both determined that the Columbia River and North Portland Harbor are "flow-control exempt" water bodies. This means that impervious surface draining to these water bodies does not require flow control facilities. Increases in impervious surface in these watersheds would have no measurable effect on flow.

4.1.1.4 Stormwater Impacts to Columbia Slough

Exhibit 4-5 summarizes the treatment scenario for impervious area that drains to the Columbia Slough watershed. Stormwater outfalls in this watershed discharge directly to Walker Slough and Schmeer Slough. From there, flows are pumped over a levee into the Columbia Slough.

The project would treat or infiltrate 44.5 acres of new and rebuilt PGIS, 2.1 acres of existing PGIS that would be retained, and 4.3 acres of non-PGIS for a net total of 50.9 acres of treated or infiltrated impervious surface. There does not appear to be adequate space between I-5 and Walker Slough to retrofit the existing stormwater conveyance system to treat runoff from approximately 3.7 acres of resurfaced and 3.4 acres of new and rebuilt I-5 PGIS. Therefore, 7.1 acres of impervious area would not receive treatment according to the current design.

Exhibit 4-5. Summary of Changes to Impervious Area and Stormwater Treatment – Columbia Slough Watershed

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS	3.0	0.0	39.8	42.8
Existing Non-PGIS	0.0	0.0	1.6	1.6
Existing CIA	**3.0**	**0.0**	**41.4**	**44.4**
Post-project PGIS				
Existing PGIS retained as-is	0.0	2.1	0.0	2.1
New, rebuilt, or resurfaced PGIS	0.0	44.5	7.1	51.6
Post-project Non-PGIS	0.0	4.3	0.0	4.3
Post-project CIA	**0.0**	**50.9**	**7.1**	**58.0**
Net change in CIA	**-3.0**	**50.9**	**-34.3**	**13.6**

It is difficult to quantify exactly how the treatment scenario would affect water quality in the Columbia Slough. However, given that the project would treat nearly 400 percent of the net new impervious area in this watershed, it is likely that the stormwater treatment would decrease pollutant loads entering the Columbia Slough, resulting in a net benefit to the environmental baseline during the majority of storm events (i.e., events that do not exceed the design storm). However, there may be a slight increase in dissolved copper pollutant loads due to the addition of impervious area and the lack of stormwater treatment provided for 7.1 untreated PGIS acres. The CRC design team will continue to explore options to provide stormwater treatment for the 7.1 acres of untreated impervious surface. During most events, fish would continue to be exposed to pollutants, but due to increased stormwater treatment they would likely be exposed to lower pollutant levels than current conditions (with the exception of dissolved copper).

Only during events that exceed the design storm would untreated stormwater be discharged into Walker Slough and Schmeer Slough. Exhibit 4-4 depicts the predicted frequency and probability that untreated runoff would enter these sloughs (note the City of Portland and ODOT frequencies). Such events are very likely to occur from September to March, but are also possible during the other months of the year. These events are very unlikely in July and August.

Upon entering Walker and Schmeer Sloughs, stormwater runoff would become diluted at the outfalls. The water would then travel through several thousand feet of vegetated open conveyance, where it would be further diluted in the water column before discharging to Columbia Slough. The diluted runoff would discharge into the Columbia Slough only during periods when the pump is running. (The pump schedule is unknown. This analysis assumes that the pump is continually running in order to provide a worst-case scenario). Because discharge to Walker and Schmeer Sloughs is likely to occur only during larger events (that is, events that exceed the design storm), untreated runoff is likely to become highly diluted by the increased volume of water. Given the high levels of dilution and the large distance between the nearest outfall and the Columbia Slough, it is expected that dilution would reduce pollutant concentrations so they are similar to background levels before this runoff enters fish-bearing waters. Therefore, exposure to fish in Columbia Slough is unlikely.

Traffic models projected to 2030 predict that the project would substantially decrease overall traffic congestion in the areas that drain to the Columbia Slough. Idling and brake pad wear, which contribute to the amount of oil, grease, copper, and other pollutants that are released, are expected to decrease with congestion relief, as would the amount of pollutants transported to the Columbia Slough. This may have a net benefit for fish species using this waterway.

With the exception of bull trout, all of the salmonids addressed by this analysis could potentially use the Columbia Slough for rearing and migration. Of these ESUs/DPSs, the following are likely to be present, based on numerous documented detections: Lower Columbia River Chinook, Upper Willamette River Chinook, Lower Columbia River steelhead, Upper Willamette River steelhead, and Lower Columbia River coho. Other ESUs/DPSs are not documented but are presumed present, given that recent studies have documented up-river (i.e., Middle and Upper Columbia River) ESUs using the Slough and its adjacent floodplain wetlands (Teel et al. 2009). Because the Columbia Slough portion of the project area is accessible to fish, their presence in this area cannot be discounted.

There are no precise data on the times of year that listed salmonids use Columbia Slough. However, they are likely only present from fall through spring, and may to be exposed to water quality effects at any time during this period when there are events that exceed the design storm (Exhibit 4-4). However, as described earlier, exposure is likely to be minimal due to the high level of stormwater treatment and the high levels of in-stream dilution. Exposure during the summer is possible but not likely, because events that exceed the design storm are relatively rare in summer and because water temperatures often exceed levels in which juvenile salmonids can survive (DEQ 2007).

Green sturgeon and eulachon are not known to occur in the Columbia Slough. These species are not likely to be exposed to stormwater effects in the Columbia Slough. However, a recent study showed sturgeon—likely white sturgeon—to be present in the lower Columbia Slough (Van Dyke et al. 2009). Therefore, it is possible that white sturgeon would be exposed to stormwater effects in the Columbia Slough.

Native resident fish, such as sculpins, threespine sticklebacks, and suckers, occur in the Columbia Slough and would be exposed to stormwater effects. There are no precise data on the times of year that these species use the Columbia Slough, although they may be present year-round. These species may be exposed to water quality effects at any time when there are events that exceed the design storm (Exhibit 4-4). However, exposure is likely to be minimal due to the high level of stormwater treatment and the high levels of in-stream dilution.

No data are available on Pacific lamprey distribution, abundance, timing, or habitat use in the Columbia Slough. However, there is a minimal chance that Pacific lampreys would be exposed to degraded water quality in the Columbia Slough. Stormwater outfalls discharge directly into water bodies that do not contain listed fish, and by association, are unlikely to contain lampreys. Stormwater discharging into these water bodies would travel through several thousand linear feet of a vegetated open conveyance system before entering the Columbia Slough. Given the distance between stormwater outfalls and the nearest locations where fish and lamprey are present, and given the high levels of dilution likely to occur, pollutants would likely dissipate to ambient levels before discharging to fish bearing waters.

Addition of impervious surface to this stormwater drainage area would have no effect on flows in the Columbia Slough. The Columbia Slough is a flow control-exempt water body, meaning that addition of impervious surface in this area is not expected to degrade the flow regime in the Slough, and therefore, the stormwater treatment facilities in this drainage area do not require flow control. Discharges to the Slough are regulated by a Multnomah County Drainage District pump system designed to handle up to the 100-year event. Because the pumps regulate flows between the outfalls and Columbia Slough, additional runoff from these areas would not affect flows in the Slough during the large majority of events, and the inclusion of flow control in treatment facilities would be redundant. Additionally, the tidal influence in Columbia Slough is likely to overwhelm any water quantity impacts occurring during high tides.

LPA with Highway Phasing

The highway phasing option would result in lower levels of pollutants, including dissolved copper, entering the Columbia Slough. Stormwater impacts with highway phasing would be slightly lower because 1) the flyover ramp from eastbound Marine Drive and northbound I-5 would not be initially constructed; and 2) the ramp would be terminated north of Victory Boulevard. These changes would reduce the PGIS within the Columbia Slough watershed by about 5.5 acres (from 53.5 acres to 48.0 acres).

4.1.1.5 Stormwater Impacts to Burnt Bridge Creek

Exhibit 4-6 summarizes the treatment scenario for facilities that drain to the Burnt Bridge Creek watershed. At present, nearly all of the impervious area in this watershed is treated. The project would increase the total impervious area in the watershed by 6.6 acres and would infiltrate 23.1 acres of impervious surface. According to Ecology standards, discharge to Burnt Bridge Creek between 50 percent of the 2-year event and the 50-year event must be reduced to the pre-development (forested) condition.

Exhibit 4-6. Summary of Changes to Impervious Area and Stormwater Treatment – Burnt Bridge Creek Watershed

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS	14.5	0.0	1.7	16.2
Existing Non-PGIS	0.0	0.0	0.3	0.3
Existing CIA	**14.5**	**0.0**	**2.0**	**16.5**
Post-project PGIS				

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS retained as-is	1.9	0.0	0.0	1.9
New, rebuilt, or resurfaced PGIS	20.5	0.0	0.0	20.5
Post-project Non-PGIS	0.7	0.0	0.0	0.7
Post-project CIA	**23.1**	**0.0**	**0.0**	**23.1**
Net change in CIA	**8.6**	**0.0**	**-2.0**	**6.6**

It is difficult to quantify whether the enhanced proportion of infiltration would outweigh the impacts associated with the net new impervious area. However, given that the project would provide treatment or infiltration for more than 300 percent of the net new impervious area in this watershed, it is possible that the improved treatment scenario would result in a net benefit to the environmental baseline and to fish in Burnt Bridge Creek during events that do not exceed the design storm. In any case, the project is not likely to significantly degrade conditions in the creek during events less than the design storm.

During events that exceed the design storm, however, untreated runoff would certainly enter Burnt Bridge Creek. Exhibit 4-7 depicts the estimated frequency and probability of events that would exceed the design storm. These types of events are most likely to occur from November through February, but may also occasionally occur during the rest of the year. Discharge during May, July, and August is highly unlikely. However, given the high level of infiltration in this drainage area, actual discharge of untreated stormwater is expected to occur less often than predicted in Exhibit 4-7. Additionally, pollutants would likely be diluted due to the large volume of water that typically is present during these events. Although fish may be exposed to untreated stormwater during events that exceed the design storm, exposure would likely be less than it is currently due to the high level of treatment proposed.

Exhibit 4-7. Frequency and Probability of Design-storm Event Exceedance – Burnt Bridge Creek

	91% Design Volume	
Month	**No. Events**	**Probability of Exceedance**
Jan	12	14%
Feb	9	11%
Mar	1	1%
Apr	1	1%
May	0	0%
Jun	3	4%
Jul	0	0%
Aug	0	0%
Sep	4	5%
Oct	4	5%
Nov	18	22%
Dec	24	29%

During events that exceed the design storm, stormwater runoff may also degrade the flow regime in Burnt Bridge Creek. However, due to the high levels of infiltration proposed, impacts are expected to be slight.

All freshwater life stages of coho, Chinook, and steelhead are potentially present in the creek (Weinheimer 2007 pers. comm.). Therefore, runoff may affect all life stages, as well as spawning, migration, foraging, and rearing habitat. The abundance of these species is thought to be very low in Burnt Bridge Creek (PSMFC 2003). Therefore, it is expected that very few individuals would be exposed to these effects. Steelhead and coho have been detected in Burnt Bridge Creek in proximity to stormwater outfalls, and exposure of these species to stormwater effects is likely. Chinook have been detected in Burnt Bridge Creek within 1 mile of the project-area stormwater outfalls. However, because abundance of Chinook is very low and there is a partial passage barrier between the location of the detection and the nearest project-area outfall, the likelihood of exposure is discountable.

Lower Columbia River coho, Chinook, and steelhead could be exposed to stormwater runoff during events that exceed the design storm. Exposure is likely from fall through spring, when design storm-exceeding events most frequently occur and when these species have been documented in the stream. Due to the limited data on fish presence, there are no precise dates for when these species occur in Burnt Bridge Creek. There are only two known stream surveys in Burnt Bridge Creek, conducted in November/December 2002 and April 2003 (PSMFC 2003). The results of the surveys indicate that these species are at least present from November through April. They presumably occur there at all times of year except during the warmest summer months.

During summer, exposure is possible, but less likely. Given the lack of data, we cannot discount the possibility that fish occur there during the summer. However, the Washington 303(d) list has documented water temperatures that exceed the range tolerated by salmonids during some summers (Ecology 2009b). Therefore, these species may not be present in Burnt Bridge Creek in the summer, at least not during some years. Additionally, events exceeding the design storm are less likely in the summer, further reducing the likelihood for exposure.

Lamprey ammocoetes have been documented in Burnt Bridge Creek (PBS 2003); however, no comprehensive data are available on Pacific lamprey abundance, timing, or habitat use in Burnt Bridge Creek. Lampreys may be exposed to degraded water quality and flow regime during periods when lamprey are present and when there is an event that exceeds the design storm.

Native resident fish, such as dace, threespine stickleback, redside shiners, suckers, and sculpin, are present in Burnt Bridge Creek (PBS 2003), and may be exposed to degraded water quality and flow regime when there is an event that exceeds the design storm.

Other salmonid ESUs/DPSs, eulachon, and green sturgeon are not present in Burnt Bridge Creek and would not be affected by stormwater runoff in this stream.

LPA with Highway Phasing

Stormwater impacts to Burnt Bridge Creek would be lower with highway phasing because there would be no improvements to I-5 itself north of 39th Street. Phasing of this highway construction would result in a reduction in impervious area of approximately 5.2 acres, all of which is in the Burnt Bridge Creek watershed.

4.1.1.6 Ruby Junction

The expansion of the Ruby Junction maintenance facility would result in a slight decrease of impervious area (0.5 acre). Since the City of Gresham's requirements for stormwater treatment and flow control must be met for this portion of the project, runoff from all impervious areas within the expansion area would be infiltrated to reduce pollutants of concern. The infiltration techniques would comply with the City of Gresham stormwater management requirements and would protect and/or improve the quality and quantity of existing groundwater flows. There would be no discharge to any surface water body at any time. During events that exceed the design storm, stormwater would pond in a nearby field adjacent to the treatment facility. Because there would be no discharge to any surface water body, this element of the project would have no effect on fish or on the water quality of Fairview Creek.

4.1.1.7 Summary of Stormwater Effects to Fish

The project would provide a high level of treatment for a large proportion of the project CIA, installing treatment not just for new PGIS but also for 228 acres of impervious area that is currently untreated. Project-wide, there would be treatment for about seven times the area of net new impervious area. While the project would not completely eliminate effects to water quality and flow, the high level of treatment would be expected to provide an overall benefit to current conditions. Effects to individual species are summarized below.

Bull trout adults and subadults could potentially be exposed to degraded water quality in the Columbia River and North Portland Harbor. However, given the very low abundance of bull trout and high levels of dilution in these water bodies, the likelihood of exposure is insignificant.

Green sturgeon adults and subadults could also be exposed to degraded water quality in the Columbia River and North Portland Harbor. However, given the high levels of dilution, exposure is expected to be insignificant. Due to the rarity of green sturgeon in the areas subjected to diminished water quality, the likelihood of exposure is discountable.

Stormwater effects to fish species are as follows:

- In the Columbia River and North Portland Harbor, listed salmon and steelhead, bull trout, green sturgeon, white sturgeon, eulachon, lamprey, and other native resident fish (e.g., sculpins, threespine sticklebacks, suckers, dace) may be exposed to degraded water quality within a short distance of the outfalls during periods when fish are present and when there is an event that exceeds the design storm (Exhibit 4-4). Exposure would be minimal due to the high dilution capacity of these large water bodies. During events that do not exceed the design storm, the project is expected to discharge runoff that has less pollutant content than the pre-project condition due to the high level of stormwater treatment relative to the net new PGIS. While it is inconclusive whether this constitutes a benefit to these fish, the high level of treatment makes it improbable that the runoff would degrade current levels of water quality or cause higher levels of exposure during these events.
- In the Columbia Slough, there is a minimal chance that listed salmonids, white sturgeon, lamprey, and othert native resident fish (e.g., sculpins, threespine sticklebacks, and suckers would be exposed to degraded water quality. Stormwater outfalls discharge directly into water bodies that do not contain sensitive fish species and travel through several thousand linear feet of a vegetated open conveyance system before entering the Columbia Slough. Given the distance between stormwater outfalls and the nearest locations where sensitive fish species are present, and given the high levels of dilution likely to occur, pollutants would likely dissipate to ambient levels before discharging to fish-bearing waters.
- In Burnt Bridge Creek, LCR coho, steelhead, Chinook, lamprey, and othert native resident fish (e.g., sculpins, threespine sticklebacks, suckers, dace) may be exposed to degraded water quality and flow regime during periods when fish are present (fall through spring) and when there is an event that exceeds the design storm (Exhibit 4-7).

Due to the low abundance of these species in Burnt Bridge Creek, few individuals would be exposed to these effects. Steelhead and coho would be likely to experience exposure to these effects, as they have been detected in proximity to stormwater outfalls associated with this project. For Chinook, exposure would be insignificant, as they have been detected more than a mile from the nearest outfall and downstream of a partial passage barrier.

4.1.2 Effects to Aquatic Habitat

Potential project impacts to aquatic habitat would be manifested in effects to both shallow- and deep-water habitat. These effects are discussed below.

4.1.2.1 Shallow-water Habitat

The project would have permanent impacts on shallow-water habitat in the Columbia River and North Portland Harbor, including the addition of in-water and overwater bridge elements and the removal of existing in-water and overwater structures. For analysis purposes, the project defined shallow water as that water 20 feet or less in depth (approximate depth from observed lowest water [0'CRD]).

This section outlines the role of shallow-water habitat in the life history of fish and provides an analysis of the project's likely effects on fish in shallow-water habitat in the CRC project area.

Fish Distribution in Shallow-Water Habitat

Shallow water is of particular importance in the life history of fish for migration, feeding, holding, rearing, and predator avoidance (Simenstad et al. 1982; Spence et al. 1996; Everhart et al. 1953). Lower Columbia River Chinook and Columbia River chum migrate as subyearlings and are particularly dependent on nearshore, shallow-water areas during outmigration (Levy and Northcote 1982, Myers and Horton 1982, Simenstad et al. 1982, and Levings et al. 1986 as cited in Bottom et al. 2005). Typically, these fish are less than less than 50 to 60 mm fork length and primarily use water that is less than 1 meter deep (Bottom et al. 2005). Numerous studies have documented smaller fish (subyearling Chinook) utilizing nearshore habitats (Johnsen and Sims 1973; Dawley et al. 1986; McCabe et al. 1986; Ledgerwood et al. 1991, as cited in Carter et al. 2009), frequently at depths of 3 meters or less (Carlson et al. 2001, as cited in Carter et al. 2009). However, Lower Columbia River Chinook and Columbia River chum can and do occupy other parts of the channel (Bottom et al. 2005). While these fish are highly dependent on shallow water and are most likely to occur there, they do not occur exclusively in the nearshore and may potentially be present across the entire cross-section of the channel (Bottom et al. 2005).

Other juvenile salmonids outmigrate after they reach the yearling stage or older. These species include all of the salmonid runs addressed by this analysis except for chum (note that Lower Columbia River Chinook may emigrate as either subyearlings or as yearlings). In general, cross-sectional distribution of these larger juveniles in the stream channel appears to be correlated with size. Fish measuring 60 to 100 mm fork length use deeper water, such as shoals and distributary channels. Fish greater than 100 mm in length are found in both deep and shallow water habitats, indicating that these individuals do not show preferential use of a particular water depth (Bottom et al. 2005), although they may seek out these areas for resting or as flow refugia during high-velocity events. Fish that migrate as yearlings or older tend to move quickly and occupy deeper-water habitats, but it is well documented that all use the nearshore to some extent during their outmigration (Bottom et al. 2005; NMFS 2006; Celedonia et al. 2008; Southard et al. 2006; Friesen 2005; Carter et al. 2009). These juveniles may alternate active migration in deeper water interspersed with periods of holding and resting in shallow water and/or low-velocity areas (Bottom et al. 2005; Celedonia et al. 2008). Thus, while these older juveniles are less dependent on the nearshore than their subyearling migrant counterparts, they are likely to be present across the entire cross-section of the channel (Bottom et al. 2005; Southard et al. 2006).

Rearing juveniles are largely dependent on shallow-water habitats (Bottom et al. 2005; Southard et al. 2006; NMFS 2006). Listed ESUs that rear in the project area include Lower Columbia River Chinook, Upper Columbia River spring-run Chinook, Upper Willamette River Chinook, Columbia River chum, Lower Columbia River coho, and Lower Columbia River steelhead.

Adult salmonids generally migrate at mid-channel, but may occupy depths of 1 to 50 feet (NMFS 2006). While they may occur in shallow-water habitat, they are not particularly dependent on it, although they may seek out these areas for resting or as flow refugia during upstream migration (Bottom et al. 2005).

Similar to the salmonids discussed above, bull trout sub-adults and adults may use shallow-water habitat for migration and holding. Bull trout are thought to occur in extremely low numbers in this portion of the project area; therefore, effects to shallow-water habitat and bull trout are expected be insignificant.

Adult green sturgeon and sub-adult and juvenile white sturgeon may use shallow-water habitat for feeding and migration, although they tend to be less dependent on shallow-water areas and are often found holding in fairly deep holes. Green sturgeon are thought to occur in extremely low numbers in this portion of the project area; therefore, effects to shallow-water habitat and green sturgeon are expected to be insignificant.

Eulachon use shallow water habitat during all life stages: feeding, spawning, and migration (Langness 2009 pers. comm.).

White sturgeon utilize shallow water habitat during periods of high activity (i.e., summer months), and deep water during the winter (Brannon and Sutter 1992). In the Columbia River, adult white sturgeon have been observed at a mean water depth of 36 feet (11m) (Counihan et al. 1999), although they are also known to utilize habitat in the Columbia River of less than 23 ft (7 m) in depth (Parsley et al. 1993). Adult and sub-adult white sturgeon are primarily benthic feeders, taking prey such as crabs, clams, and shrimp, and are likely to use shallow water for foraging (Moyle 2002). In the lower Columbia River, most spawning was observed at depths of 19 feet (6 m) (Parsley et al. 1993). Juvenile white sturgeon prefer deep-water habitat and are often observed in the deepest part of the channel; however, they have been observed in water as shallow as 6 feet (Parsley et al. 1993).

Shallow-water habitat is used by lamprey for spawning, rearing, and migration (Ocker et al 2001).

Native resident fish such as sculpins, threespine sticklebacks, dace, and suckers spend the majority of their life cycle in shallow water habitat, utilizing emergent vegetation for cover, spawning, and foraging. Because their life history requirements include the use of emergent vegetation and other types of cover (e.g., rocks, overhanging trees), their distribution even within shallow water areas is relatively limited to depths of only a few feet where emergent vegetation is present. These fish species typically forage on prey items (e.g., benthic invertebrates, algae, and detritus) that also depend on emergent vegetation, or at least are present at depths at which primary productivity is high. These species may migrate locally among habitat areas in the project area in response to seasonal flows, water temperatures, life stage, and temporal cycles (e.g., moving between various depths according to time of day).

There would be no long-term impacts to shallow-water habitat for California or Steller sea lions.

Physical Loss of Shallow-water Habitat

Several new bridge piers would be located in water of 20 feet depth or less (Exhibit 4-8). The in-water portions of the new structures would result in the permanent physical loss of approximately 250 square feet of shallow-water habitat at pier complex 7 (Pier 7) in the Columbia River. Demolition of the existing Columbia River structures would permanently restore about 6,000 square feet of shallow-water habitat. Additional shallow-water habitat would be restored by removal of a portion of the large overwater structure at the Quay, although the area cannot be quantified at this stage in the design. Overall, there would be a net permanent gain of at least 5,945 square feet of shallow-water habitat in the Columbia River (Exhibit 4-9). In North Portland Harbor, there would be a permanent net loss of about 2,435 square feet of shallow-water habitat associated with the new in-water bridge bents (Exhibit 4-10). Note that all North Portland Harbor impacts are in shallow water.

Physical loss of shallow-water habitat is of particular concern for rearing or subyearling migrant salmonids. In general, in-water structures that completely block the nearshore may force these juveniles to swim into deeper-water habitats to circumvent them. Deep-water areas generally represent lower quality habitat because predation rates may be higher there. Numerous studies show that predators such as walleye and northern pikeminnow occur in deepwater habitat for at least part of the year (Johnson 1969; Ager 1976; Paragamian 1989; Wahl 1995; Pribyl et al. 2004). In the case of the CRC project, in-water portions of the structures would not pose a complete blockage to nearshore movement anywhere in the project area. Although these structures would cover potential rearing and nearshore migration areas, the habitat is not rare and is not of particularly high quality. These juveniles would still be able to use the abundant shallow-water habitat available for miles in either direction. Neither the permanent nor the temporary structures would force these juveniles into deeper water, and therefore pose no added risk of predation. Additionally, northern pikeminnow and walleye tend to avoid high-velocity areas during the spring juvenile salmonid outmigration (NMFS 2000; Gray and Rondorf 1986; Pribyl et al. 2004). The high velocities present in deep-water portions of the CRC project area may limit the potential for actual predation in deep-water areas.

6220

Pier # / Location	Min. Depth	Max. Depth	Average Depth
P-2	15	30	23
P-3	24	29	27
P-4	24	27	25
P-5	28	31	30
P-6	28	30	29
P-7	6	31	20
N. Portland Harbor	6	20	13

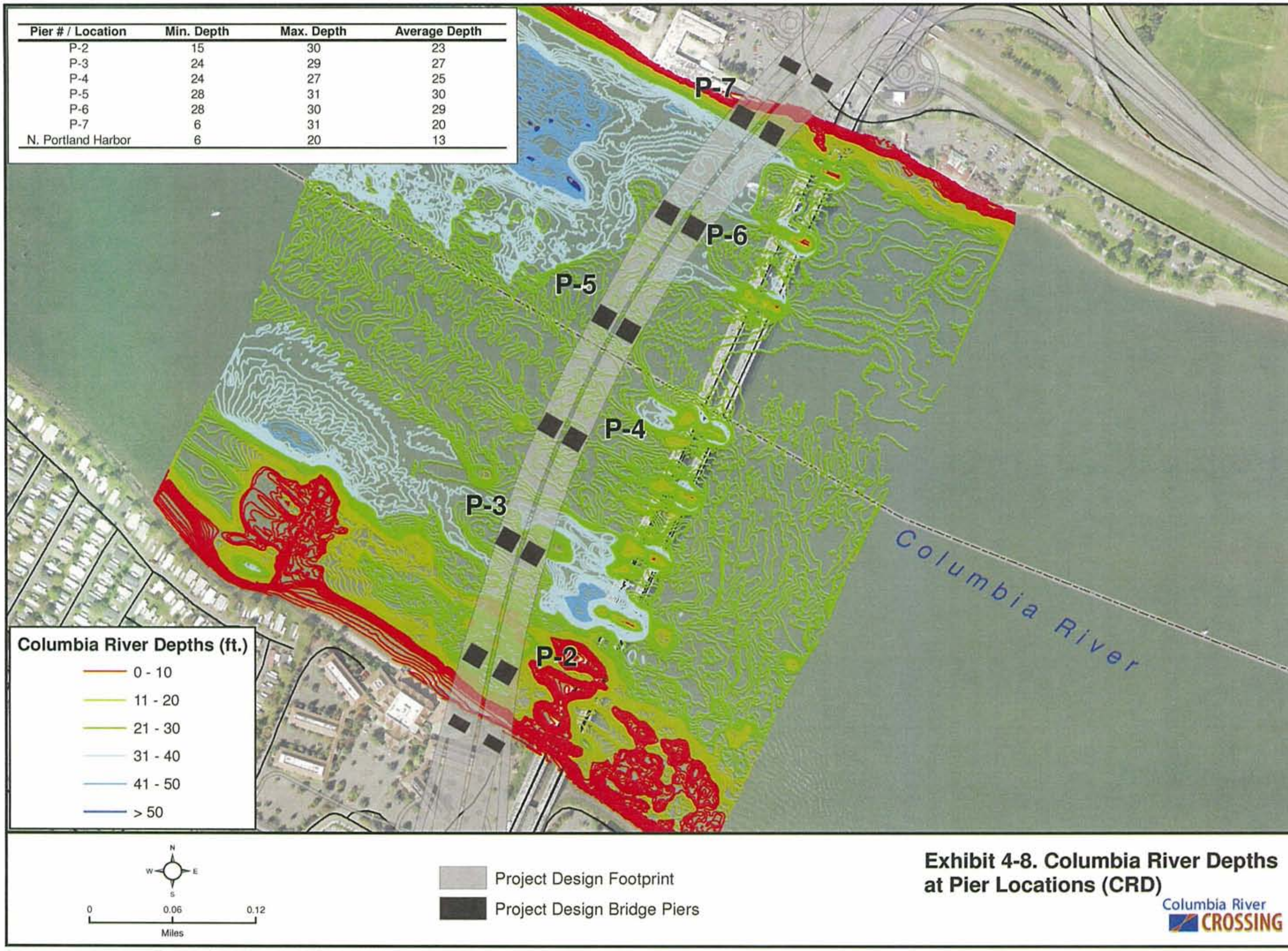


Exhibit 4-8. Columbia River Depths at Pier Locations (CRD)

Exhibit 4-9. Physical Impacts to Shallow-water Habitat in the Columbia River

Structure	Columbia River Area	Columbia River Time in Water
Permanent		
New Bridge Shafts (2 Drilled Shafts @ Pier 7)	236 sq. ft.	Permanent
Existing bridges piers to be removed (existing Pier 10, 11)	- 6,181 sq. ft.	Permanent
Total Permanent Impact	**- 5,945 sq. ft.[a]**	---

a This total does not include square footage of existing piers to be removed at the Red Lion at the Quay because that figure cannot be quantified at this stage of design; therefore, this total likely underestimates the amount of shallow-water habitat that will be restored via removal of in-water structure.

Exhibit 4-10. Physical Impacts to Shallow-water Habitat in North Portland Harbor

Structure	North Portland Harbor Area	North Portland Harbor Time in Water
Permanent		
New Bridge Piers (31 columns)	2,435 sq. ft.	Permanent
Total Permanent Impact	**2,435 sq. ft.**	---

Increase in Overwater Coverage

The project would place several overwater structures in shallow water in the Columbia River and North Portland Harbor; however, permanent overwater structures likely to have effects on fish include only the shaft caps on the Columbia River bridges. Exhibit 4-11 quantifies the area and duration of project-related overwater structures in the project area.

Effects of overwater coverage on fish and fish habitat are discussed in Section 5.3.2.

Exhibit 4-11. Overwater Coverage in Shallow-water Habitat in the Columbia River

Structure Type	Columbia River Area	Columbia River Duration in Water
Shaft Caps (P7 – Half of SB)	1,688 sq. ft.	Permanent
Pier at Red Lion at the Quay to be Removed	-18,965 sq. ft.	Permanent
Total Permanent Impact	**-17,277 sq. ft.**	---

4.1.2.2 Deep-water Habitat

Deep-water habitat occurs only in the Columbia River portion of the project area. Aquatic SOI have mixed use of this deep-water habitat. Typically, subyearling migrant salmonids are restricted to shallow-water habitat in the upper estuary (including the project area) (Carter et al 2009); however, the possibility exists that some will occasionally stray into the surface layer of deeper waters (Bottom et al. 2005). Larger juvenile salmonid migrants commonly use deep-water portions of the navigation channel in high numbers during outmigration, taking advantage of higher velocities there (Carter et al. 2009).

Adult salmonids do not show any specific preference for deep-water habitat over shallow-water habitat (Bottom et al. 2005). While they generally migrate at mid-channel, they may be found at depths of 1 to 50 feet (NMFS 2006). They commonly use deep-water portions of the project area for foraging and hold in low-velocity areas of deep-water habitat (such as behind bridge piers).

Eulachon adults and juveniles are known to forage at depths of greater than 50 feet and are likely to be present in deep-water portions of the project area (Hay and McCarter 2000).

Adult and subadult green sturgeon use waters at a depth of 30 feet or less and also could be present in deep-water portions of the project area (73 FR 52084).

Data on Steller sea lion, California sea lion, and harbor seal use of the water column within the Columbia River during transiting are not available. However, these species utilize marine habitat of significantly greater depths of 20 feet, and it is reasonable to assume that they would utilize deep water habitat of the Columbia River for transiting.

As discussed in the previous section on shallow water habitat, white sturgeon are known to utilize both shallow and deep water habitat in the Columbia River. Adult white sturgeon have been observed in waters approximately 7 to 98 feet (2 m to 30 m) in depth (Counihan et al. 1999) and are likely to use deep water habitat for foraging, resting, breeding, and spawning (Moyle 2002). White sturgeon may spawn in the lower Columbia River in depths of up to 75 feet (23 m) (Parsley et al. 1993). Juvenile white sturgeon in the Columbia River system have been documented in median water depths of 52 to 62 feet (16 to 19 m) (Parsley et al. 1993). White sturgeon may be more likely to use deep-water habitat during the winter months, often congregating in deep holes in the Columbia River (Brannon et al. 1992).

Other native fish resident to the Columbia River that may be present in deep water habitat include northern pikeminnow (*Ptychocheilus oregonensis*).

The project would have permanent impacts on deep-water habitat in the Columbia River, including physical gain of habitat area and an increase in overwater coverage.

Impacts to deep-water habitat would affect the following species and life stages:

- Feeding, holding and migration habitat for juveniles and holding and migration habitat for adults of the following ESUs/DPSs: LCR coho; CR chum; SR sockeye; LCR, MCR, UCR, and SR steelhead; and LCR, UCR spring-run, SR fall-run, and SR spring/summer-run Chinook.
- Rearing habitat for juvenile Chinook (LCR, UCR spring-run, and UWR), LCR coho, LCR steelhead, and CR chum.
- Adult and subadult bull trout migration and holding habitat. (Because of the extremely low numbers of bull trout in this portion of the project area, risk of exposure to this effect is discountable).
- Adult and subadult green sturgeon feeding and migration habitat. (Because of the extremely low numbers of green sturgeon in this portion of the project area, risk of exposure to this effect is discountable).
- All life stages of white sturgeon.
- Adult and larval eulachon spawning and migration habitat.
- Lamprey rearing and migration habitat.

Physical Gain of Deep-water Habitat

Exhibit 4-12 summarizes physical impacts to deep-water habitat in the Columbia River.

Exhibit 4-12. Physical Impacts to Deep-water Habitat in the Columbia River

Impact	Columbia River Area	Columbia River Time in Water
Permanent		
New bridge drilled shafts (P2 - P7)	6,361 sq. ft.	permanent
Existing bridges piers to be removed (existing Piers 2 – 9)	- 21,633 sq. ft.	permanent
Total Permanent Impact	**-15,272 sq. ft.**	**---**

The in-water portions of the new structures would result in the permanent physical loss of approximately 6,300 square feet of deep-water habitat at pier complexes 2 through 7 in the Columbia River. Demolition of the existing Columbia River piers would permanently restore about 21,000 square feet of deep-water habitat. Overall, there would be a net permanent gain of about 15,000 square feet of deep-water habitat in the Columbia River.

Increase in Overwater Coverage

The project would place several overwater structures in deep-water portions of the Columbia River. The only permanent new overwater structures likely to have effects on fish would be the shaft caps on the Columbia River bridges. Exhibit 4-13 quantifies the area and duration of project-related overwater structures in deep-water portions of the project area.

Exhibit 4-13. Overwater Coverage in Deep-water Habitat in the Columbia River

Type	Area	Duration in Water (days)
Permanent		
Shaft caps (P3 – P6)	56,813 sq. ft.	Permanent
Total permanent impact	**56,813 sq. ft.**	

Overwater coverage may create dense shade that may potentially attract predators. The sharp dark-light interface found underneath overwater structures may also cause visual disorientation to juvenile fish, which may in turn result in delayed migration and increased vulnerability to predators. Of the juvenile fish that use the project area, rearing juveniles and subyearling-migrant salmonids are highly dependent on shallow-water habitat and therefore are less vulnerable to these effects in deep water. However, as these individuals are not restricted to the nearshore (Bottom et al. 2005), they may stray or be carried into deeper water with the current, and there is a small chance of exposure to these effects. Larger juveniles of the yearling age class or older commonly use deep-water habitat during migration, and therefore are likely to be exposed to these effects.

The existing and proposed bridge spans in the Columbia River are more than 30 feet above the water surface and are therefore not likely to create dense shade on the water surface. For this reason, shade cast by these structures is unlikely to affect fish.

The shaft caps of the proposed Columbia River structures are at the water line and could create a net gain of permanent new dense shade (approximately 57,000 sq. ft.) in deep water.

The permanent structures would not create a swath of dense shade completely spanning deep-water habitat. Therefore, even if these structures were to create a shadow line that juvenile salmonids avoid crossing during daylight hours, juveniles could simply circumvent the shadow, resulting in no measurable delay to migration. Nighttime migration would be unaffected. Larval eulachon do not have volitional movement and are therefore not subject to visual disorientation or migration delays. Both adult and juvenile lamprey migrate primarily at night and are unlikely to be affected by shade.

The increase in the shade footprint increases the amount of suitable habitat for predators and therefore could presumably increase the number of predators in this portion of the project area. This could potentially cause a temporary and/or permanent increase in predation rates on juvenile salmonids, although it is not possible to quantify the extent of this effect.

Although it is impossible to quantify the extent to which increased shade may affect predation rates or cause visual disorientation in juveniles, it is possible to estimate the physical extent and duration of the effect. This effect would occur both when the structures are present in the water and during the timing of juvenile fish presence in this portion of the project area.

4.1.3 Hydraulic Shadowing

The modeling for the Columbia River bridges uses an earlier design with three sets of bridge piers with up to twelve drilled shafts each. The proposed design now consists of only two sets of piers, with only nine drilled shafts per pier. At present, the design team has not yet revised the hydraulics analysis for the two pier structure. In lieu of this information, we will continue to use data from the three pier hydraulics analysis. Because the three-pier scenario would result in a larger hydraulic shadow, it is assumed that this is an overestimate of the effect of hydraulic shadowing.

The in-water piers of the new structure would permanently increase hydraulic shadowing in North Portland Harbor and the Columbia River. Exhibit 4-14 shows the current hydraulic footprint of the existing structures at Columbia River for the 100-year event, given preliminary construction design data. In the Columbia River, the hydraulic shadow extends 200 to 1,100 feet downstream of the piers, with velocities in the shadow ranging from 0 to 3 feet per second (fps). The hydraulic footprint was not modeled for the existing North Portland Harbor structures (DEA 2006).

Exhibit 4-15 and Exhibit 4-16 show the predicted post-project hydraulic footprint for a 100-year flow event in the Columbia River and North Portland Harbor. In the Columbia River, the hydraulic shadow of the completed structures is expected to increase significantly compared to that of the existing structures, extending up to 1,600 feet downstream of each pier, with velocities in the shadow ranging from 0 to 3 fps.

Although the hydraulic shadow was not modeled at the existing North Portland Harbor structures, it is expected to increase in length because of the increase in the number of shafts and the width of the structures. The hydraulic shadow of the completed North Portland Harbor structures is expected to extend up to approximately 400 feet downstream of each pier, with velocities in the shadow ranging from 0 to 2 fps.

4.1.3.1 Effects of Hydraulic Shadowing on Fish

Hydraulic shadowing may affect fish by creating low-velocity eddies that have the potential to increase predation, interfere with movement patterns, and alter sediment transport.

Predation

In general, hydraulic shadowing has the potential to harm prey fish by creating low-velocity areas or eddies that enhance the foraging success of predaceous fish and birds. Juvenile salmonids, all life stages of eulachon, juvenile lamprey, and all life stages of other native resident fish are vulnerable to predation. Subyearling salmonids are particularly vulnerable (Pribyl et al. 2004). Yearling salmon move quickly and migrate when they are of a size that reduces vulnerability to predators. In contrast, subyearling salmon are slower and are of a size that increases their vulnerability to predation (Gray and Rondorf 1986). Likewise, juvenile eulachon do not have volitional mobility and consequently cannot evade predation easily. Additionally, subyearling salmonids and other juvenile fish are highly dependent on low-velocity areas for rearing and resting. This overlaps with the preferred habitat type of northern pikeminnow, smallmouth bass, largemouth bass, and walleye (Pribyl et al. 2004), which are chief predators of juvenile salmon and other native fish in the lower Columbia River (Gray and Rondorf 1986). Predation on juvenile salmonids by fish generally occurs at velocities of 4 fps or less (NMFS 2008d). Predation rates on native resident fish (e.g., dace, threespine stickleback, redside shiners, suckers, and sculpin) are not available for the project area; however, these species are also taken as prey by larger fish.

Northern pikeminnow is the major predator of emigrating juvenile salmonids in the Lower Columbia (Poe et al. 1994; NMFS 2000). Northern pikeminnow are associated with pilings and other in-water structures during most of the year (Pribyl et al. 2004; Petersen and Poe 1993). Northern pikeminnow select slower-velocity areas, generally avoiding velocities greater than 2.3 fps (NMFS 2000). Petersen and Poe (1993) reported northern pikeminnow congregating at overwater structures, such as back eddies behind pilings. Consumption rates are especially high in areas where juvenile salmonids congregate.

The literature is not in complete agreement about northern pike minnow consumption rates of juvenile salmonids in the Lower Columbia basin. Buchanan et al. (1981, as cited in NMFS 2000) reported that only 2 percent of northern pikeminnow found in free-flowing sections of the Willamette River contained salmonids in their diets. In a free-flowing reach of the lower Columbia River, Thompson (1959, as cited in NMFS 2000) found that only 7.5 percent of northern pikeminnow contained salmonids in their diets. However, in a survey of the lower Columbia River from Bonneville Dam (RKm 235) to Jones Beach (RKm 71–77), Petersen and Poe (1993) found that catches of northern pikeminnow and the number of salmonid prey per pikeminnow were higher in free-flowing sections of the river than in impounded areas in John Day Reservoir. At a sampling site in Vancouver, the spring diet of northern pikeminnow was comprised of 70 percent fish, 92 percent of which were salmonid smolts. In summer, the diet was 25 percent fish, 84 percent of which were salmonid smolts (Petersen and Poe 1993). The study estimated that the average predation rate in spring at the Vancouver site was 1.3 smolts per pikeminnow. In summer, the predation rate in the same location was 1.7 smolts per pikeminnow. Of the non-salmonid fish prey, approximately half were sculpins (*Cottus* spp.); evidence of predation on lamprey was noted less than 1 percent of sampled pikeminnow. Zimmerman (1999) found that daily consumption of juvenile salmonids in unimpounded portions of the Columbia River were about 0.8 prey per northern pikeminnow in the spring and 1.6 in the summer.

Mean maximum length of salmon consumed was 167 mm, although northern pikeminnow consumed both steelhead and Chinook measuring more than 200 mm in length. Of the salmonid smolts consumed, the large majority were juvenile Chinook (64 percent of all fish consumed), but they also ate steelhead (2 percent of fish consumed), and "unidentified salmonids" (26 percent of fish consumed). In another study, NMFS (2000b) estimates that the ratio of northern pikeminnow to the number of salmon smolts consumed between Bonneville Dam to the mouth to the Columbia River is 0.09 smolts per day. Northern pikeminnow are especially abundant in free-flowing reaches of the lower Columbia River. In a 2-year predator sampling study of the Lower Columbia from Bonneville Dam to RKm 70, northern pikeminnow comprised over 90 percent of the predaceous fish species encountered (Poe et al. 1994). Other predators (smallmouth bass and largemouth bass) were few in the study area. Other important prey species identified in these studies included redside shiners (*Richardonius balteatus*) and threespine sticklebacks (*Gasterosteus aculeatus*) (Gray and Rondorf 1986).

Smallmouth bass are known to exhibit strong cover-seeking behavior and typically seek out pools or deep areas behind rocks where the current is slack (Edwards et al. 1983; Pflug and Pauley 1984; Probst et al. 1984, as cited in Pribyl et al. 2004). They also associate with in-water structures such as pilings and riprap (Pribyl et al. 2004). In the Columbia River basin, smallmouth bass prey heavily on juvenile salmonids (Gray and Rondorf 1986). While Zimmerman (1999) found that the mean maximum length of smolts consumed was 119 mm, they may also ingest very large prey (up to 240 mm) (NMFS 2000). Subyearling salmonids are at highest risk, not only because their shallow-water habitat overlaps with the preferred habitat of smallmouth bass in summer, but also because they are the ideal forage size for this species (Gray and Rondorf 1986). Rearing subyearling Chinook are particularly vulnerable (Poe at al. 1994; NMFS 2000). Zimmerman (1999) estimates that consumption rates exceeded 1.0 juvenile salmonids per smallmouth bass in both impounded and unimpounded reaches of the Columbia River. All of the prey items were either Chinook (12 percent of all fish consumed) or "unidentified salmonids" (3 percent of all fish consumed). No steelhead were detected. Other important prey species identified in these studies included sculpins and suckers (*Catostomus* spp.) (Gray and Rondorf 1986, Zimmerman 1999).

Largemouth bass prefer low-velocity areas, such as backwaters, when in riverine environments (Wheeler and Allen 2003; Wydoski and Whitney 2003). Additionally, when located in high-velocity river channels they are associated with in-water structures (Pribyl et al. 2004). Largemouth bass are present in the Columbia system, but because their numbers are relatively low, they do not have the potential to significantly affect the abundance of juvenile salmonids (Gray and Rondorf 1986).

Walleye are present in the lower Columbia River, but there is disagreement about the impact of this species on the abundance of juvenile salmonids in this area (Gray and Rondorf 1986). Walleye are frequently associated with pilings, as they avoid strong current. During their spring spawning period, walleye may prey preferentially on smaller juvenile salmonids (less than 100 mm) where both overlap in shallow-water habitat (Gray and Rondorf 1986). At other times of the year, walleye may be spatially segregated from juvenile salmonids, occurring more frequently offshore in deep water (Pribyl et al. 2004). In a sampling study, Poe et al. (1994) found that walleye abundance was low in the Columbia River from Bonneville Dam to RKm 70, comprising only 2 percent of all piscivorous fish captured. Zimmerman (1999) also detected very few walleye in the same area and found that 12.5 percent of the walleye diet was Chinook, with no other salmonids species detected. In the lower Columbia River, NMFS (2002) research underscores this point, noting that non-salmonid fish dominated the walleye diet.

It is not possible to quantify the number of individuals potentially exposed to increased predation. However, given that there is a net increase in the extent of suitable predator habitat, it is probable that the project would result in some level of increased predation on juvenile salmonids, eulachon, possibly juvenile lamprey, and other native resident fish in the Columbia River and North Portland Harbor.

There are no specific data regarding the impact of hydraulic shadowing on predation rates of eulachon (reports do not specify prey items at the species level); however, because both adult and larval eulachon are well within the size range (less than roughly 150 mm) consumed by common predators in the Columbia River, it cannot be discounted that hydraulic shadowing could also increase predation on adult and larval eulachon in the same manner as for juvenile salmonids.

The change in hydraulic footprint is not expected to increase predation on adult salmon and steelhead, adult and subadult bull trout, or adult and subadult green sturgeon, as predation on fish of these size classes is rare (Zimmerman 1999). Additionally, because of the extremely low numbers of bull trout and green sturgeon in this portion of the project area, risk of exposure to this effect is discountable.

Outmigration of Juvenile Salmonids

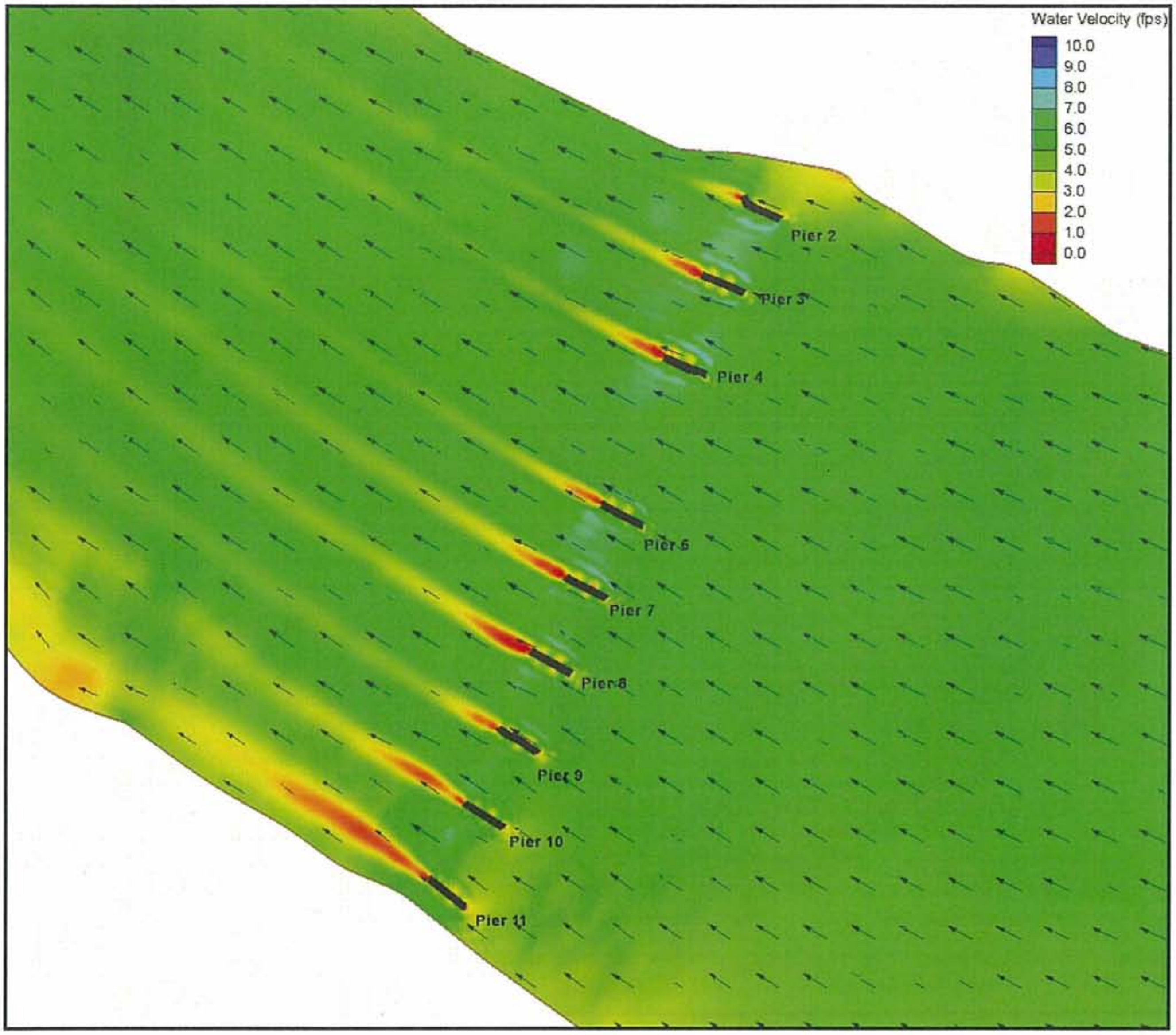
In general, hydraulic shadowing and resulting low-velocity areas have the potential to delay outmigration for smolts. Increased travel time exposes smolts to a variety of mortality vectors, including predation, disease, poor water quality, and thermal stress. Migration delays may also deplete energy reserves and disrupt arrival times in the lower estuary. The latter may cause salmonids to arrive in the estuary when predation levels are high and/or prey species are limited (NMFS 2008e). In the case of this project, effects to outmigration are expected to be slight. Although the size of the hydraulic shadow would increase, the range of velocities found in the hydraulic shadow is comparable to that which fish would encounter in the natural environment. Therefore, none of the juvenile fish present in the CRC project area are likely to become trapped or significantly delayed by the hydraulic shadow. Additionally, none are likely to be directed towards or away from shallow-water habitat because the structures neither pose a complete physical blockage to the shallow-water habitat, produce water velocities low enough to trap fish, nor produce velocities high enough to direct fish into deeper water. The effects of hydraulic shadowing on juvenile migration would be insignificant.

Velocity Refugia

Increased hydraulic shadowing may also benefit salmonids by creating larger velocity refugia for both adults and juveniles during periods or in reaches of high flow. A Bonneville Power Administration study showed that upstream passage through reaches with long, relatively uninterrupted stretches of high-velocity flow requires high levels of bio-energetic expenditure, similar to that of ascending a waterfall. Without resting areas, migrating adults use larger amounts of energy, posing risks for spawning success (Brown and Geist 2002). Velocity refugia allow fish to rest and replenish energy reserves. The CRC project area and vicinity consist of long relatively uninterrupted stretches of high-velocity flow. Presumably, the increased size of the hydraulic shadows would increase the area of flow refugia over the preproject condition. The extent to which this increase may benefit listed fish is impossible to quantify, but given that the increase in flow refugia is small relative to the large size of the Columbia River and North Portland Harbor, the effect is probably slight and therefore insignificant.

Sediment Transport

The hydraulic effect of the new bridges may alter sediment transport in the Columbia River and North Portland Harbor. Between bridge piers, water velocities are likely to increase, resulting in increased sediment transport. In lower-velocity areas behind the piers, sediment is likely to accumulate. Several new piers are located immediately adjacent to the shoreline (in the Columbia River: pier complexes 2 and 7; in North Portland Harbor, the six new nearshore bridge bents). Low-velocity areas behind these piers would likely accumulate sediment; therefore, the new bridge piers are not anticipated to cause shoreline erosion.



Source: CRC Hydraulic and Scour Parameters Report 2008

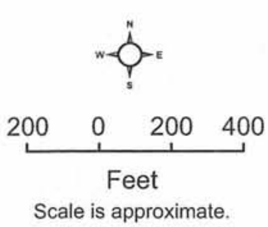
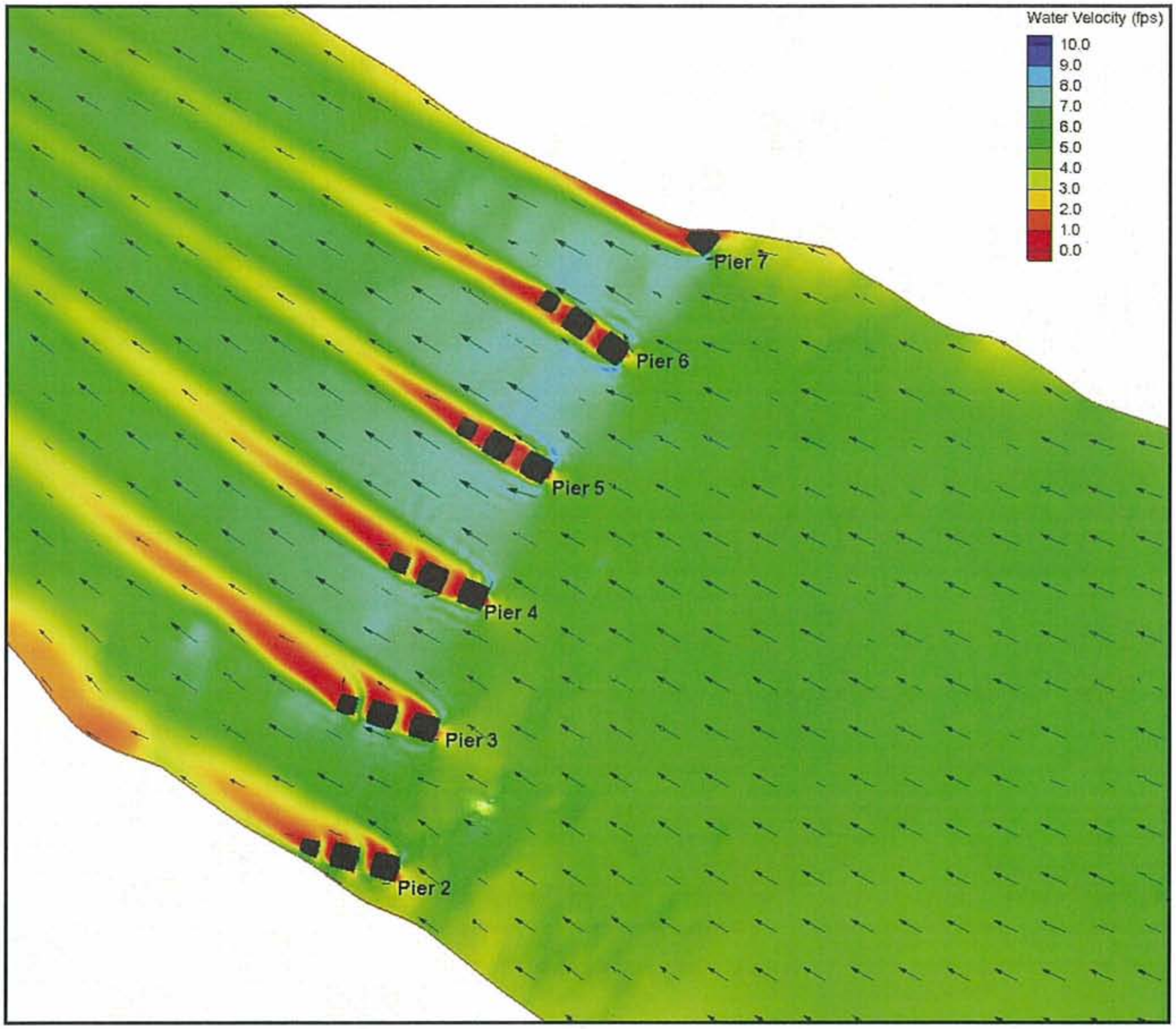


Exhibit 4-14. Velocity Vector Plot of Existing Structures in the Columbia River for 100-Year Flood

Columbia River CROSSING



Source: CRC Hydraulic and Scour Parameters Report 2008

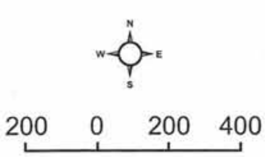
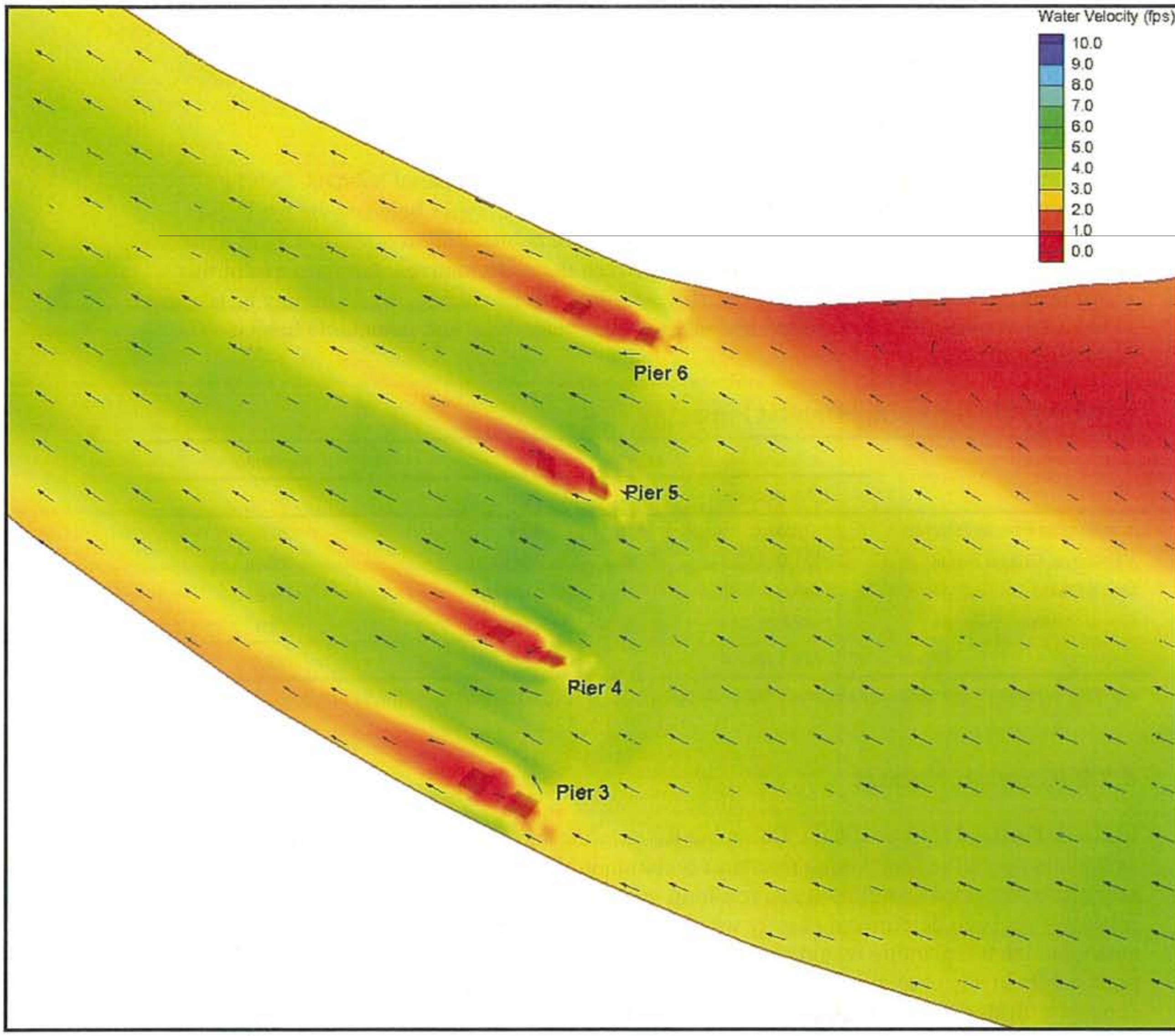


Figure 4-15. Velocity Vector Plot of Proposed Structures in the Columbia River for 100-Year Flood

Columbia River CROSSING



Source: CRC Hydraulic and Scour Parameters Report 2008

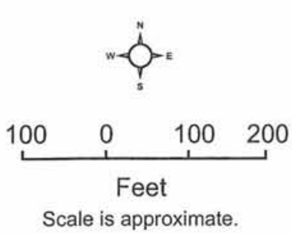


Exhibit 4-16. Velocity Vector Plot of Proposed Structures in the North Portland Harbor for 100-Year Flood

Columbia River CROSSING

4.2 Effects to Terrestrial Resources

4.2.1 Terrestrial Habitat

Construction activities associated with the LPA would impact terrestrial habitats. Exhibit 4-17 compares project impacts to the various terrestrial habitat types between the No Build alternative and the LPA. Comparison is made of acres of habitat within right-of-way to represent the most consistent project footprint possible between these alternatives. For purposes of this analysis, impacts include construction cut/fill activities, paved surface, area that may be accessed in the right-of-way for maintenance, and other ground-disturbing and potentially habitat-disturbing activities.

Exhibit 4-17. Terrestrial Habitat Impacts

	LPA[a]		No-Build
	LPA Option A	LPA Option B	
Washington Priority Habitats	37.0	36.9	29.5
Vancouver Critical Areas	121.0 (119.4)	120.7 (119.2)	108.8
Metro Goal 5	48.5 (48.6)	47.0 (46.9)	25.8
City of Portland E-Zones	42.6 (42.4)	41.3 (40.9)	27.9
Totals	**249.1 (247.4)**	**245.9 (243.9)**	**192.0**

a Text in parentheses indicates impacts if the LPA Option A or B is constructed with highway phasing.

4.2.2 Riparian Habitat

In North Portland Harbor and the Columbia River, effects to riparian habitat would be negligible, as there is very little functioning riparian vegetation in the project area. The project would revegetate disturbed shoreline areas, resulting in a net benefit to riparian habitat in the long term. It has not yet been determined exactly where replanting would take place. However, it is anticipated that replanting would occur on or adjacent to the current sites of the trees where practicable. In any case, the number, type, and size of the replanted trees would be selected to comply with standards outlined in the City of Portland and City of Vancouver tree ordinances.

In Oregon, the project would remove three deciduous trees, all with trunks less than 1 foot in diameter, from the riparian zone on the south bank of the Columbia River. The project would also remove two deciduous ornamental trees from the riparian zone adjacent to North Portland Harbor. These trees are located in a landscaped setting and have trunks of approximately 1 foot in diameter. In Washington, 10 trees with trunks less than 1 foot in diameter would be removed from the riparian zone on the north shore of the Columbia River.

In general, removal of trees from riparian areas results in a reduction of shade in the water column and a concurrent increase in water temperature. However, in the case of the CRC project, only approximately 15 trees would be removed from the Columbia River/North Portland Harbor riparian area. This represents an extremely small amount of shaded water (less than 10,000 square feet, patchily distributed among at least three locations) relative to the thousands of acres of unshaded water located immediately adjacent to the area from which trees would be removed. Because of the small size of the shaded area relative to the large volume of water and because of the high current velocity in these water bodies, it is unlikely that these fifteen riparian trees create enough shade to measurably decrease water temperatures in the water column. Thus, the loss of these trees is expected to cause only negligible effects to water temperature, if any.

Additionally, removal of trees from riparian areas may reduce the potential for large woody debris recruitment in a watershed over the long term. However, given the large size of the lower Columbia system and the thousands of remaining riparian trees in this area, removal of 15 trees would not measurably decrease the potential for long-term large woody debris recruitment in the project area or in the lower Columbia system overall.

There would be no excavation, vegetation clearing, or removal of trees from the Columbia Slough riparian area. Therefore, the project would have no effect on Columbia Slough riparian habitat.

Exhibit 4-18 illustrates the acreage and locations of PHS riparian buffer at Burnt Bridge Creek that are likely to be impacted under the LPA.

4.2.2.1 LPA with Highway Phasing

If the project improvements at SR 500 are deferred under the LPA with highway phasing option, riparian impacts near Burnt Bridge Creek would be also be deferred.

4.2.3 Threatened, Endangered, and Proposed Species

No long-term effects to terrestrial threatened, endangered, proposed, or candidate species would be expected under the LPA.

4.2.4 Species of Interest

The LPA would affect terrestrial resources by removing structures used by migratory birds and potentially by bats. Removal of these structures is a concern because life stages such as feeding and breeding may be affected. New habitat elements such as nest boxes could be included in the new structure to offset removal of habitat elements associated with the existing bridge. However, the LPA is not anticipated to have adverse long-term impacts to most terrestrial resources.

Peregrine falcons would be affected because the existing bridge, which the falcons have been documented using since 2001, would be removed. Removal of the habitat structure on the existing bridge would appreciably disrupt peregrine breeding, foraging, and roosting activity. Peregrines using the existing bridge would be forced to find alternative structures in the area, or would vacate the area in the long term.

Long-term effects to migratory birds could include altered habitat for nesting and roosting if the new bridge design provided less structure suitable for these species (e.g., the new structure would not include steel girders that birds currently use).

Exhibit 4-18. Impacts to Terrestrial Habitat at Burnt Bridge Creek Intersections with Roadway

4.2.5 Wildlife Passage

Wildlife passage may be hindered compared to existing conditions. The existing shoreline provides minimal passage habitat in the form of open riprap and concrete. Piers for the new bridges would likely impact one or both shores of the Columbia River, creating an obstruction to movement along the shoreline. Options for improving wildlife passage are limited; however, habitat connections would be upgraded where feasible, particularly in riparian areas.

4.3 Effects to Botanical Resources

The LPA is not anticipated to have long-term impacts to botanical resources. Effects to vegetation will be addressed through mitigation measures discussed in Section 6.

4.4 Indirect Effects

Changes in auto and transit use, biking and walking, as well as changes in land use, are anticipated to occur under the LPA and No-Build alternatives. Potential positive and negative impacts to species and habitats could occur from land use development and resulting changes to trip patterns, including impacts to water quality and water quantity. In addition, development may result in changes to riparian and nearshore areas, including changes in vegetation and overwater structures. Species may be affected through the addition of impervious surface (particularly PGIS), and a decrease in riparian and aquatic habitat.

The LPA and local plans are expected to promote redevelopment adjacent to or near proposed light rail stations in downtown Vancouver and on Hayden Island. With redevelopment of existing infrastructure, applicable land use codes would be implemented, in particular the need to upgrade to existing stormwater treatment regulations. Because these sites are located in already highly developed areas, habitat for terrestrial species is extremely limited to non-existent at these sites; however, stormwater runoff could indirectly positively or negatively impact habitat associated with fish species. Development and redevelopment, including removal or renovation of existing in-water structures and near-shore development, would comply with the relevant laws, regulations, policies, and codes in force at the time of the action. These regulatory approvals range from tree and street tree removal, to stormwater treatment, to environmental zone and critical areas protections, to more complicated processes for larger developments.

With the integration of local and state land use requirements, negative impacts from development and redevelopment would be limited. Local regulations require the avoidance or minimization of impacts to protected resources. These resources include shorelines, wetlands, stream banks, and their buffers, resources that are often most important to juvenile salmonids and their habitat. With implementation of regulations such as environmental zones, the Shoreline Management Act (SMA), and CAO, impacts to existing resources would be negligible.

This page intentionally left blank.

5. Short-term Effects

This section describes the short-term effects the LPA Option A ("LPA") full build would have to aquatic, terrestrial, and botanical resources. Unless stated otherwise, the LPA with highway phasing options would have the same impacts to aquatic, terrestrial, and botanical resources as the corresponding LPA full build options. Similarly, the short-term impacts to aquatic, terrestrial, and botanical resources are expected to be the same, whether Option A or Option B is built, except where noted (see section 5.3.2.1).

5.1 Introduction

Unavoidable impacts to ecosystem resources, particularly the Columbia River and North Portland Harbor, are likely to occur. Modifications to migratory bird habitats are likely to occur as existing vegetation, as well as the bridge structures themselves, are expected to be removed. This would be a short-term effect to migratory bird habitat because vegetation replanting, and new bridge construction, would occur.

Temporary effects to aquatic habitat and aquatic species are anticipated from in-water work. In-water work may include removing existing bridge piers, constructing new piers, and installing and removing temporary in-water work structures. In-water work is likely to include coffer dams, barges, drilling equipment, impact pile drivers, vibratory pile drivers, and other construction vehicles in and near the water. In-water work would likely cause localized increases in underwater noise, turbidity, artificial lighting, avian predation, hydraulic shadowing, and shading. Construction activities may cause injury or death to aquatic species. Exhibit 5-1 shows the anticipated sequencing of in-water structures for the construction in the Columbia River.

Temporary effects to terrestrial species are anticipated from construction noise and impacts to vegetation. Construction activity causing noise disturbance could result in reduced nesting success for migratory birds. Trees, shrubs, and other vegetation serving as cover, nesting, roosting, and perching habitat may be removed during construction. Such vegetation removal could also impact terrestrial wildlife using such habitat structure for cover, feeding, breeding, and dispersal.

5.2 Effects to Aquatic Resources

5.2.1 Acoustic Impacts

Direct injury, mortality, or behavioral disturbance to fish species may result from sound levels produced by impact pile driving, vibratory pile driving, and other in-water construction techniques used for the installation of temporary and permanent in-water structures in the Columbia River and North Portland Harbor. Effects associated with pile driving may include physical injury (particularly to air-filled spaces such as swim bladders), auditory tissue damage, temporary or permanent hearing loss, behavioral effects, and immediate and delayed mortality. The amount of energy and the resulting sound pressure from impact pile driving depend on the size and type of pile, type of hammer, energy of the hammer, depth of the water column, and substrate. Impacts to individual fish depend on sound pressure levels, fish species, fish size, fish condition, fish movement, and depth of the water column (Popper et al. 2006). Use of bubble curtains or other noise attenuation devices during impact pile driving may reduce the level of noise impacts to fish (Caltrans 2009).

Sound, measured in dB, is a relative measure and is referenced in the context of underwater sound pressure to 1 micropascal (μPa) ("dB re: 1 μPa"). One pascal is the pressure resulting from a force of 1 newton exerted over an area of 1 square meter. For purposes of this analysis, underwater sound is referenced in units of decibels re: 1 μPa when referring to sound pressure levels (SPLs) or 1 μPa^2-second when referring to sound exposure levels (SELs), and will be denoted as dB.

Root mean square (RMS) is the quadratic mean sound pressure over the duration of an impulse. This measurement is often used in the context of discussing behavioral effects to fish, in part because behavioral effects, which often result from auditory cues, and effects on hearing may be better expressed through averaged units rather than by peak pressures. When discussing the effects of explosions on animals, authors often use impulse as the acoustic parameter, as in Yelverton et al. (1973) discussed below. Positive impulse is the integral of pressure over time, from arrival of the leading edge of the pulse until the pressure becomes negative. Impulse is measured in pascal-seconds (Pa-s). As sound propagates away from a source, several factors change its amplitude. These factors include the spreading of the sound over a wider area (spreading loss), losses to friction (absorption), scattering and reflections from objects in the sound's path, and interference with one or more reflections of the sound off the surface of the streambed (in the case of underwater sound).

The sum of all propagation and loss effects on a signal is referred to as the transmission loss. A major component of transmission loss is spreading loss. From a point source in a uniform medium (water or air), sound spreads outward in spherical waves. Sound transmission in shallow water is highly variable and site specific. Refraction can result in either reduced or enhanced sound transmission in shallow water (Richardson et al. 1995). Ambient noise is the background noise. In water, sources of ambient noise include wind, waves, organisms, shipping traffic, and rain.

Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**4/5/17**	**928 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Work Bridge (Approx. 350 s.f.)	10/16/13	10/13/14	259 days
Tower Crane (Aprox. 100 s.f.)	2/27/15	1/22/16	236 days
Barge Moorings (Approx. 45 s.f.)	10/16/13	1/22/16	593 days
Pier 3	**9/16/13**	**9/29/15**	**532 days**
Work Bridge (Approx. 600 s.f.)	9/16/13	9/26/14	270 days
Tower Crane (Approx. 100 s.f.)	9/29/14	9/29/15	262 days
Barge Moorings (Approx. 45 s.f.)	9/16/13	9/29/15	532 days
Pier 4	**11/15/13**	**10/20/15**	**503 days**
Work Bridge (Approx. 600 s.f.)	11/15/13	11/19/14	264 days
Tower Crane (Approx. 100 s.f.)	3/20/15	10/20/15	153 days
Barge Moorings (Approx. 45 s.f.)	11/15/13	10/20/15	503 days
Pier 5	**10/29/14**	**10/19/16**	**516 days**
Work Bridge (Approx. 600 s.f.)	10/29/14	10/27/15	260 days
Tower Crane (Approx. 100 s.f.)	3/21/16	10/19/16	153 days
Barge Moorings (Approx. 45 s.f.)	10/29/14	10/19/16	516 days
Pier 6	**12/1/14**	**4/5/17**	**613 days**
Work Bridge (Approx. 600 s.f.)	12/1/14	2/15/16	315 days
Tower Crane (Approx. 100 s.f.)	4/11/16	4/5/17	258 days
Barge Moorings (Approx. 45 s.f.)	12/1/14	4/5/17	613 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Work Bridge (Approx. 350 s.f.)	9/29/14	10/13/15	272 days
Tower Crane (Aprox. 100 s.f.)	2/29/16	1/23/17	236 days
Barge Moorings (Approx. 200 s.f.)	9/29/14	1/23/17	606 days

Conceptual Schedule Only, March 2010
Note: This is a proposed schedule, so activity start and finish dates are likely to change.

Exhibit 5-1. Sequencing of In-Water Structures for Construction in the Columbia River

Columbia River CROSSING

5.2.1.1 Hydroacoustic Effects to Fish from Impact Pile Driving

Hydroacoustic injury and disturbance thresholds and guidance for fish species have been identified by NMFS and USFWS for impulse noises, such as impact pile driving (Exhibit 5-2) (Popper et al. 2006; Southall et al. 2007; NMFS 2009). Some of the thresholds are dependent on whether the fish are greater than or equal to 2 grams (g) in size. Fish potentially occurring in the project area include adult salmonids, adult and subadult green sturgeon, adult eulachon migrating upriver, larval eulachon, steelhead kelts migrating downriver, outmigrating juvenile salmonids, and other native resident fish (e.g., sculpins, threespine sticklebacks, suckers, dace, shiners). All of these species fall into the greater than 2 g size class, except for juvenile chum, larval eulachon, and some larval and juvenile resident fish.

Exhibit 5-2 lists the injury thresholds and disturbance guidance for noise impacts to fish.

Other native and non-native fishes occur in the project area. These species include lamprey species, white sturgeon, cutthroat trout, and others. Most of the fish in the project area have swim bladders or other air-filled cavities in their bodies. Lampreys do not have swimbladders and it is therefore difficult to determine the extent of this impact. Fish species without swimbladders are thought to be at lower risk from underwater sound than fishes with swimbladders (Stadler, pers. comm. 2010, Hastings and Popper 2005, Coker and Hollis 1952, Gaspin 1975, Baxter et al. 1982, Goertner 1994). No thresholds for disturbance or injury have been established for such fish (Stadler pers. comm. 2010). Therefore, hydroacoustic impacts to lamprey should not be discounted, but they cannot be quantified or analyzed with any level of certainty.

Exhibit 5-2. Hydroacoustic Injury Thresholds and Disturbance Guidance for Fish[a]

Underwater Sound Criteria (dB measured at 10 meters from source)		
Size Class	Injury Threshold	Disturbance Guidance
Fish ≥ 2 grams	206 dB_{peak}; 187 SEL_{cum}	150 dB_{RMS}
Fish < 2 grams	206 dB_{peak}; 183 SEL_{cum}	150 dB_{RMS}

a Where cumulative SEL (SEL_{cum}) is calculated as: $SEL_{(cum)}$ = SEL(single strike at ~10 meters from the pile) + 10 log * (# strikes).

Impact pile driving would occur during installation of temporary in water work structures in the Columbia River and North Portland Harbor as described in Section 1 (Description of the LPA). Temporary piles used in these structures are expected to fall into two size classes: 18 to 24 inches and 36 to 48 inches in diameter.

Approximately 1,500 temporary steel piles would be installed and removed during the multi-year construction of the Columbia River and North Portland Harbor bridges. The need for piles would be staged over the in-water construction and demolition periods so that between 100 and 400 piles may be in the water at any given time.

Temporary structures that are not load-bearing, such as mooring piles and cofferdams, would be installed with a vibratory driver only. Drilled shaft casings may also be vibrated into position. These vibratory driving activities are proposed to occur year-round and without the use of an attenuation device.

Structures requiring load bearing piles include temporary work bridges, work platforms, tower cranes, and oscillator support platforms. These piles would be installed first with a vibratory driver to refusal and then proofed with an impact hammer.

Each pier complex of the Columbia River bridges would require approximately 132 load-bearing piles for support of work platforms/bridges and an additional eight load-bearing piles for a tower crane several months later, for a total of approximately 840 impact driven piles. An average of six temporary, load-bearing piles could be installed per day using one or two impact drivers. The project is anticipating that temporary piles for each of the six work bridges/work platforms would be installed in one 22-day period. Temporary piles for each of the six tower cranes would be installed in one day. Impact pile driving in the Columbia River would occur on approximately 138 days over the approximately 4-year construction period.

Each of the 31 oscillator support platforms in North Portland Harbor would require four load-bearing piles (124 total piles). In addition, the nine temporary work bridges would each require approximately 25 load-bearing piles (225 total piles). There would be a total of approximately 349 impact-driven piles in North Portland Harbor. Only one impact driver would operate at a given time in North Portland Harbor. Impact pile driving in North Portland Harbor would occur on approximately 134 days over the approximately 4-year construction period.

In-water noise attenuation measures would be employed during impact driving activities for the majority of pile strikes. The CRC project assumes that an at-source noise reduction of approximately 10 dB is achievable through use of a noise attenuation device. Unattenuated pile driving may occur as part of the hydroacoustic monitoring program for this project or incidentally during attenuation equipment failures. In the Columbia River, unattenuated pile driving may occur for up to 7.5 minutes per week. In North Portland Harbor, unattenuated pile driving may occur on average for up to 5 minutes per week.

Based on NMFS models, calculation of distances to injury thresholds and disturbance guidance is related to noise from a single pile strike. For accumulated SEL, the variables include: single-strike dB SEL, the number of pile strikes over a time period, the time period, the distance from pile, and fish movement.

During construction of the Columbia River bridges, up to two impact pile drivers may operate simultaneously in close proximity to one another. The operation of two pile drivers is not anticipated to produce noise levels greater than that of a single pile driver. Pile strikes from both drivers would need to be synchronous (within 0.0 and approximately 0.1 seconds apart) in order to produce higher noise levels than a single pile driver operating alone. Because it is highly unlikely that two pile drivers would operate with exactly synchronous pile strikes, the CRC team assumes that two pile drivers would not generate noise at levels greater than that of a single pile driver.

For construction of the mainstem Columbia River bridges, an average of 300 impact blows per pile are estimated to be needed. Project designers estimate that up to 1,800 attenuated pile strikes would occur per day of pile driving. For construction of the North Portland Harbor bridges, a total of 1,800 attenuated pile strikes per day of driving were also assumed. The actual number of pile strikes would vary depending on the type of hammer, the hammer energy and substrate composition. However, these pile strikes would not be spread evenly throughout the work day. It is likely that day-to-day pile driving activities would vary. This hour-to-hour and day-to-day variation, coupled with timing of fish runs and fish speed through the area, creates a complex scenario for analyzing effects.

To accommodate this complex scenario of pile sizes, initial sound levels, pile strike numbers, timing and duration of pile driving, etc., the CRC team developed an analytical tool to determine the extent to which fish are exposed to potentially injurious accumulated sound levels within the project area. The CRC project has called this extent of exposure the "exposure factor." The exposure factor uses the variables for calculating the accumulated SEL through the moving fish model (size of pile [initial sound levels], daily pile strikes, timing and duration of pile strikes, fish speed, and fish mass) and combines that with variables, such as days of pile driving within a week, to estimate the potential exposure to fish that are within or pass through the project area. Different combinations of any of these elements (such as pile strikes, duration or timing of pile strikes, and initial sound levels) would yield different exposure factors. During construction, the contractor would calculate the weekly, maximum yearly, average yearly, and total project exposure factor to ensure that they do not exceed levels specified in Section 6 of this document.

Exposure factors were calculated for impact pile driving activities in both the Columbia River and North Portland Harbor.

The Services have accepted the use of a revised moving fish model based on this project's specific conditions to determine exposure factors and to quantify effects to listed fish. This model uses the mass and the measured or assumed rate of travel for juvenile and adult fish through the project area. Juvenile chum and larval eulachon were assumed to be under 2 g in mass and travel with the current at 0.6 m/s. Other juvenile fish were assumed to be over 2 g in mass and travel a little faster than the current of 0.8 m/s. All adult fish were assumed to be over 2 g in mass and travel at 0.1 m/s through the project area.

It is important to correctly assume the rate of travel and mass for the moving fish model. The faster a fish moves through an area, the less time it has to become exposed to accumulated levels of potentially injurious sound energy. The effect of speed on the area of effect is more noticeable at higher fish movement speeds (nearing 1.0 m/s), whereas the area of effect for fish moving 0.1 m/s are substantially the same as the area of effect calculated using the stationary fish model. For example, an attenuated 36- to 48-inch-diameter pile struck 300 times would result in a pile-driving time of approximately 7.5 minutes. A fish (over 2 g) moving at a speed of 0.8 m/s would travel approximately 360 m in a 7.5-minute period. If that fish passed within approximately 47 m of the driven pile, it could receive enough sound energy for injury to occur. If the fish were traveling at only 0.6 m/s, then it could experience enough sound energy for injury to occur within approximately 58 m from the pile. If the fish were traveling at 0.1 m/s or was stationary, then it could experience enough sound energy for injury to occur within approximately 83 m from the pile. If the fish passed inside of the threshold distance for its given speed, injury would be more likely.

In order to analyze potential impacts to listed fish, the CRC project team calculated the proportion of a listed fish run that may be impacted within the Columbia River and North Portland Harbor through potential injury due to increased sound pressure levels from the impact driving of temporary piles. Calculating exposures to fish requires multiplying the proportion of a fish run likely present in the project area in a given week by the weekly exposure factor for that week. The CRC project used 13 full Columbia River Bridge construction scenarios to estimate potential and maximum exposure factors.

Due to the numerous variables in determining exposure factors, the CRC team used representative numbers of pile strikes, such as those in Exhibit 5-3 and Exhibit 5-4, to estimate exposure factors for the project. The numbers in Exhibit 5-3 and Exhibit 5-4 are also used to illustrate the extent of underwater noise exceeding the injury thresholds and disturbance guidance.

Exhibit 5-3. Pile-Strike Summary for Columbia River Bridge Construction

Pile Size	Strikes per Day	Days per Week[a]	Strike Interval[b]
Without Attenuation Device			
Single pile driver: 18- to 24-inch pile	150	1	1.5

Pile Size	Strikes per Day	Days per Week[a]	Strike Interval[b]
Single pile driver: 36- to 48-inch pile	150	1	1.5
With Attenuation Device			
Single pile driver: 18- to 24-inch pile	400	5	1.5
Single pile driver: 36- to 48-inch pile	800	5	1.5
Two pile drivers: each with 18- to 24-inch pile	200	5	0.75
Two pile drivers: one 18- to 24-inch pile and one 36- to 48-inch pile, or two 36- to 48-inch piles	400	5	0.75

a Days per week during active driving only.

b Measured in seconds between strikes.

Exhibit 5-4. Pile-Strike Summary for North Portland Harbor Bridge Construction

Pile Size	Strikes per Day	Days per Week[a]	Strike Interval[b]
Without Attenuation Device			
Single pile driver: 18- to 24-inch pile	75	1	1.5
Single pile driver: 36- to 48-inch pile	75	1	1.5
With Attenuation Device			
Single pile driver: 18- to 24-inch pile	900	3 to 5	1.5
Single pile driver: 36- to 48-inch pile	900	2	1.5

a Days per week during active driving only.

b Measured in seconds between strikes.

Estimated Extent, Timing, and Duration of Effect

Exhibit 5-5, Exhibit 5-6, Exhibit 5-12, and Exhibit 5-13 summarize the distances within which noise exceeds the injury thresholds and disturbance guidance in the Columbia River and North Portland Harbor during impact pile driving. These distances are presented for impact pile driving occurring both with and without the use of an attenuation device for comparison. Note that the upstream extent of pile-driving noise may differ from the downstream extent. These values indicate the distance at which noise encounters a landform (such as an island or streambank) that completely blocks the spread of in-water noise. The calculations assume that the noise attenuation device would achieve 10 dB of noise reduction at the source.

Exhibit 5-5, Exhibit 5-7, and Exhibit 5-8 show the distances within which noise exceeds peak injury thresholds.

Exhibit 5-5. Distances at Which Underwater Noise Exceeds 206 dB Peak Injury Threshold Levels for Peak Noise in the Columbia River and North Portland Harbor

	Distance (m)	
Pile Size	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	25	5
36- to 48-inch pile	34	7

Exhibit 5-9, Exhibit 5-10, and Exhibit 5-11 show the distances within which noise is estimated to exceed the 187 dB SEL injury thresholds for fish over 2 g and moving at 0.1 m/s for a single pile driver and for two pile drivers operating simultaneously, as calculated using the moving fish model.

Exhibit 5-6. Distances at Which Underwater Noise Exceeds 187 dB SEL Injury Threshold for Adult Fish Under 2 g at 0.1 m/s in the Columbia River and North Portland Harbor

	Distance (m)	
Pile Size	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	113	50
36- to 48-inch pile	243	156
Two 18- to 24-inch piles	N/A	59[a]
Two 36- to 48-inch piles OR One 18- to 24-inch and one 36- to 48-inch pile	N/A	130[a]

Note: Includes adult salmon, steelhead, and eulachon.

a Applies to Columbia River only.

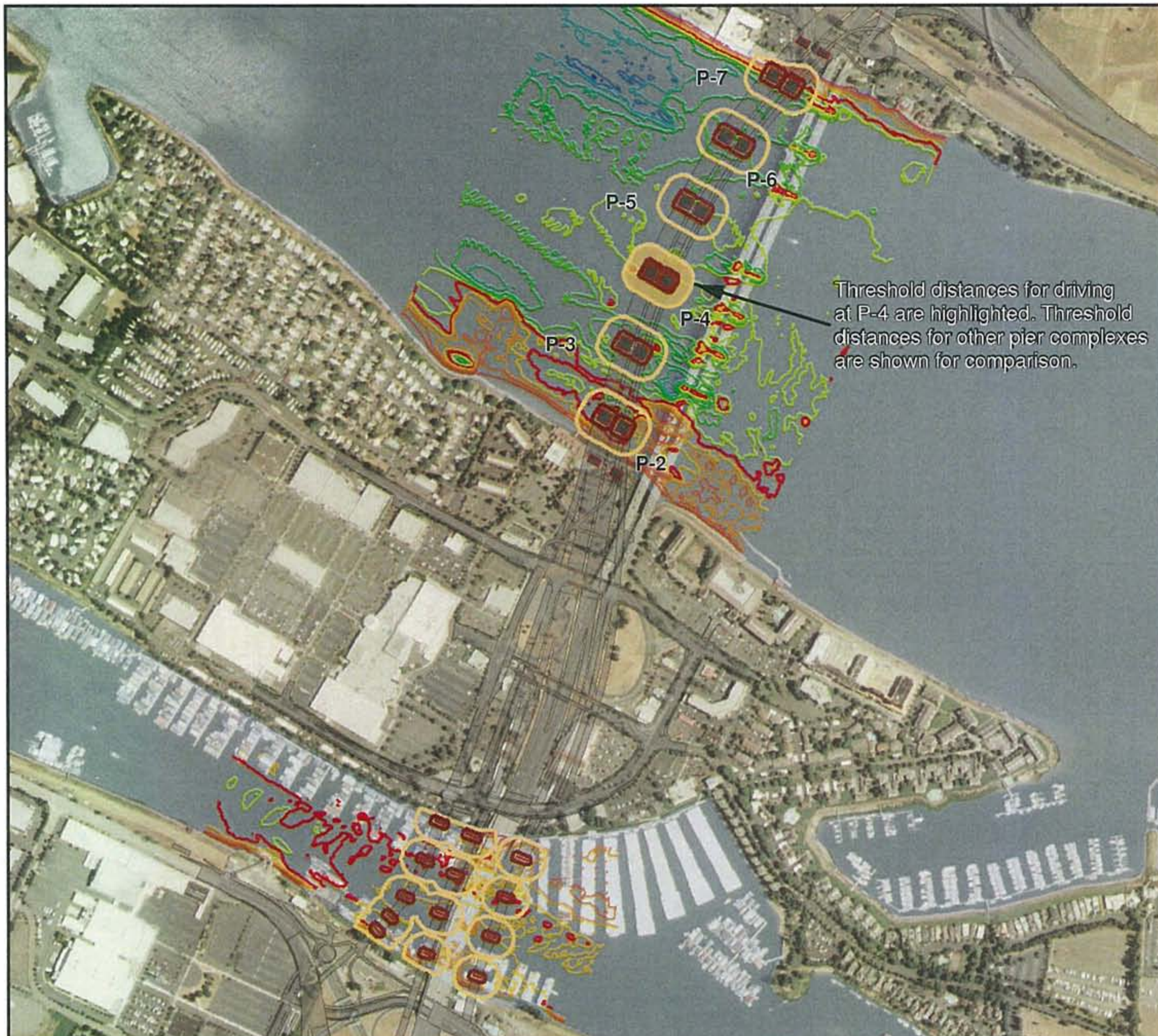


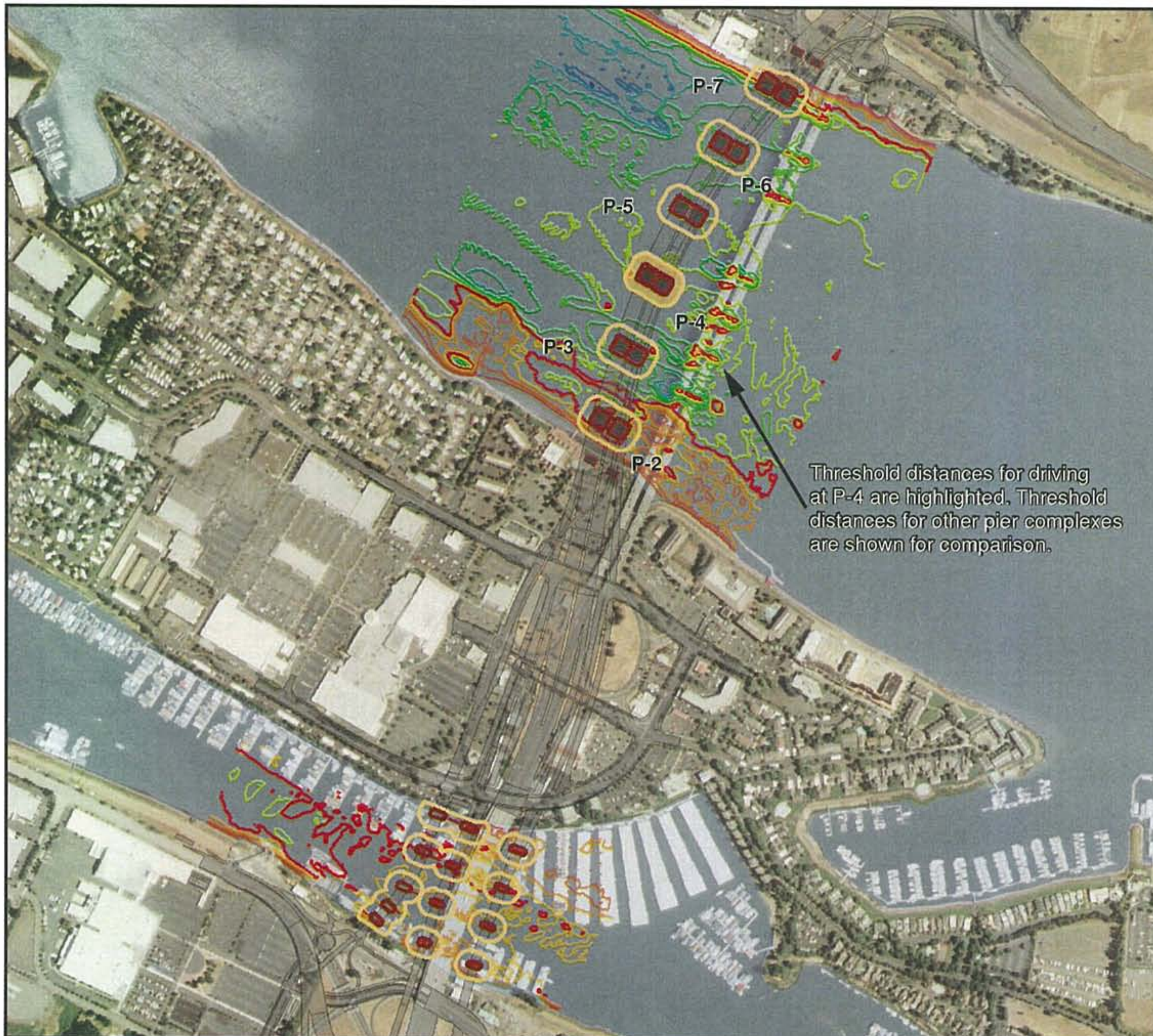
Figure 5-7. Extent of underwater impact pile-driving noise exceeding 206 dB peak injury threshold for fish. 36- to 48-inch pile.

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

PRELIMINARY

Exhibit 5-8. Extent of underwater impact pile-driving noise exceeding 206 dB peak injury threshold for fish, 18- to 24-inch pile.



Distance to Exceedance of Threshold

- 5 meters with attenuation device
- 25 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 5 meters with attenuation device
- 25 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 520 1,040
Feet

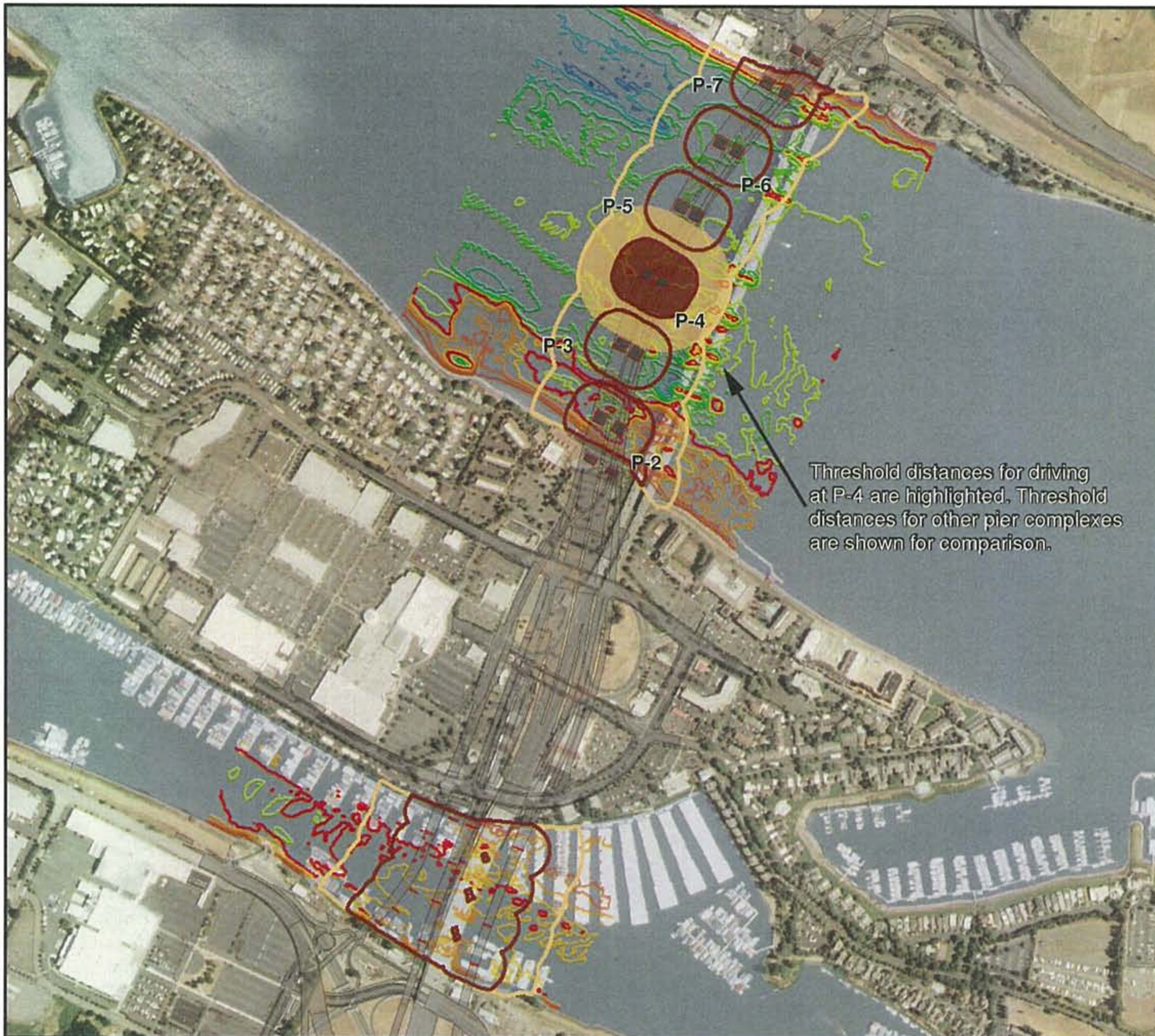
Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound MG246 2.mxd

Exhibit 5-9. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 18- to 24-inch pile, single pile driver

Fish speed 0.1 m/s



Distance to Exceedance of Threshold

- 50 meters with attenuation device
- 113 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 50 meters with attenuation device
- 113 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

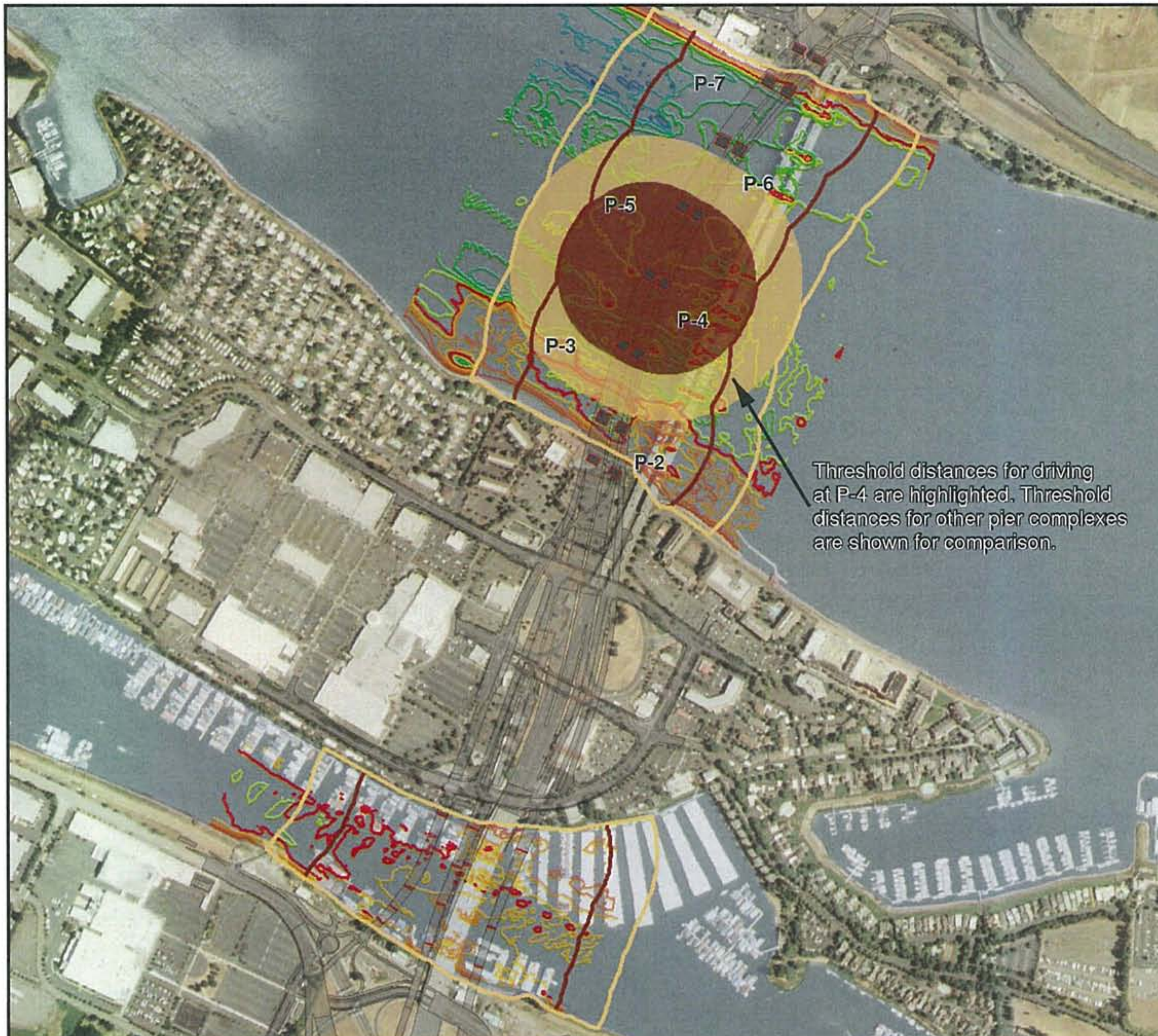
0 520 1,040
Feet

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound_MG248_2.mxd

6247



This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Figure 5-10. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 36- to 48-inch pile, single pile driver.

Fish speed 0.1 m/s

Distance to Exceedance of Threshold

- 156 meters with attenuation device
- 243 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 156 meters with attenuation device
- 243 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 510 1,020
Feet

Columbia River CROSSING

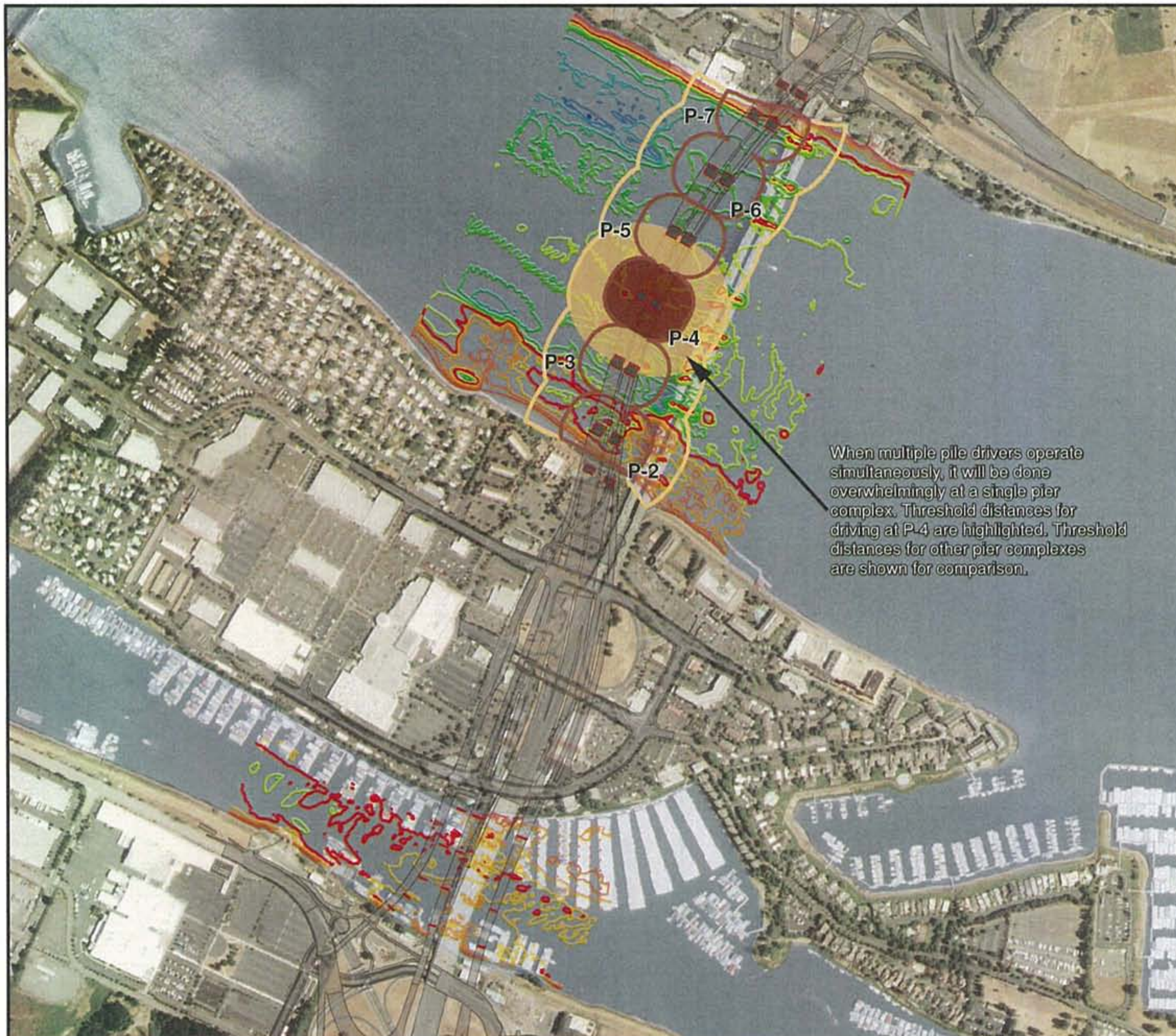


Exhibit 5-11. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, multiple pile drivers.

Fish speed 0.1 m/s

Distance to Exceedance of Threshold

- 59 meters, two 18 to 24-inch piles
- 130 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Area of affect for multiple pile drivers at a single pier using P4 as an example

- 59 meters, two 18 to 24-inch piles
- 130 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 550 1,100
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at seperate pier complexes.

Exhibit 5-12, Exhibit 5-17, Exhibit 5-18, and Exhibit 5-19 show the distances within which noise is estimated to exceed the 187 dB SEL injury thresholds for fish over 2 g and moving 0.8 m/s for a single pile driver and for two pile drivers operating simultaneously.

Exhibit 5-12. Distances at which Underwater Noise Exceeds 187 dB SEL Injury Threshold for Moving Fish Over 2 g at 0.8 m/s in the Columbia River and North Portland Harbor

	Distance (m)	
Pile Size	**Without Attenuation Device**	**With Attenuation Device**
18- to 24-inch pile	102	9
36- to 48-inch pile	237	67
Two 18- to 24-inch piles	N/A	48[a]
Two 36- to 48-inch piles OR One 18- to 24-inch and one 36- to 48-inch pile	N/A	111[a]

Note: Includes juvenile salmonids except for chum.

a Applies to Columbia River only.

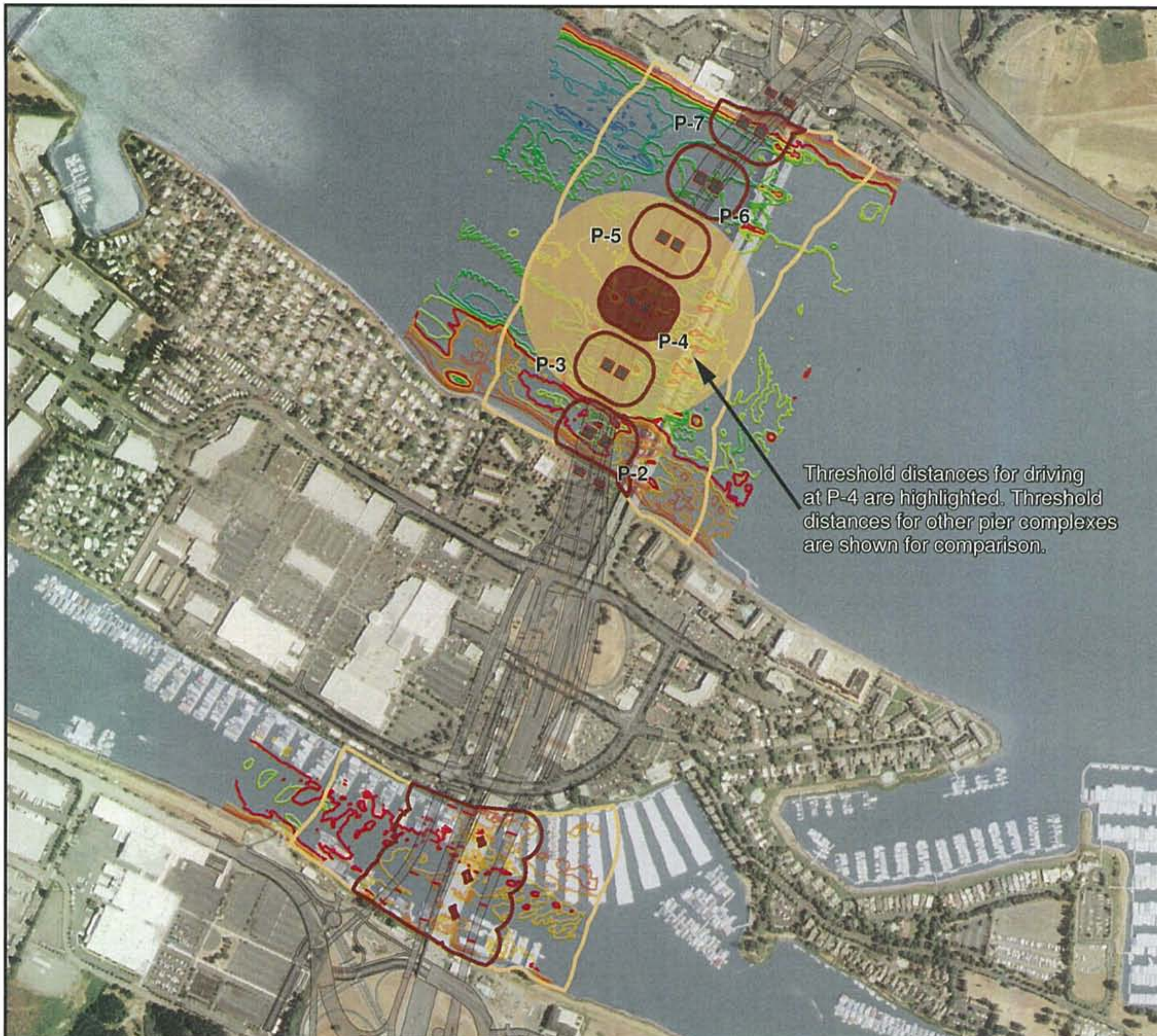
Exhibit 5-13, Exhibit 5-14, Exhibit 5-15, and Exhibit 5-16 present the results of calculations showing distances within which noise is estimated to exceed the 183 dB SEL injury thresholds for fish under 2 g and moving at 0.6 m/s for a single pile driver and for two pile drivers operating simultaneously.

Exhibit 5-13. Distances within which Underwater Noise Exceeds 183 dB SEL Injury Threshold for Moving Fish Under 2 g at 0.6 m/s in the Columbia River and North Portland Harbor

	Distance (m)	
Pile Size	**Without Attenuation Device**	**With Attenuation Device**
18- to 24-inch pile	200	50
36- to 48-inch pile	446	235
Two 18- to 24-inch piles	N/A	79[a]
Two 36- to 48-inch piles OR One 18- to 24-inch and one 36- to 48-inch pile	N/A	209[a]

Note: Includes juvenile chum and larval eulachon.

a Applies to Columbia River only.



This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Exhibit 5-14. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, 18- to 24-inch pile, single pile driver.

Fish speed 0.6 m/s

Distance to Exceedance of Threshold

- 50 meters with attenuation device
- 205 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 50 meters with attenuation device
- 205 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 550 1,100
Feet

Columbia River CROSSING

PRELIMINARY

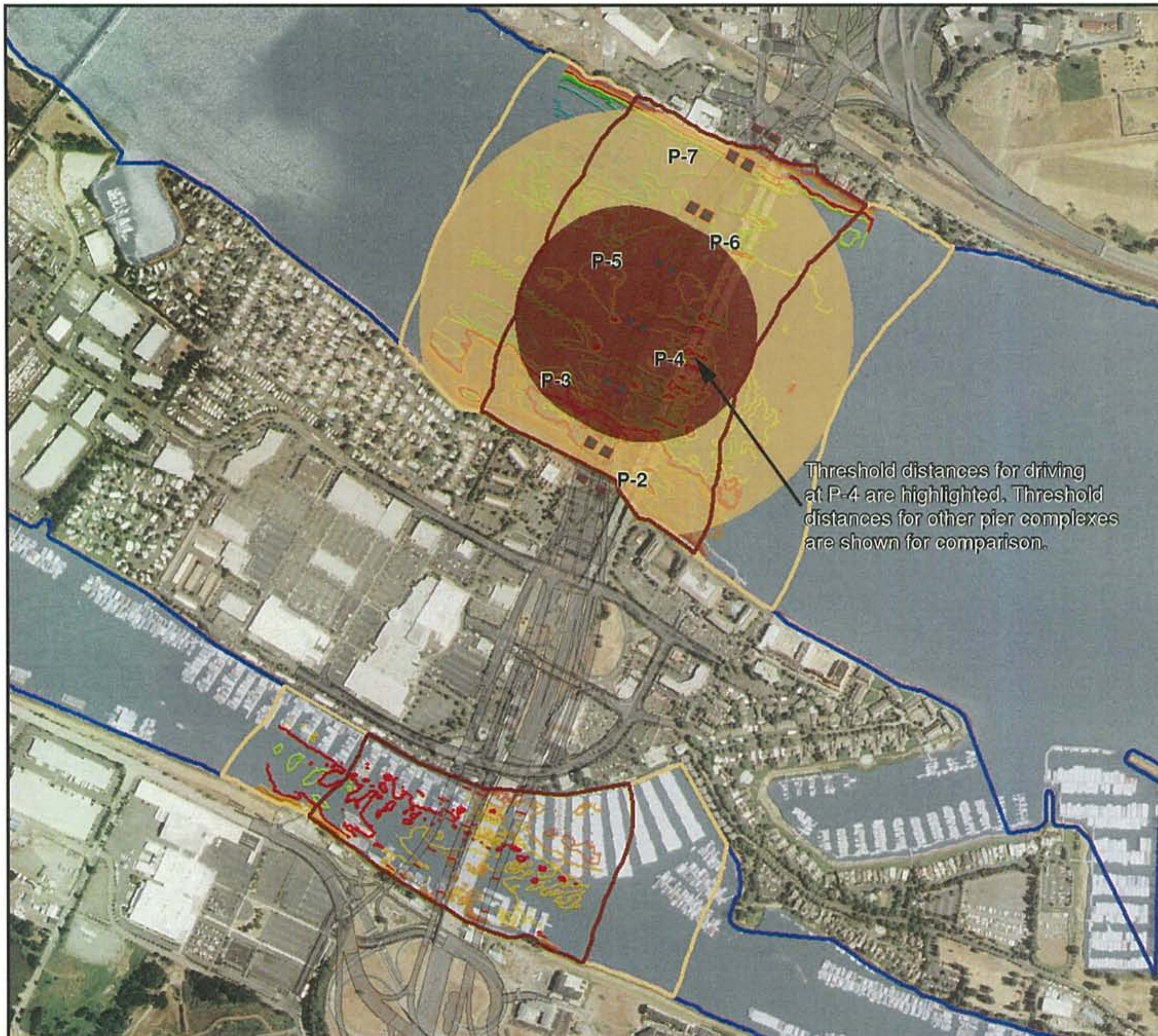


Exhibit 5-15. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, 36 to 48-inch pile, single pile driver.

Fish speed 0.6 m/s

Distance to Exceedance of Threshold

- 235 meters with attenuation device
- 446 meters without attenuation

Area of affect for single pile drivers at a single pier using P4 as an example

- 235 meters with attenuation device
- 446 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 600 1,200
Feet

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

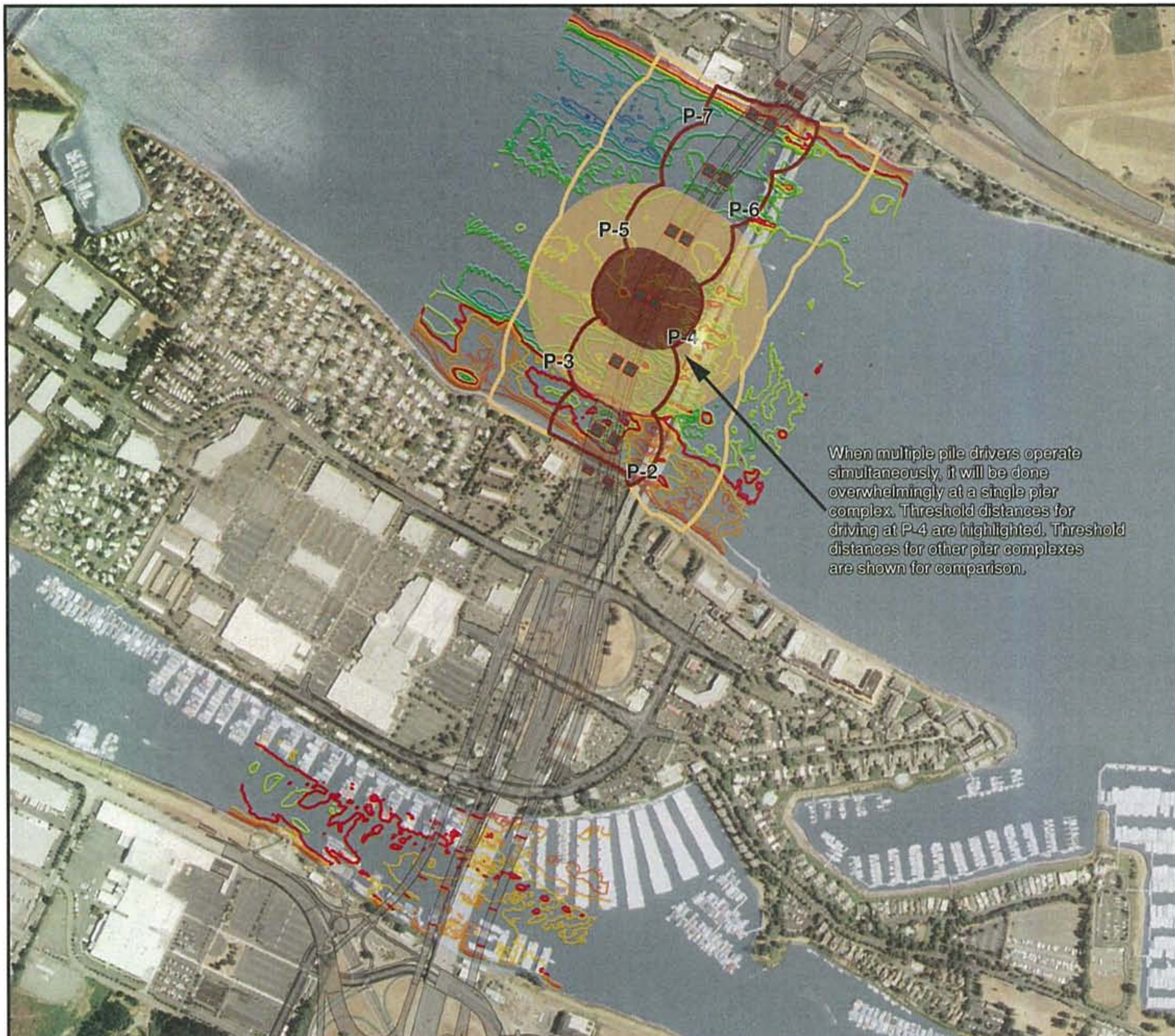


Exhibit 5-16. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, multiple drivers.

Fish speed 0.6 m/s

Distance to Exceedance of Threshold

- 79 meters, two 18 to 24-inch piles
- 209 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Area of affect for multiple pile drivers at a single pier using P4 as an example

- 79 meters, two 18 to 24-inch piles
- 209 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Depth (CRD, ft.)

0
5
10
15
20
25
30
35
40
45
50
55

Project Bridge Piers
Project Footprint

N
W E
S

0 550 1,100
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at seperate pier complexes.

Analysis by J. [illegible] Analysis Date: 20 May 2011 File Name: F:\Transfer051111\ESY\HydroSound_MG246_2.mxd

PRELIMINARY

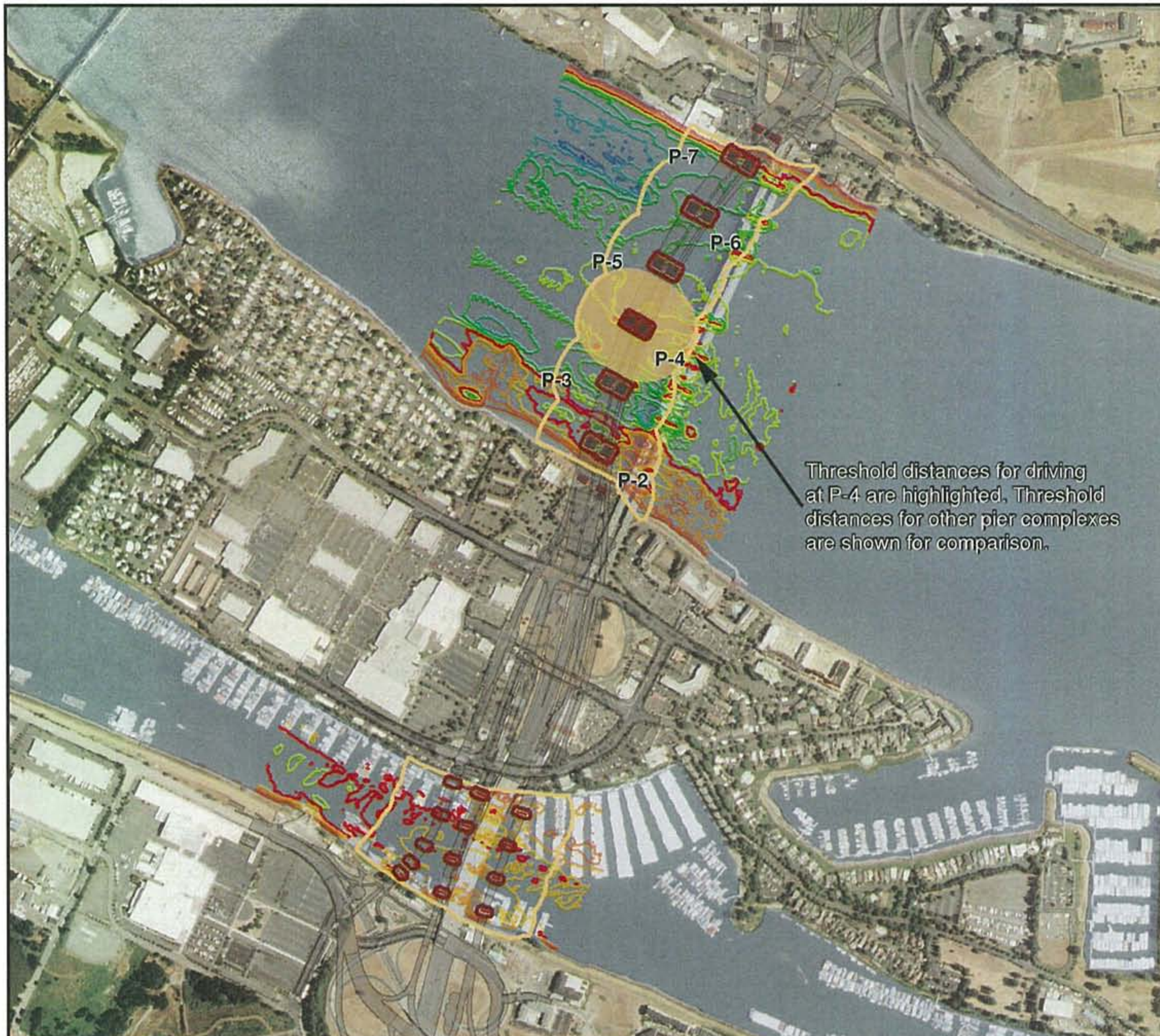


Exhibit 5-17. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 18- to 24-inch pile, single pile driver.

Fish speed 0.8 m/s

Distance to Exceedance of Threshold
9 meters with attenuation device
102 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example
9 meters with attenuation device
102 meters without attenuation device

Depth (CRD, ft.)
0
5
10
15
20
25
30
35
40
45
50
55

Project Bridge Piers
Project Footprint

N
W E
S

0 600 1,200
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis Date: 20 May 2011 File Name: F:\Transfer051111\ESY\HydroSound_MG246_2.mxd

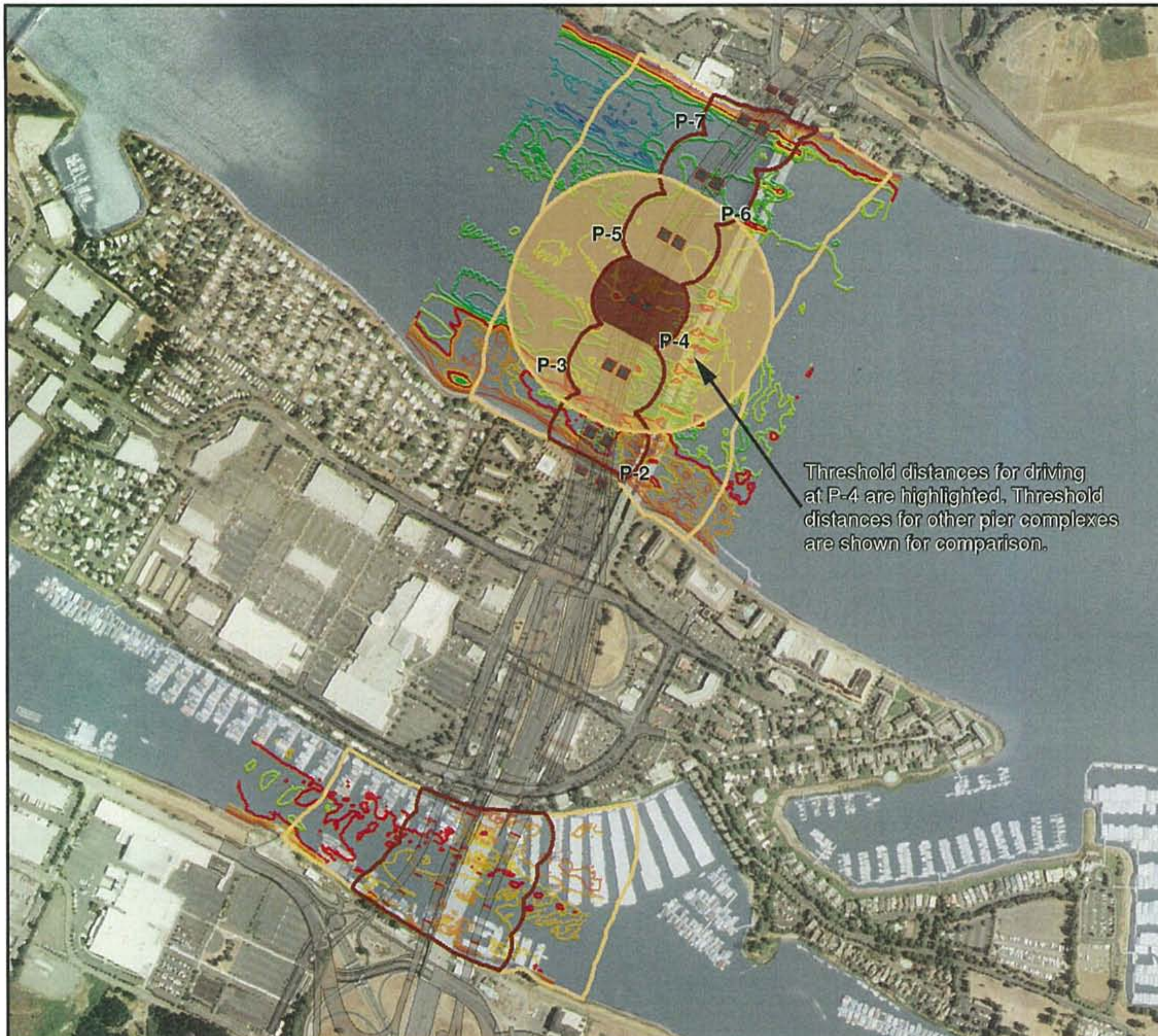


Exhibit 5-18. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 36- to 48-inch pile, single pile driver.

Fish speed 0.8 m/s

Distance to Exceedance of Threshold

- 67 meters, with attenuation device
- 237 meters, without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 67 meters, with attenuation device
- 237 meters, without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N W E S

0 550 1,100
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by J. Koloszar; Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound_MG246_2.mxd

6256

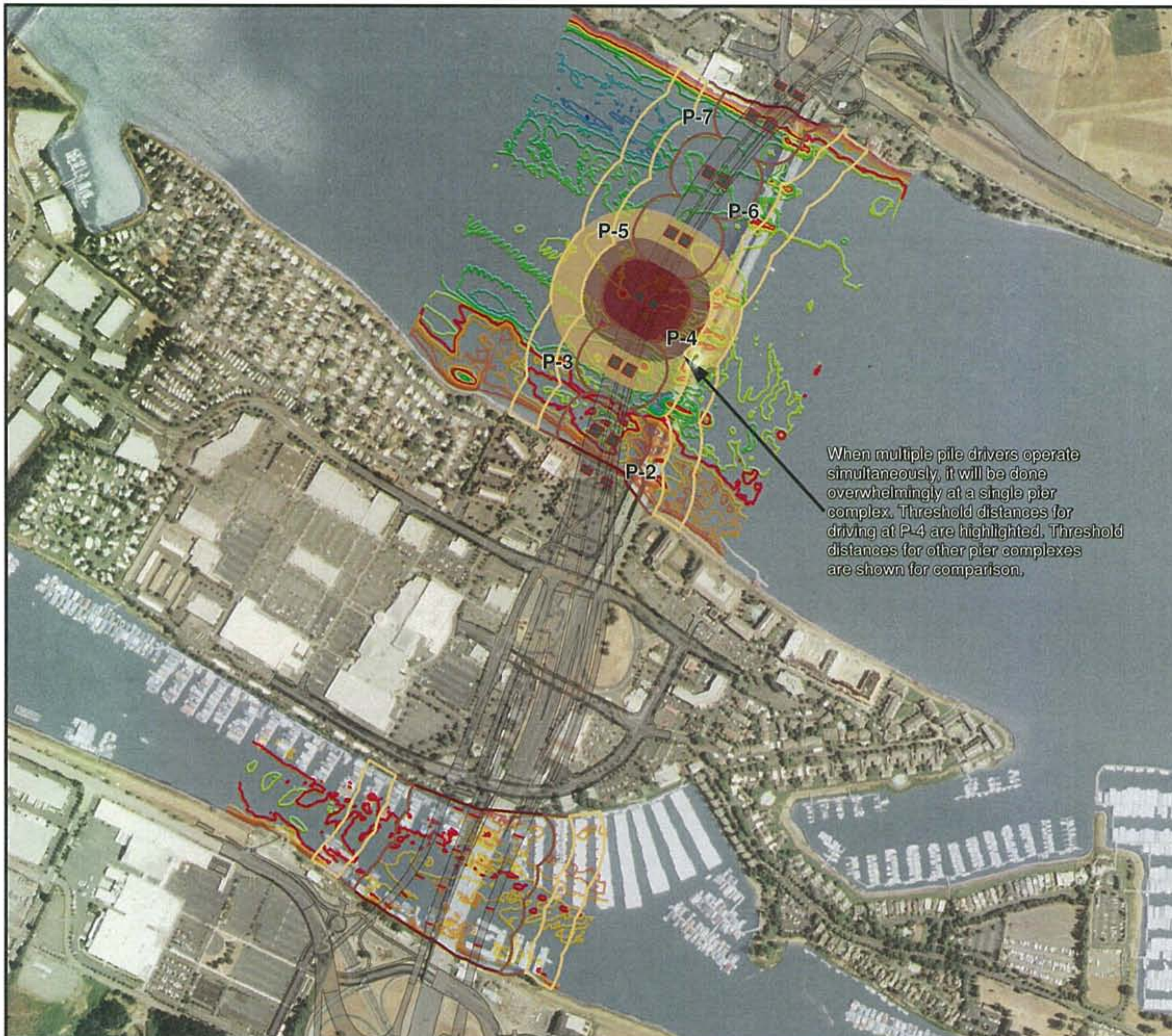


Exhibit 5-19. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, multiple drivers.

Fish speed 0.8 m/s

Distance to Exceedance of Threshold

- 60 meters, two 18 to 24-inch piles
- 100 meters, two 18 to 24-inch piles
- 160 meters, two 36 to 48-inch piles

Area of affect for multiple pile drivers at a single pier using P4 as an example

- 60 meters, two 18 to 24-inch
- 100 meters, two 18 to 24-inch piles plus one 36 to 48-inch piles
- 160 meters, two 36 to 48-inch piles

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 550 1,100
Feet

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at seperate pier complexes.

Columbia River CROSSING

Analysis by J. [illegible]; Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound MG246 2.mxd

Exhibit 5-20, Exhibit 5-21, and Exhibit 5-22 show the distances within which noise is estimated to exceed the 150 dB RMS disturbance guidance.

Exhibit 5-20. Distances at Which Underwater Noise Exceeds 150 dB RMS Disturbance Guidance in the Columbia River and North Portland Harbor

	Columbia River		North Portland Harbor	
Impact Pile Driving	Distance Upstream (m)	Distance Downstream (m)	Distance Upstream (m)	Distance Downstream (m)
Without Attenuation Device				
18- to 24-inch pile	3,981	3,981	3,058	3,981
36- to 48-inch pile	20,166	8,851	3,058	5,632
With Attenuation Device				
18- to 24-inch pile	858	858	858	858
36- to 48-inch pile	5,412	5,412	3,058	5,412

PRELIMINARY

Exhibit 5-21. Extent of underwater impact pile-driving noise exceeding 150 dB RMS disturbance threshold for fish, 36- to 48-inch pile.

Distance to Exceedance of Threshold

- 5,412 meters with attenuation device
- 20,166 meters without attenuation device

Design Shapes

- Project Bridge Piers
- Project Footprint

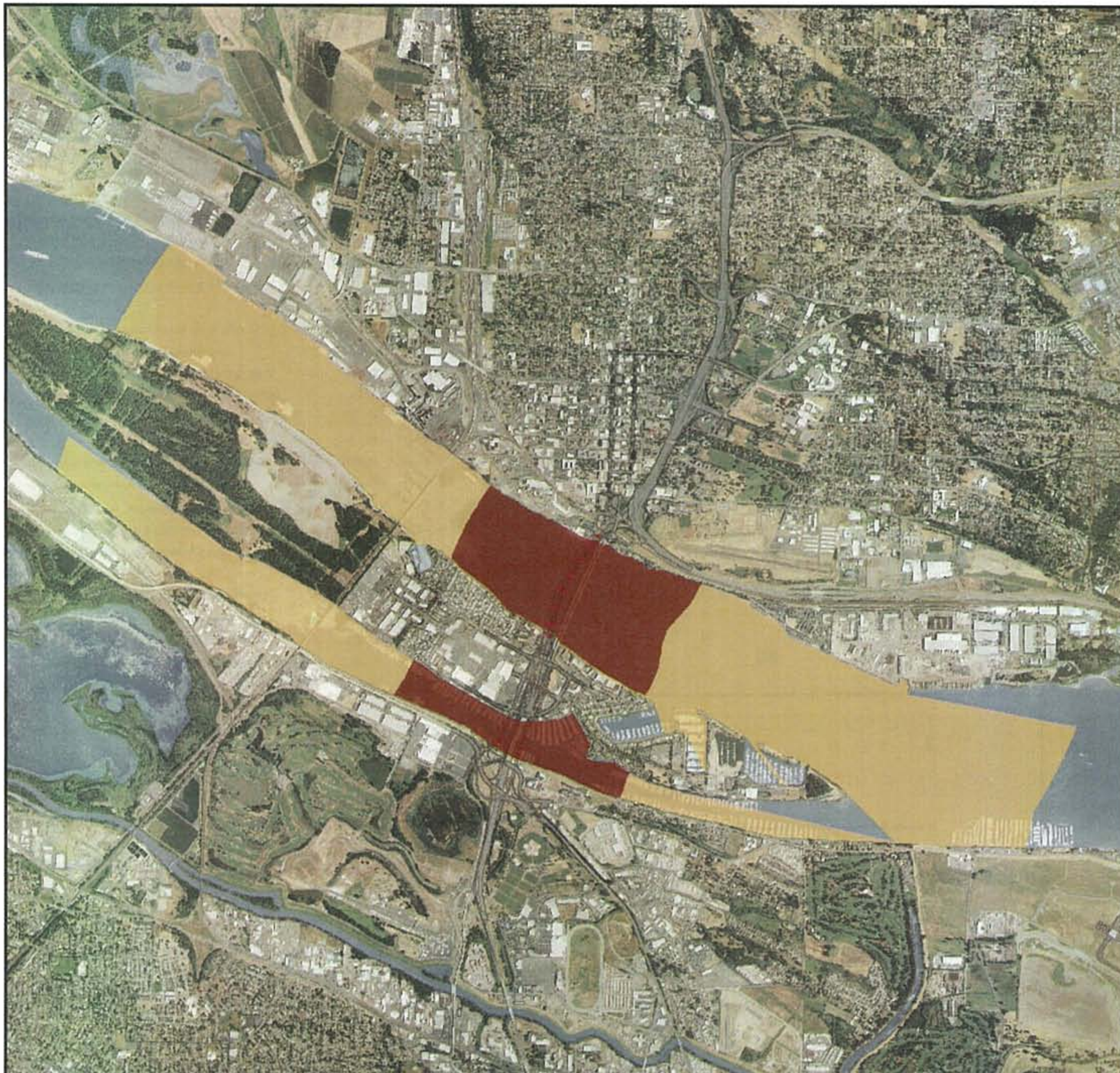
N
W E
S

0 6,600 13,200
Feet

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound_MG246_2a.mxd

Exhibit 5-22. Extent of underwater impact pile-driving noise exceeding 150 dB RMS disturbance threshold for fish, 18- to 24-inch pile.

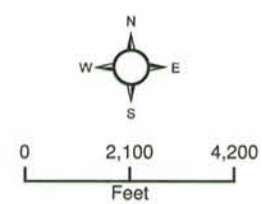


Distance to Exceedance of Threshold

- 858 meters with attenuation device
- 3981 meters without attenuation device

Design Shapes

- Project Bridge Piers
- Project Footprint



Columbia River CROSSING

Analysis by J. Kalopzar, Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound_MG246_2a.mxd

6260

PRELIMINARY

Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**4/5/17**	**928 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	10/16/13	11/14/13	22 days
Install Cofferdam (Vibratory Installation)	12/31/13	3/11/14	51 days
Remove Work Bridge & Piles (Vibratory Removal)	9/16/14	10/13/14	20 days
Remove Cofferdam (Vibratory Removal)	2/27/15	3/19/15	15 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	2/27/15	3/19/15	15 days
Remove Tower Crane (Vibratory Removal)	1/11/16	1/22/16	10 days
Barge Moorings (Vibratory Installation & Removal)	10/16/13	1/22/16	593 days
Pier 3	**9/16/13**	**9/29/15**	**532 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	9/16/13	10/15/13	22 days
Remove Work Platform & Piles (Vibratory Removal)	3/24/14	9/26/14	135 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	9/29/14	10/17/14	15 days
Remove Tower Crane (Vibratory Removal)	9/16/15	9/29/15	10 days
Barge Moorings (Vibratory Installation & Removal)	9/16/13	9/29/15	532 days
Pier 4	**11/15/13**	**10/20/15**	**503 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	11/15/13	12/17/13	23 days
Remove Work Platform & Piles (Vibratory Removal)	10/9/14	11/19/14	30 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	3/20/15	4/9/15	15 days
Remove Tower Crane (Vibratory Removal)	10/7/15	10/20/15	10 days
Barge Moorings (Vibratory Installation & Removal)	11/15/13	10/20/15	503 days
Pier 5	**10/29/14**	**10/19/16**	**516 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	10/29/14	11/28/14	23 days
Remove Work Platform & Piles (Vibratory Removal)	9/16/15	10/27/15	30 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	3/21/16	4/8/16	15 days
Remove Tower Crane (Vibratory Removal)	10/6/16	10/19/16	10 days
Barge Moorings (Vibratory Installation & Removal)	10/29/14	10/19/16	516 days
Pier 6	**12/1/14**	**4/5/17**	**613 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	12/1/14	12/31/14	23 days
Remove Work Platform & Piles (Vibratory Removal)	1/5/16	2/15/16	30 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	4/11/16	9/23/16	120 days
Remove Tower Crane (Vibratory Removal)	3/23/17	4/5/17	10 days
Barge Moorings (Vibratory Installation & Removal)	12/1/14	4/5/17	613 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	9/29/14	10/28/14	22 days
Install Cofferdam (Vibratory Installation)	12/11/14	2/20/15	52 days
Remove Work Bridge & Piles (Vibratory Removal)	9/16/15	10/13/15	20 days
Remove Cofferdam (Vibratory Removal)	2/29/16	3/18/16	15 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	2/29/16	3/18/16	15 days
Remove Tower Crane (Vibratory Removal)	1/10/17	1/23/17	10 days
Barge Moorings (Vibratory Installation & Removal)	9/29/14	1/23/17	606 days

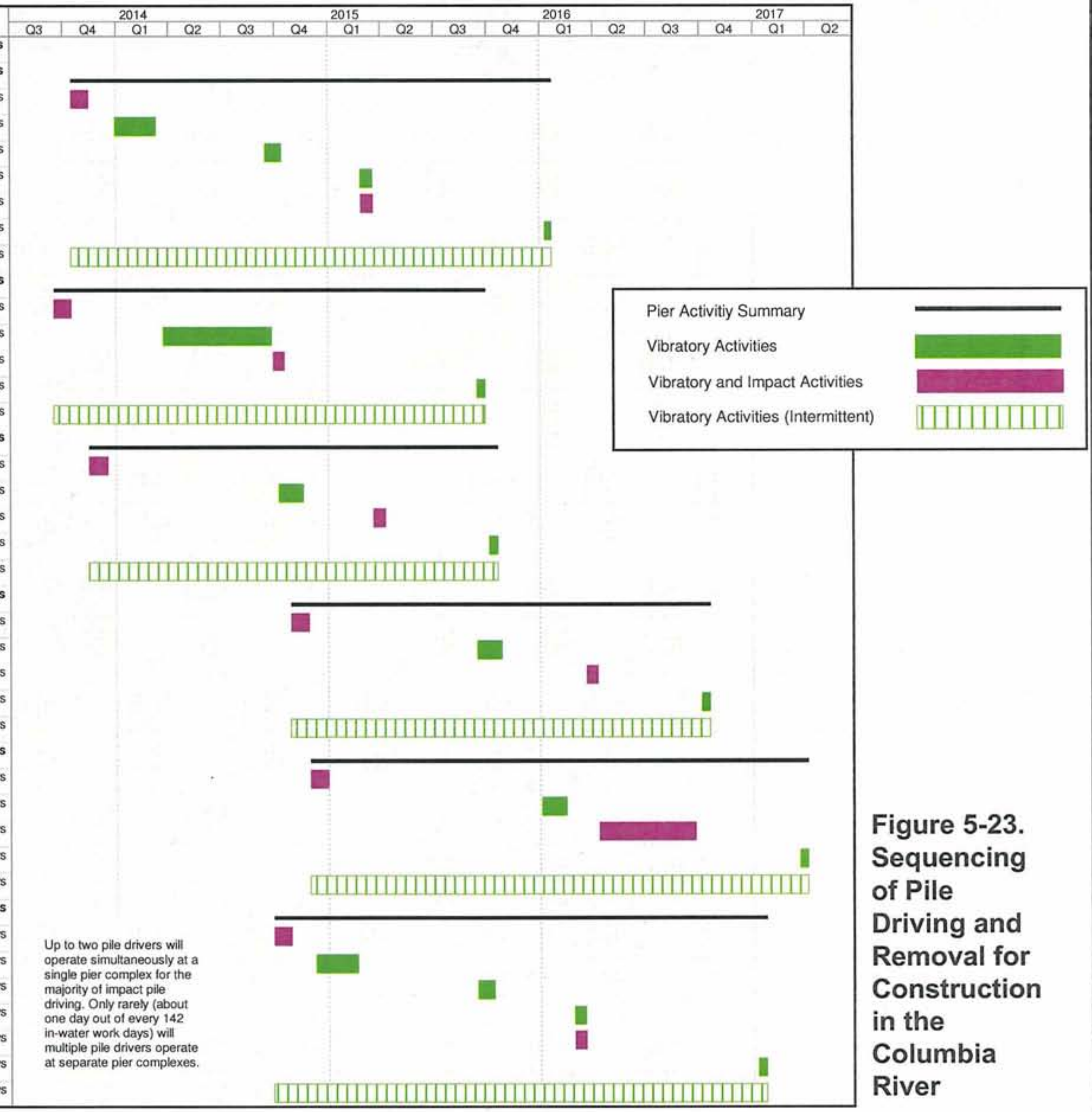


Figure 5-23. Sequencing of Pile Driving and Removal for Construction in the Columbia River

Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Columbia River CROSSING

Task Name	Duration	Start	Finish
Widening of Existing Bridge	**111 days**	**9/15/13**	**1/30/14**
Bent 4	**20 days**	**9/15/13**	**10/8/13**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	9/15/13	9/22/13
Remove Work Bridge and Piles (Vibratory Removal)	1 day	10/8/13	10/8/13
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	9/23/13	9/24/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/8/13	10/8/13
Bent 5	**10 days**	**10/11/13**	**10/24/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/11/13	10/14/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/24/13	10/24/13
Bent 6	**10 days**	**10/27/13**	**11/7/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/27/13	10/28/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	11/7/13	11/7/13
Bent 7	**10 days**	**11/10/13**	**11/21/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/10/13	11/11/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	11/21/13	11/21/13
Bent 8	**22 days**	**11/24/13**	**12/19/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/24/13	11/25/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	12/19/13	12/19/13
Bent 9	**42 days**	**12/12/13**	**1/30/14**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	12/12/13	12/19/13
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	1/1/14	1/8/14
Remove Work Bridge and Piles (Vibratory Removal)	1 day	1/30/14	1/30/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/22/13	12/23/13
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	1/9/14	1/10/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	1/18/14	1/20/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	1/30/14	1/30/14
Barge Moorings - All Bents (Vibratory Installation & Removal)	111 days	9/15/13	1/30/14
Light Rail Transit/Multi-Use Plan Bridge	**142 days**	**9/15/14**	**3/12/15**
Bent 2	**30 days**	**9/15/14**	**10/22/14**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	9/15/14	9/22/14
Remove Work Bridge and Piles (Vibratory Removal)	1 day	10/22/14	10/22/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	9/22/14	9/23/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/2/14	10/3/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/22/14	10/22/14
Bent 3	**21 days**	**10/25/14**	**11/20/14**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/25/14	10/26/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/4/14	11/5/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	11/20/14	11/20/14
Bent 4	**20 days**	**11/23/14**	**12/18/14**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/23/14	11/24/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/3/14	12/4/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	12/18/14	12/18/14
Bent 5	**34 days**	**12/21/14**	**1/29/15**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/21/14	12/22/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/31/14	1/1/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	7 days	1/10/15	1/17/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	1/29/15	1/29/15
Bent 6	**41 days**	**1/22/15**	**3/12/15**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	1/22/15	1/29/15
Remove Work Bridge and Piles (Vibratory Removal)	1 day	3/12/15	3/12/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	2/1/15	2/2/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	2/11/15	2/12/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	2/21/15	2/22/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	3/12/15	3/12/15
Barge Moorings - All Bents (Vibratory Installation & Removal)	142 days	9/15/14	3/12/15

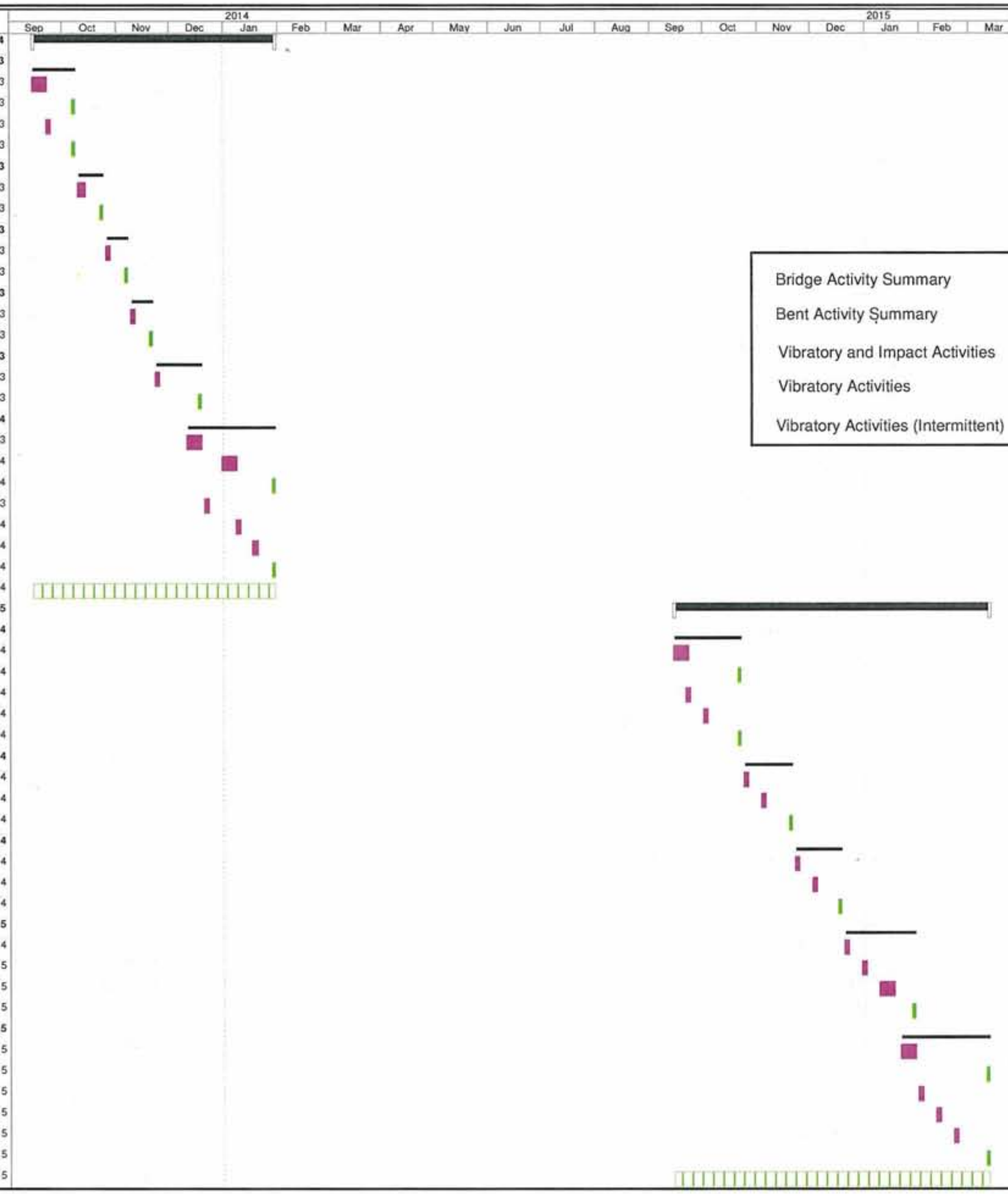


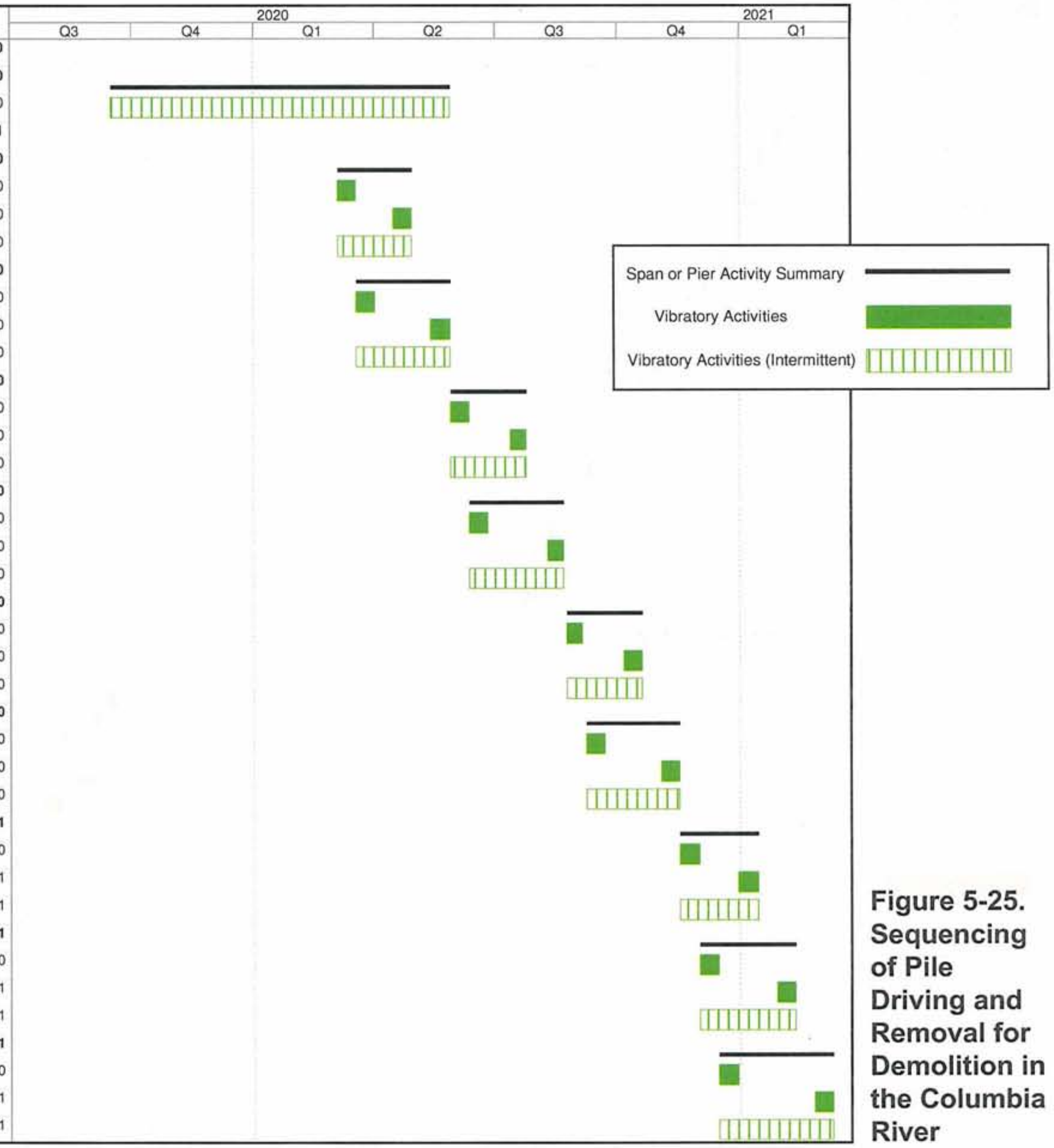
Figure 5-24. Sequencing of Pile Driving and Removal for Construction in North Portland Harbor

Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Columbia River CROSSING

PRELIMINARY

Task Name	Duration	Start	Finish
Superstructure Demolition	**184 days**	**9/16/19**	**5/28/20**
Spans 1-10	**184 days**	**9/16/19**	**5/28/20**
Install and Remove Barge Moorings (Vibratory)	184 days	9/16/19	5/28/20
Substructure Demolition	**266 days**	**3/5/20**	**3/11/21**
Pier 2	**40 days**	**3/5/20**	**4/29/20**
Install Cofferdam (Vibratory Installation)	10 days	3/5/20	3/18/20
Remove Cofferdam (Vibratory Removal)	10 days	4/16/20	4/29/20
Install and Remove Barge Moorings (Vibratory)	40 days	3/5/20	4/29/20
Pier 3	**51 days**	**3/19/20**	**5/28/20**
Install Cofferdam (Vibratory Installation)	10 days	3/19/20	4/1/20
Remove Cofferdam (Vibratory Removal)	11 days	5/14/20	5/28/20
Install and Remove Barge Moorings (Vibratory)	51 days	3/19/20	5/28/20
Pier 4	**41 days**	**5/29/20**	**7/24/20**
Install Cofferdam (Vibratory Installation)	10 days	5/29/20	6/11/20
Remove Cofferdam (Vibratory Removal)	10 days	7/13/20	7/24/20
Install and Remove Barge Moorings (Vibratory)	41 days	5/29/20	7/24/20
Pier 6	**51 days**	**6/12/20**	**8/21/20**
Install Cofferdam (Vibratory Installation)	10 days	6/12/20	6/25/20
Remove Cofferdam (Vibratory Removal)	10 days	8/10/20	8/21/20
Install and Remove Barge Moorings (Vibratory)	51 days	6/12/20	8/21/20
Pier 7	**41 days**	**8/24/20**	**10/19/20**
Install Cofferdam (Vibratory Installation)	10 days	8/24/20	9/4/20
Remove Cofferdam (Vibratory Removal)	10 days	10/6/20	10/19/20
Install and Remove Barge Moorings (Vibratory)	41 days	8/24/20	10/19/20
Pier 8	**50 days**	**9/8/20**	**11/16/20**
Install Cofferdam (Vibratory Installation)	10 days	9/8/20	9/21/20
Remove Cofferdam (Vibratory Removal)	10 days	11/3/20	11/16/20
Install and Remove Barge Moorings (Vibratory)	50 days	9/8/20	11/16/20
Pier 9	**43 days**	**11/17/20**	**1/14/21**
Install Cofferdam (Vibratory Installation)	11 days	11/17/20	12/1/20
Remove Cofferdam (Vibratory Removal)	11 days	12/31/20	1/14/21
Install and Remove Barge Moorings (Vibratory)	43 days	11/17/20	1/14/21
Pier 10	**52 days**	**12/2/20**	**2/11/21**
Install Cofferdam (Vibratory Installation)	10 days	12/2/20	12/15/20
Remove Cofferdam (Vibratory Removal)	10 days	1/29/21	2/11/21
Install and Remove Barge Moorings (Vibratory)	52 days	12/2/20	2/11/21
Pier 11	**62 days**	**12/16/20**	**3/11/21**
Install Cofferdam (Vibratory Installation)	11 days	12/16/20	12/30/20
Remove Cofferdam (Vibratory Removal)	10 days	2/26/21	3/11/21
Install and Remove Barge Moorings (Vibratory)	62 days	12/16/20	3/11/21



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 5-25. Sequencing of Pile Driving and Removal for Demolition in the Columbia River

Columbia River CROSSING

Note that in most instances, use of an attenuation device decreases the area of effect appreciably. For example, when comparing scenarios in which a single pile driver is operating:

- The radius of the 206 dB peak injury zone decreases by about 80 percent.
- In the Columbia River, the radius of the disturbance zone decreases by about 80 percent for smaller piles and by 40 to 70 percent for larger piles, depending on the direction (upstream or downstream).
- In North Portland Harbor, radius of the disturbance zone decreases for smaller piles by about 75 percent. For the larger piles, use of a noise attenuation device does not shrink the disturbance zone because noise encounters landforms at fairly short distances from the source (3,058 m upstream and 5,412 m downstream).
- Similar reductions in distances to accumulated SEL threshold levels would occur with attenuation devices, but details are not presented here due to the numerous variables associated with calculating accumulated SEL in the moving fish model.

Exhibit 5-26 and Exhibit 5-27 summarize these results, showing the duration of impact and the areas in which noise levels would exceed the injury thresholds and disturbance guidance.

Exhibit 5-26. Exposure of Fish to Threshold/Guidance Levels of Underwater Noise in the Columbia River[a]

		Without Attenuation Device[a]			With Attenuation Device (assumes 10 dB of attenuation)		
Size Class	**Threshold or Guidance**	**Distance (m)**	**Duration**	**Number of Days**	**Distance (m)**	**Duration**	**Number of Days**
≥ 2 grams	Injury: 206 dB Peak	25 - 34	7.5 min/ week	38	5 - 7	0.66 hr / day	138
	Injury[b]: 187 SEL_{cum}						
	0.1 m/sec	113 - 243			50 - 156		
	0.8 m/sec	102 - 237			9 - 111		
	Disturbance: 150 dB RMS						
	Upstream	3,981 - 20,166			858 - 5,412		
	Downstream	3,981 - 8,851			858 - 5,412		
< 2 grams	Injury: 206 dB Peak	25 - 34	7.5 min/ week	38	5 - 7	0.66 hr / day	138
	Injury[b]: 183 SEL_{cum}	205 - 446			50 - 235		
	Disturbance: 150 dB RMS						
	Upstream	3,981 - 20,166			858 - 5,412		
	Downstream	3,981 - 8,851			858 - 5,412		

a As part of the hydroacoustic monitoring program and to account for equipment failure, impact pile driving is assumed to occur for up to 7.5 minutes, one day per week.

b Accumulated SEL (injury) threshold distances are based on the construction scenario presented in Exhibit 5-3.

c Distances show extent of calculated values or where noise stops at landforms.

Exhibit 5-27. Exposure of Fish to Threshold/Guidance Levels of Underwater Noise in North Portland Harbor

		Without Attenuation Device			With Attenuation Device (assumes 10 dB of attenuation)		
Size Class	**Threshold**	**Distance (m)**	**Duration**	**Number of Days**	**Distance (m)**	**Duration**	**Number of Days**
≥ 2 grams	Injury: 206 dB Peak	25 -34	2–5 min/ week	18 - 31	5 - 7	0.66 hr / day	134
	Injury: 187 SEL_{cum}						
	0.1 m/sec	113 - 243			50 - 156		
	0.8 m/sec	102 - 237			9 - 111		
	Disturbance: 150 dB RMS						
	Upstream	3,058			858 - 3,058		
	Downstream	3,981-5,632			858 - 5,412		
< 2 grams	Injury: 206 dB Peak	25 - 34	2–5 min/ week	18 - 31	5 - 7	0.66 hr / day	134
	Injury: 183 SEL_{cum}	205 - 446			50 - 235		
	Disturbance: 150 dB RMS						
	Upstream	3,058			858 - 3,058		
	Downstream	3,981-5,632			858 - 5,412		

a As part of the hydroacoustic monitoring program and to account for equipment failure, impact pile driving is assumed to occur for up to 3.75 minutes one day per week.

b Accumulated SEL (injury) threshold distances are calculated based on the construction scenario presented in Exhibit 5-4.

c. Distances show extent of calculated values or where noise stops at landforms.

Impact pile driving would result in effects to fish that may range from behavioral disturbance to immediate death, depending on size of the fish, duration of exposure to sound pressure, proximity to the strike site, size of the pile, and number of strikes in a given time frame (e.g., per 12-hour period).

Actual exposure to noise above the injury thresholds and disturbance guidance would be fairly limited, restricted to the periods when impact pile driving is occurring: 138 days in the Columbia River and 134 days in North Portland Harbor interspersed over the entire four-year in water construction period from roughly mid-September through mid-April of each year (Exhibit 5-23 and Exhibit 5-24). Within this time period, exposure would be further restricted to no more than approximately 40 minutes per 12 hour work day.

Project-generated noise above the injury threshold may cause a range of lethal and sublethal injuries to fish, as outlined in Appendix K of the BA (CRC 2010). Effects may include damage to non-auditory tissues, including rupture of air-filled organs, such as the swim bladder. Damage to the swim bladder may lead to loss of control over vertical movement or may result in mortality. Loud noise may cause damage to the skin, nerves, and eyes of fish. Elevated sound levels may also result in the formation of gas bubbles in tissue, causing inflammation, cellular damage, and blockage or rupture of blood vessels. These injuries may lead to immediate or delayed mortality.

Intense sound may lead to hearing loss in fish. Such hearing loss may be temporary and reversible, known as temporary threshold shift (TTS). TTS and represents fatigue of the hair cells in the inner ear and is not considered tissue damage (Carlson et al. 2007). Intense sound may also reach levels that cause permanent threshold shift (PTS): permanent hearing loss resulting from the irreversible death of sensory hair cells in the inner ear. Such auditory damage may result in a general decrease in fitness, foraging success, ability to avoid predators, and ability to communicate. Thus, even if intense noises do not directly result in death, auditory damage could result in delayed mortality to fish.

Project-generated noise above the disturbance guidance may cause behavioral effects to fish. Literature related to the effect of pile driving on fish behavior is extremely limited and somewhat conflicting. Effects could be relatively minor, limited to startling, disruption in feeding, or avoidance of the project area (WSDOT 2008). Other effects could be more significant, with consequences for survival and reproduction. For example, while exposure to noise levels above 150 dB RMS is not likely to directly cause mortality or injury, it could result in an impaired ability to avoid predators, indirectly resulting in death (WSDOT 2008). Additionally, avoidance of the project area could presumably cause delays in migration for those species that migrate. Migration delays, in turn, may present a variety of risks for fish including: depletion of energy reserves; delayed or reduced spawning; increased exposure to predation, disease, and thermal stress; disruption of arrival timing to the estuary (which may desynchronize arrival with prey availability); and an increase in residualism in some steelhead and Chinook (NMFS 2009).

Lampreys do not have swimbladders and it is therefore difficult to determine the extent of this impact. Fish species without swimbladders are thought to be at lower risk from underwater sound than fishes with swimbladders (Stadler, pers. comm. 2010, Hastings and Popper 2005, Coker and Hollis 1952, Gaspin 1975, Baxter et al. 1982, Goertner 1994). Hydroacoustic impacts to lamprey should not be discounted, but they cannot be quantified or analyzed with any level of certainty.

Overall, this element of the project is likely to appreciably impact individuals of all listed salmon, steelhead, eulachon, and resident fish present in the areas exposed to noise above the injury threshold and disturbance guidance during impact pile driving activities. Exhibit 5-28 summarizes the species and life stages of listed fish likely to be exposed to this effect.

Due to the extremely limited numbers of green sturgeon and bull trout present in the project area, risk of exposure is discountable. Thus, this element of the project is not likely to appreciably impact green sturgeon and bull trout.

Exhibit 5-28. Species and Life Stages Expected to be Present in the Project Area during Pile Driving

	Life Stage				
Species	**Spawning**	**Incubation**	**Rearing**	**Outmigrating Juveniles**	**Migrating/ Holding Adults**
Chinook					
Lower Columbia River ESU[a]			X	X	X
Upper Columbia River Spring-Run ESU			X	X	X
Upper Willamette River ESU			X	X	X
Snake River Fall-Run ESU				X	X
Snake River Spring/Summer-Run ESU				X	X
Steelhead					
Lower Columbia River DPS[a]			X	X	X
Middle Columbia River DPS				X	X

Species	Life Stage				
	Spawning	Incubation	Rearing	Outmigrating Juveniles	Migrating/ Holding Adults
Upper Willamette River DPS				X	X
Upper Columbia River DPS				X	X
Snake River Basin DPS				X	X
Sockeye					
Snake River ESU				X	X
Coho					
Lower Columbia River ESU			X	X	X
Chum					
Columbia River ESU	X	X	X	X	X
Bull Trout					
Columbia River DPS					X
Green Sturgeon					
Southern DPS					X
Eulachon					
Southern DPS	X	X		X	X
White sturgeon	X	X	X	X	X
Lamprey Species			X	X	X
Resident fish (e.g., sculpin, dace, threespine stickleback, sucker, shiner)	X	X	X		

a ESU = evolutionarily significant unit; DPS = distinct population segment.

5.2.1.2 Hydroacoustic Impacts to Fish from Vibratory Pile Driving and Removal

Vibratory pile driving would be used to install cofferdams and temporary piles throughout the in-water project area in the Columbia River and North Portland Harbor. Load bearing piles (used for temporary work platforms, work bridges, tower cranes, and oscillator platforms) would be vibrated into place before being proofed with an impact hammer. Piles that are not load bearing (mooring piles) would be installed using vibration only.

Vibratory pile driving produces lower peak noise levels than impact pile driving of the same sized pile, and this generally results in fewer injuries to fish (USFWS 2009). Rise time is also much slower during vibratory pile driving, decreasing the potential for injury (Carlson et al. 2001, Nedwell and Edwards 2002, as cited in USFWS 2009). USFWS states that there are no documented kills attributed to the use of a vibratory hammer (USFWS 2004, as cited in WSF 2009).

Currently there are no established thresholds for noise levels generated by vibratory pile driving that are likely to cause injury or behavioral disturbance to fish. Additionally, there are no established threshold distances at which vibratory noise is likely to harm fish. However, NMFS offers the guidance that vibratory pile driving noise at 150 dB RMS may cause behavioral disturbance to fish.

Vibratory pile driving on the CRC project is likely to create noise above 150 dB RMS. Exhibit 5-29 outlines a range of typical noise levels produced by vibratory pile driving as measured by Caltrans during hydroacoustic monitoring of several construction projects (Caltrans 2009). The monitoring showed that vibratory driving of pipe pile (up to 72 inches in diameter) is likely to generate initial sound levels of up to 180 dB RMS, and vibratory driving of sheet pile is likely to generate initial sound levels of 160 to 165 dB RMS.

Exhibit 5-29. Summary of Unattenuated Underwater Sound Pressures for Vibratory Pile Driving

Pile Type and Approximate Size	Water Depth (meters)	SPLs (dB RMS)a
0.30-meter (12-inch) steel H-type	<5	150
0.30-meter (12-inch) steel pipe pile	<5	155
0.6-meter (24-inch) AZ steel sheet – typical	~15	160
0.6-meter (24-inch) AZ steel sheet – loudest	~15	165
1.0-meter (36-inch) steel pipe pile – typical	~5	170
1.0-meter (36-inch) steel pipe pile – loudest	~5	175
1.8-meter (72-inch) steel pipe pile – typical	~5	170
1.8-meter (72-inch) steel pipe pile – loudest	~5	180

Source: Caltrans 2009, CRC 2010.

a Impulse level (35 millisecond average).

On the CRC project, vibratory pile driving is likely to occur frequently during installation of temporary structures throughout the four-year in water construction period and the 18-month in-water demolition period. Vibratory pile driving for installation of temporary structures would likely take place up to approximately 5 hours per day during the in-water construction period and may occur during any hour of day.

Vibration may also be used to install the 10-foot-diameter steel casings for the drilled shafts of the permanent structures in the Columbia River and North Portland Harbor. No data were available regarding the initial SPLs generated by steel casings of this size. Therefore, it is not possible at this time to calculate the extent of noise generated from vibratory installation of 10-foot-diameter casings. However, it seems reasonable that vibration of the 10-foot steel casings would produce at least as many initial SPLs as 72-inch steel pipe pile (180 dB RMS at 5 meters), and therefore, noise from 10-foot casings would extend at least as far as that from 72-inch steel pipe pile. The design team estimates that vibratory installation of 10-foot casings would take approximately 90 days in the Columbia River and 31 days in North Portland Harbor. Vibratory installation of 10-foot casings is not restricted to the in water work window and therefore may take place any time during the four-year in-water construction period.

All of the species and life stages of salmon, steelhead, eulachon, and resident fish shown in Exhibit 5-28 could be exposed to this effect when they are present in this portion of the project area. However, fish kills attributed to the use of a vibratory hammer have never been documented (USFWS 2004, as cited in WSF 2009), this activity is unlikely to injure fish and is not expected to significantly interfere with behaviors such as migration, rearing, or foraging. Thus, vibratory pile driving is not likely to appreciably impact any of these species.

Due to the extremely limited numbers of green sturgeon and bull trout present in this portion of the project area, risk of exposure is discountable. Thus, this element of the project is not likely to appreciably impact green sturgeon or bull trout.

5.2.1.3 Noise Impacts to Fish from Excavation Drilled Shaft Casings

After the casings are installed, the project would excavate the material from inside of the permanent shafts. Hydroacoustic impacts from drilling and excavating inside of casings have not been well documented but would be far less than impacts from impact pile driving. Drilling shafts would likely elevate in-water noise levels, causing disturbance to fish, but the extent of this disturbance cannot be calculated. Lethal effects from drilling of shafts have not been documented on other projects and are not likely to occur. Shafts would be excavated year-round during the in water construction period (roughly, January 2014 to August 2017 in the Columbia River and September 2013 to February 2016 in North Portland Harbor). Effects to fish are expected to be insignificant.

5.2.2 Acoustic Impacts to Pinnipeds

5.2.2.1 Acoustic Effects from Pile Driving

Project-generated noise, including impact and vibratory pile driving, may have impacts to Steller sea lions, California sea lions, and harbor seals (referred to in this section collectively as pinnipeds), which migrate through the project area. The following sections present background information about how pinnipeds respond to noise, criteria for noise levels likely to cause injury or disturbance to sea lions, and an analysis of how pile-driving noise is likely to affect pinnipeds present in CRC project area.

5.2.2.2 How Pinnipeds Respond to Noise

There are few studies that quantify reactions of pinnipeds to noise, and even fewer that have directly observed reactions of pinnipeds to pile-driving noise (Southall et al. 2007). (Pinnipeds are a taxonomic category of marine mammals that includes seals and sea lions). Southall et al. (2007) performed a literature review of all known studies on the effects of noise on marine mammals. The review offers guidelines on how pinnipeds exhibit behavioral effects, temporary hearing loss, and injury resulting from elevated levels of underwater and airborne noise.

Behavioral Effects

Behavioral response to sound is dependent on a number of site-specific characteristics, including the intensity of the noise source, the distance between the noise source and the individual, and the ambient noise levels at the site (Southall et al. 2007). Behavioral response is also highly dependent on the characteristics of the individual animal. Marine mammals that have been previously exposed to noise may become habituated, and therefore may be less sensitive to noise. Such animals are less likely to elicit a behavioral response.

Behavioral responses have been observed experimentally and have been determined to be highly variable. In some cases, marine mammals may detect a sound and exhibit no obvious behavioral responses. In other cases, marine mammals may exhibit minor behavioral responses, including annoyance, alertness, visual orientation towards the sound, investigation of the sound, change in movement pattern or direction, habituation, alteration of feeding and social interaction, and temporary or permanent avoidance of the area affected by sound. Minor behavioral responses do not necessarily cause long-term effects to the individuals involved. Severe responses include panic, immediate movement away from the sound, and stampeding, which could potentially lead to injury or mortality (Southall et al. 2007).

In their comprehensive review of available literature, Southall et al. (2007) noted that quantitative studies on behavioral reactions of seals to underwater noise are rare. A subset of only three studies observed the response of pinnipeds to underwater multiple pulses of noise (a category of noise types that includes impact pile driving) and were also deemed by the authors as having results that are both measurable and representative.

Harris et al. (2001) observed the response of ringed, bearded, and spotted seals to underwater operation of a single airgun and an eleven-gun array. Received exposure levels were 160 to 200 dB RMS re: (referenced to) 1 µPa. Results fit into two categories. In some instances, seals exhibited no response to noise. However, the study noted significantly fewer seals during operation of the full array in some instances. Additionally, the study noted some avoidance of the area within 150 meters of the source during full array operations.

Blackwell et al. (2004) is the only study directly related to pile driving. The study observed ringed seals during impact installation of steel pipe pile. Received underwater SPLs were measured at 151 dB RMS re: 1 µPa at 63 meters. The seals exhibited either no response or only brief orientation response (defined as "investigation or visual orientation"). It should be noted that the observations were made after pile driving was already in progress. Therefore, it is possible that the low-level response was due to prior habituation.

Miller et al. (2005) observed responses of ringed and bearded seals to a seismic airgun array. Received underwater sound levels were estimated at 160 to 200 dB RMS re: 1 µPa. There were fewer seals present close to the noise source during airgun operations in the first year, but in the second year the seals showed no avoidance. In some instances, seals were present in very close range of the noise. The authors concluded that there was "no observable behavioral response" to seismic airgun operations.

Southall et al. (2007) conclude that there is little evidence of avoidance of SPLs from pulsed noise ranging between 150 and 180 dB RMS re: 1 µPa. Additionally, they conclude that behavioral response in ringed seals is likely to occur at 190 dB RMS. It is unclear whether or not these data apply to Steller and California sea lions. Given that there are so few data available, it is difficult to draw conclusions about what specific behaviors pinnipeds would exhibit in response to underwater noise.

Southall et al. (2007) also compiled known studies of behavioral responses of marine mammals to airborne noise, noting that studies of pinniped response to airborne pulsed noises are exceedingly rare. The authors deemed only one study as having quantifiable results.

Blackwell et al. (2004) studied the response of ringed seals within 500 meters of impact driving of steel pipe pile. Received levels of airborne noise were measured at 93 dB RMS re: 20 µPa at a distance of 63 meters. Seals had either no response or limited response to pile driving. Reactions were described as "indifferent" or "curious."

Due to the extremely limited data on this topic, it is not possible to draw definitive conclusions about what specific behaviors pinnipeds would exhibit in response to airborne noise generated by impact pile driving.

Several field observations indicate that sea lions exhibit mixed responses to elevated noise levels.

During a Caltrans installation demonstration project for retrofit work on the East Span of the San Francisco Oakland Bay Bridge, California, sea lions responded to pile driving by swimming rapidly out of the area, regardless of the size of the pile-driving hammer or the presence of sound attenuation devices (74 FR 63724).

Dyanna Lambourn, marine mammal research biologist at WDFW, noted that Steller sea lions generally avoid unfamiliar loud noises. In response to pile driving, they would be likely to exit areas exposed to elevated noise, unless there were a particularly strong attraction, such as an abundant food source (Lambourn 2010 pers. comm.). Lambourn also stated that Steller sea lions could become habituated to noises that are continuous and occurring over longer periods of time.

The USACE has conducted hazing of sea lions at Bonneville Dam since 2004 in an attempt to decrease rates of predation on listed salmonids and sturgeon. The 2010 monitoring report (Stansell et al. 2010) documented the response of both California and Steller sea lions to several types of deterrents, including Acoustic Deterrent Devices (ADDs). These devices produce noise levels of 205 dB in the frequency range of 15 kHz. (The report did not specify whether these values referred to airborne or underwater noise). The crews also employed above-water pyrotechnics (cracker shells, screamer shells, or rockets) and underwater percussive devices called seal bombs. Hazing occurred seven days a week from March 2 to the end of May. The study did not differentiate between Steller sea lions and California sea lions, so it is uncertain whether these two species respond differently to hazing.

The observers reported that sea lions tended to spend more time underwater and temporarily avoided the area while hazing activities were occurring, but returned to forage soon after the activities ceased. They concluded that hazing only slowed the rate of predation, rather than effectively deterring it. The sea lions slightly shifted foraging times, preying more heavily at dawn and dusk, when hazing activities were beginning or ending. Nevertheless, despite active hazing, the rate of predation on salmon and sturgeon was still quite high. Observers noted that sea lions swam to within 20 feet of the ADDs to forage.

The explosive and percussive noises produced during these hazing activities are quite different from pile-driving noise, as they are abrupt and non-pulsed. These results may not be applicable to pile-driving projects; however, the results were included to demonstrate that high SPLs alone do not necessarily cause significant behavioral responses in sea lions. Also, the study is specific to sea lion behavior in the lower Columbia River, and it observed the same individuals that transit through the CRC project area. The results suggest that these individuals either are already habituated to some loud noises or could readily become habituated.

Temporary Threshold Shift

Temporary Threshold Shift (TTS) is reversible hearing loss caused by fatigue of hair cells and supporting structures in the inner ear. Technically, TTS is not considered injury, as it consists of fatigue to auditory structures rather than damage to them. Pinnipeds have demonstrated complete recovery from TTS after multiple exposures to intense noise, as described in the studies below (Kastak et al. 1999, 2005).

There are no studies of the underwater noise levels likely to cause TTS in Steller sea lions. However, TTS studies have been conducted on harbor seals, California sea lions, and northern elephant seals. Southall et al. (2007) report several studies on non-pulsed noise (a category that includes vibratory pile-driving noise), but only one study on pulsed noise.

- Finneran et al. (2003) studied responses of two individual California sea lions. The sea lions were exposed to single pulses of underwater noise, and experienced no detectable TTS at received noise level of 183 dB peak re: 1 μPa, and 163 dB SEL re: 1 μPa^2-s.

There were three studies of pinniped TTS in response to non-pulsed underwater noise. All of these studies were performed in the same lab and on the same test subjects, and therefore the results may not be applicable to all pinnipeds or in field settings.

- Kastak and Schusterman (1996) studied the response of harbor seals to non-pulsed construction noise, reporting TTS of about 8 dB.
- Kastak et al. (1999) exposed a harbor seal, California sea lion, and elephant seal to octave-band noise at 60 to 70 dB above their hearing thresholds. After 20 to 22 minutes, the subjects experienced TTS of 4 to 5 dB.
- Kastak et al. (2005) used the same test subjects above, exposing them to higher levels of noise for longer durations. The animals were exposed to octave-band noise for up to 50 minutes of net exposure.

  The study reported that the harbor seal experienced TTS of 6 dB after a 25-minute exposure to 2.5 kHz of octave-band noise at 152 dB re: 1 μPa and 183 dB SEL re: 1 μPa2-s.

  The California sea lion demonstrated onset of TTS after exposure to 174 dB re: 1 μPa and 206 dB SEL re: 1 μPa2-s.

  The northern elephant seal demonstrated onset of TTS after exposure to 172 dB re: 1 μPa and 204 dB SEL re: 1 μPa2-s.

Combining the above data, Southall et al. (2007) assume that pulses of underwater noise result in the onset of TTS in pinnipeds when underwater noise levels reach 212 dB peak or 171 dB SEL. They did not offer criteria for non-pulsed sounds.

Southall et al. 2007 reported only one study of TTS in pinnipeds resulting from airborne pulsed noise:

- Bowles et al. (unpubl. data) exposed pinnipeds to simulated sonic booms. Harbor seals demonstrated TTS at 143 dB peak re: 20 μPa and 129 dB SEL re: 20 μPa^2-s. California sea lions and northern elephant seals experienced TTS at higher exposure levels than the harbor seals.

Two studies examined TTS in pinnipeds resulting from airborne non-pulsed noise. These studies may not be relevant to the CRC project, but are provided for general reference.

- Kastak et al. (2004) used the same test subjects as in Kastak et al. 2005, exposing the animals to non-pulsed noise (2.5 kHz octave-band noise) for 25 minutes.

  The harbor seal demonstrated 6 dB of TTS after exposure to 99 dB re: 20 μPa and 131 dB SEL re: 20 μPa2-s.

  The California sea lion demonstrated onset of TTS at 122 dB re: 20 μPa and 154 dB SEL re: 20 μPa2-s.

  The northern elephant seal demonstrated onset of TTS at 121 dB re: 20 μPa and 163 dB SEL re: 20 μPa2-s.
- Kastak et al. (2007) studied the same California sea lion as in Kastak et al. 2004 above, exposing this individual to 192 exposures of 2.5 kHz octave-band noise at levels ranging from 94 to 133 dB re: 20 μPa for 1.5 to 50 minutes of net exposure duration. The test subject experienced up to 30 dB of TTS. TTS onset occurred at 159 dB SEL re: 20 μPa^2-s. Recovery times ranged from several minutes to 3 days.

Southall et al. (2007) assume that multiple pulses of airborne noise result in the onset of TTS in pinnipeds when levels reach 143 dB peak or 129 dB SEL.

Lambourn (2010) noted that, in a field setting, sea lions are unlikely to remain in areas exposed to noise levels high enough to cause hearing loss, unless there is a particular attraction keeping them in the area.

Injury – Permanent Threshold Shift

Permanent threshold shift (PTS) is irreversible loss of hearing sensitivity at certain frequencies caused by exposure to intense noise. It is characterized by injury to or destruction of hair cells in the inner ear. Southall et al. (2007) note that there are no empirical studies demonstrating the noise levels that prompt PTS in marine mammals. Furthermore, they found that there is virtually no understanding of the relationship between TTS and PTS in marine mammals, as no studies have been performed.

Southall et al. (2007) propose that noise levels inducing 40 dB of TTS may result in onset of PTS in marine mammals. The authors present this threshold with precaution, as there are no specific studies to support it. Because direct studies on marine mammals are lacking, the authors base these recommendations on studies performed on other mammals. Additionally, the authors assume that multiple pulses of underwater noise result in the onset of PTS in pinnipeds when levels reach 218 dB peak or 186 dB SEL. In air, noise levels are assumed to cause PTS in pinnipeds at 149 dB peak or 144 dB SEL (Southall et al. 2007).

5.2.2.3 Criteria for Injury and Disturbance

NMFS is currently developing comprehensive guidance on sound levels likely to cause injury and behavioral disruption in the context of the MMPA. Until formal guidance is available, NMFS uses conservative thresholds of sound pressure levels likely to cause injury or disturbance to sea lions (Exhibit 5-30) (NMFS 2009; WSDOT 2009a).

Exhibit 5-30. Injury and Disturbance Thresholds for Pinnipeds

Location	Threshold
Underwater – impact pile driving	Injury: 190 dB RMS re: 1 μPa Disturbance: 160 dB RMS re: 1 μPa
Underwater – vibratory pile driving	Injury: None designated Disturbance: 120 dB RMS re: 1 μPa
Above water	Injury: None designated Disturbance: 90 dB RMS re: 20 μPa (unweighted) for harbor seals 100 dB_{RMS} re: 20 μPa (unweighted) for all other pinnipeds

Source: NMFS (2009), WSDOT (2009a).

5.2.2.4 Estimating Noise Levels and Acoustic Area of Effect

The extent of in-water and airborne project-generated noise was calculated for the locations where pile driving would occur in the Columbia River and North Portland Harbor.

The extent of underwater noise was modeled for several pile driving scenarios:

- For two sizes of pile: 18- to 24-inch pile and 36- to 48-inch pile.
- For impact pile drivers operating both with and without an attenuation device. Use of an attenuation device was assumed to decrease initial SPLs by 10 dB.
- For all vibratory pile driving of pipe pile and sheet pile used for temporary structures.

Although two impact pile drivers would operate simultaneously in close proximity to one another in the Columbia River, the two drivers are not expected to generate noise levels greater than a single pile driver. Pile strikes from both drivers would need to be synchronous (within 0.0 and approximately 0.1 second apart) in order to produce higher noise levels than a single pile driver operating alone. Because it is highly unlikely that two pile drivers would operate in exact synchronicity, we assume that two pile drivers would not generate noise levels greater than that of a single pile driver. Therefore, initial noise levels for multiple pile drivers are assumed to be the same as for a single pile driver.

No data were available regarding the initial SPLs generated by vibratory installation of 10-foot diameter steel casings that are proposed for the drilled shafts. Therefore, the project team extrapolated initial SPLs from published values, as described in the subsection on vibratory pile driving below.

The extent of airborne noise was modeled for impact pile driving only.

Impact Pile Driving – Underwater Noise

Exhibits 5-31 and 5-32 quantify the extent, timing, and duration of impact pile driving noise that would exceed threshold levels for disturbance and injury to seals and sea lions. Impact pile driving is expected to take place only within a 31-week in-water work window, ranging from Week 38 of one year to Week 16 of the next (or approximately from September 15 to April 15) over the bridge construction period. There will be a total of about 138 days of impact pile driving in the Columbia River and about 134 days of impact pile driving in North Portland Harbor for the entire project from the start of bridge construction in 2013 to its anticipated completion in 2017 (approximately 4.25 years for both Columbia River and North Portland Harbor Bridges). Impact pile driving in the mainstem Columbia River would occur at more than one pier complex on about 1 or 2 days total during the course of the approximately 4-year construction period. Impact pile driving would be restricted to approximately 45 minutes per 12 hour work day. After initial hydroacoustic monitoring to test its effectiveness, a noise attenuation device would be used during all other impact pile driving. Each work day would include a period of at least 12 consecutive hours with no impact pile driving in order to minimize disturbance to aquatic animals. Impact pile driving would only occur during daylight hours.

Exhibit 5-31. Summary of Impact Pile Driving Noise Above 190 dB RMS Underwater Injury Threshold

	Columbia River			North Portland Harbor		
Pile Size and Number	Distance (m)	Duration	No. Days	Distance (m)	Duration	No. Days
Without Attenuation Device						
18- to 24-inch pile	9	7.5 min/week	38	9	2.5 – 5 min/week	18
36- to 48-inch pile	54	7.5 min/week	38	54	2.5 – 5 min/week	31
With Attenuation Device						
18- to 24-inch pile	2	45 min/day	138	2	45 min/day	72
36- to 48-inch pile	12	45 min/day	138	12	45 min/day	62

Note: Elevated noise levels would occur throughout the 5-year in-water work period. Potential exposure may only occur from approximately September through May, the range of months when seals and sea lions have been observed at Bonneville Dam and could be present in the project area. However, seals and sea lions would actually not be exposed to injurious levels of noise, because impact pile driving would stop when seals and sea lions approach the injury isopleth, i.e. the area where underwater noise is at or above 190 dB RMS.

Exhibit 5-32. Summary of Impact Pile Driving Noise Above 160 dB RMS Underwater Disturbance Threshold

	Columbia River			North Portland Harbor		
Pile Size and Number	Distance (m)	Duration	No. Days	Distance (m)	Duration	No. Days
Without Attenuation Device						
18- to 24-inch pile	858	7.5 min/week	38	858	2.5 – 5 min/week	18
36- to 48-inch pile	5,412	7.5 min/week	38	3,058 – u 5,412 - d	2.5 – 5 min/week	31
With Attenuation Device						
18- to 24-inch pile	185	45 min/day	138	185	45 min/day	72
36- to 48-inch pile	1,166	45 min/day	138	1,166	45 min/day	62

Note: Elevated noise levels would occur throughout the 5-year in-water work period. Potential exposure may only occur from approximately September through May, the range of months when seals and sea lions have been observed at Bonneville Dam and could be present in the project area.

u = upstream, d = downstream

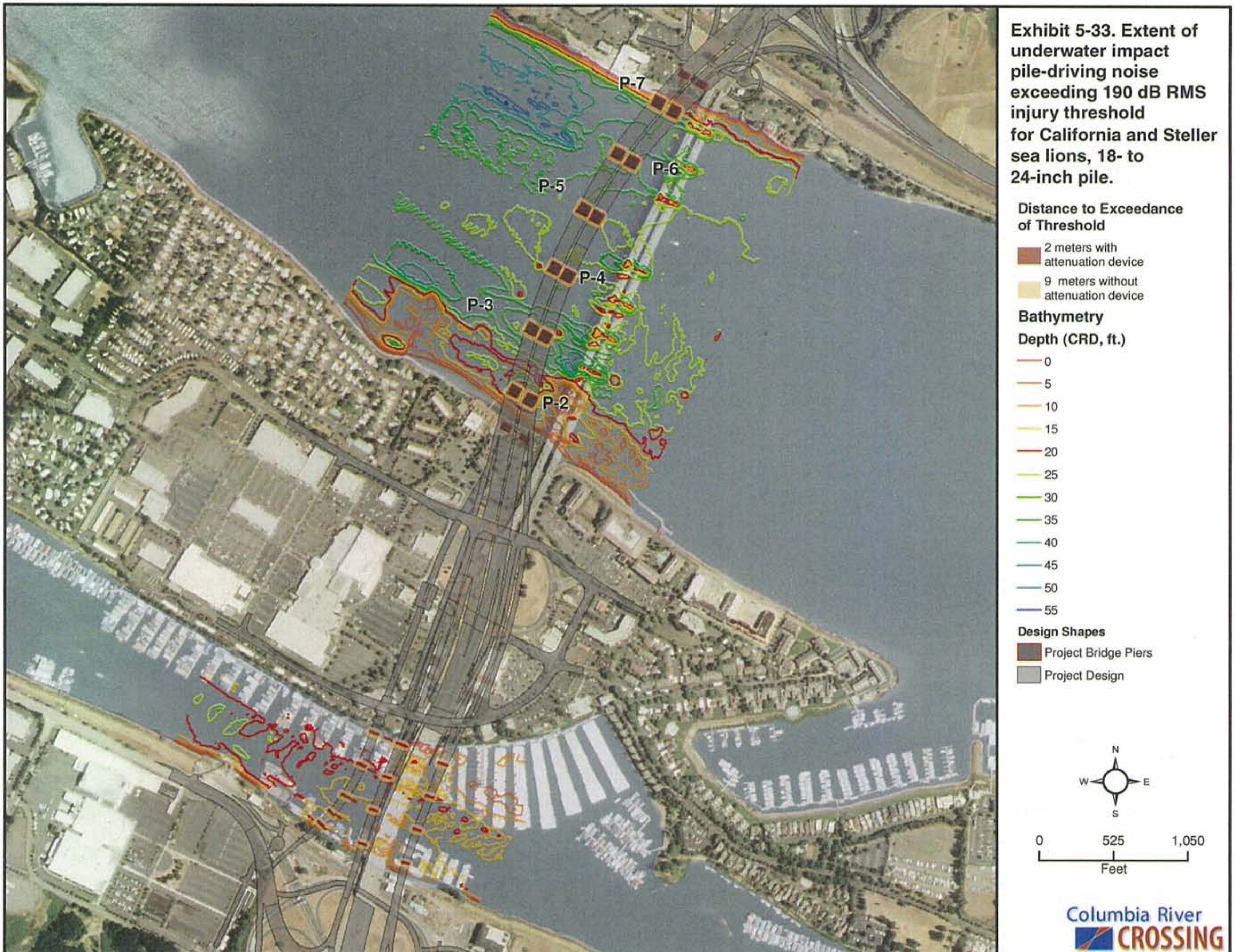


Exhibit 5-33. Extent of underwater impact pile-driving noise exceeding 190 dB RMS injury threshold for California and Steller sea lions, 18- to 24-inch pile.

Analysis by J. Koloszar; Analysis Date: 20 May 2011; File Name: F:\MXD_PDF\FEIS\TECH_REPORTS\ECOSYSTEMS\old\BA_Hydro\HydroSound_MG246_3.mxd

6276

PRELIMINARY

Exhibit 5-34. Extent of underwater impact pile-driving noise exceeding 160 dB RMS injury threshold for California and Steller sea lions, 18- to 24-inch pile.

Distance to Exceedance of Threshold

- 185 meters with attenuation device
- 858 meters without attenuation device

Bathymetry

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Design Shapes

- Project Bridge Piers
- Project Design

N
W E
S

0 680 1,360
Feet

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 20 May 2011; File Name: F:\MXD_PDF\FEIS\TECH_REPORTS\ECOSYSTEMS\old\BA_Hydro\HydroSound_MG246_3.mxd

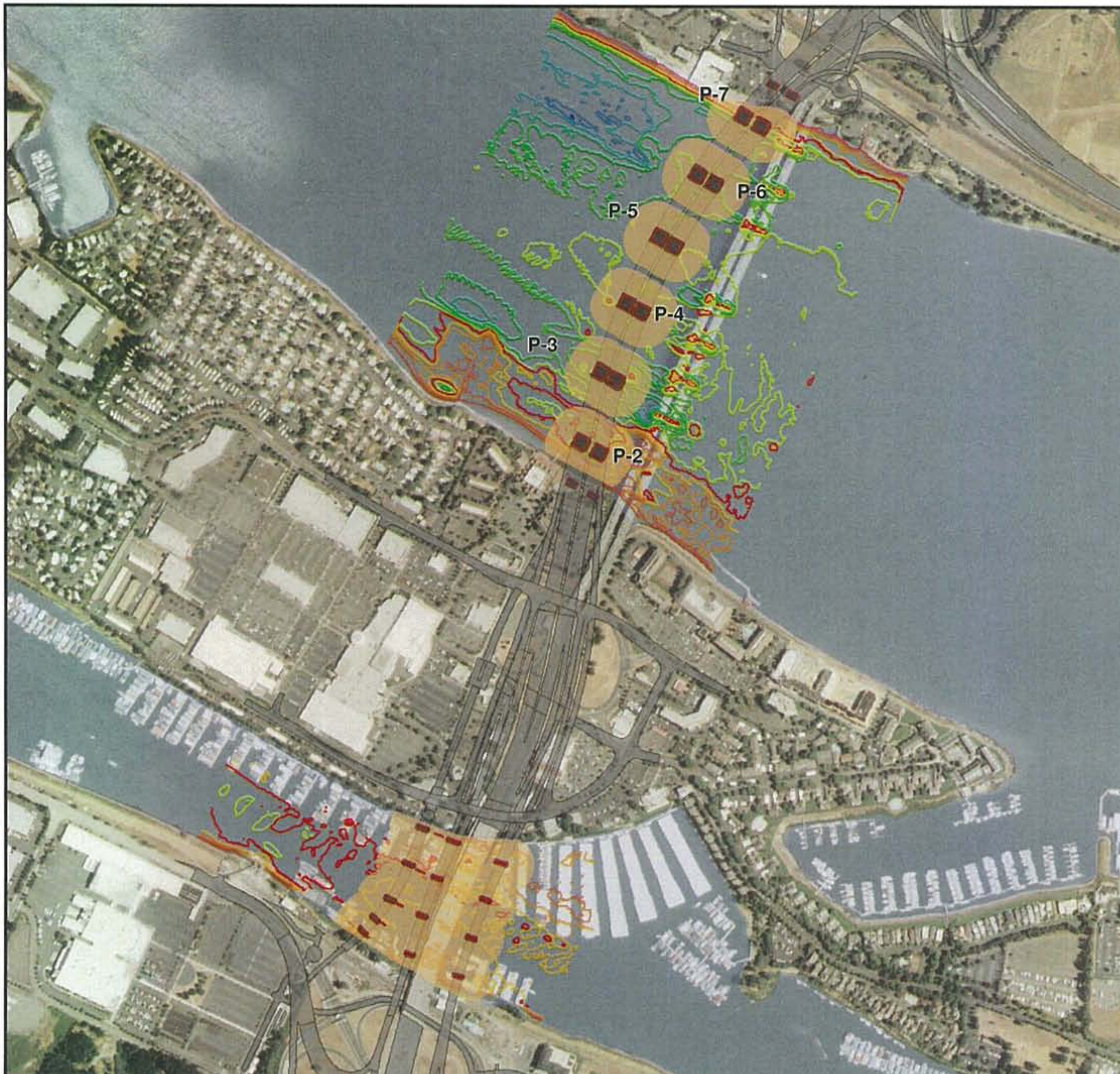


Exhibit 5-35. Extent of underwater impact pile-driving noise exceeding 190 dB RMS injury threshold for California and Steller sea lions, 36- to 48-inch pile.

Distance to Exceedance of Threshold

- 5 meters with attenuation device
- 54 meters without attenuation device

Bathymetry

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Design Shapes

- Project Bridge Piers
- Project Design

N
W E
S

0 525 1,050
Feet

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 20 May 2011; File Name: F:\MXD_PDF\FEIS\TECH_REPORTS\ECOSYSTEMS\old\BA_Hydro\HydroSound_MG246_3.mxd

PRELIMINARY

Exhibit 5-36. Extent of underwater impact pile-driving noise exceeding 160 dB RMS injury threshold for California and Steller sea lions, 36- to 48-inch pile.

Distance to Exceedance of Threshold

- 541 meters with attenuation device
- 5,412 meters without attenuation device

Bathymetry

Depth (CRD, ft.)

0
5
10
15
20
25
30
35
40
45
50
55

Design Shapes

- Project Bridge Piers
- Project Design

N
W E
S

0 2,750 5,500
Feet

Columbia River CROSSING

Analysis by J. Kolozar; Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound_MG246_3.mxd

For 18- to 24-inch pile in both water bodies, and for 36- to 48-inch pile in the Columbia River, the actual, site-specific distances are the same as the calculated distances (Exhibit 5-33 and Exhibit 5-35).

Vibratory Pile Driving – Underwater Noise

No studies were available that measured site-specific initial noise levels generated by vibratory pile driving in the CRC project area. However, Exhibit 5-37 outlines a range of typical noise levels produced by vibratory pile driving as measured by Caltrans during hydroacoustic monitoring of several construction projects (Caltrans 2009).

Exhibit 5-37. Summary of Unattenuated Underwater Sound Pressures for Vibratory Pile Driving

Pile Type and Approximate Size	Water Depth	SPLs (dB RMS)[a]
0.30-meter (12-inch) steel H-type	<5 meters	150
0.30-meter (12-inch) steel pipe pile	<5 meters	155
1-meter (36-inch) steel pipe pile – typical	~5 meters	170
0.6-meter (24-inch) AZ steel sheet – typical	~15 meters	160
0.6-meter (24-inch) AZ steel sheet – loudest	~15 meters	165
1-meter (36-inch) steel pipe pile – loudest	~5 meters	175
1.8-meter (72-inch) steel pipe pile – typical	~5 meters	170
1.8-meter (72-inch) steel pipe pile – loudest	~5 meters	180

Source: Caltrans 2009, CRC 2010.

a Impulse level (35 millisecond average).

Pipe Pile

Exhibit 5-38 summarizes the extent, timing, and duration of noise above the 120 dB RMS disturbance threshold during vibratory installation of pipe pile and sheet pile. Vibratory installation of pipe pile would be likely to occur throughout the entire 5-year construction period of all new in-water piers or bents and for installation of mooring piles. Vibratory installation of sheet pile would only occur in the Columbia River during construction of the new Columbia River bridges and demolition of the existing Columbia River bridges. This activity would occur intermittently throughout the construction and demolition period. This activity would not be restricted to an in-water work window, and therefore may take place during any time of the year.

Exhibit 5-38. Summary of Vibratory Pile Driving Noise Above 120 dB RMS Underwater Disturbance Threshold – Pipe Pile and Sheet Pile

		Columbia River			North Portland Harbor		
Pile Type	Timing	Distance (m)	Hours/ Day	No. Days	Distance (m)	Hours/Day	No. Days
Pipe Pile	Year-round	20,166 – u 8,851 – d	Up to 5	1,470–1,620	3,058 – u 5,632 - d	Up to 5	~334
Sheet Pile	Year-round	6,962	Up to 24	99	N/A	N/A	N/A

Note: Elevated noise levels will occur throughout the in-water work period. Potential exposure may only occur from approximately September through May, the range of months when seals and sea lions have been observed at Bonneville Dam and could be present in the project area.

u = upstream, d = downstream

5.2.3 Vibratory Installation of Steel Casings

If steel casings for drilled shafts are vibrated into place, the CRC project design team estimates that installation of the 10-foot diameter casings will take approximately 90 days in the Columbia River and 31 days in North Portland Harbor. Vibratory installation of casings is not restricted to the in-water work window and therefore may take place any time during the in-water construction period. Exhibit 5-39 summarizes the estimated extent, timing, and duration of noise above the injury and disturbance thresholds during vibratory installation of steel casings. Hydroacoustic monitoring will be conducted to field verify the distances within which noise exceeds these thresholds.

Exhibit 5-39. Summary of Vibratory Pile Driving Noise above Disturbance and Injury Thresholds – Steel Casings

		Columbia River		North Portland Harbor	
Threshold	Timing	Distance (m)	No. Days	Distance (m)	No. Days
120 dB RMS	Year-round	20,166 – u 8,851 – d	90	3,058 – u 5,632 - d	31
190 dB RMS	Year-round	5	90	5	31

Note: Elevated noise levels will occur throughout the 4-year in-water construction period. Potential exposure may only occur from approximately September through May, the range of months when seals and sea lions have been observed at Bonneville Dam and could be present in the project area.

u = upstream, d = downstream

Exhibit 5-40. Extent of underwater vigratory pile-driving noise exceeding 120 dB RMS disturbance threshold for California and Steller sea lions.

Distance to Exceedance of Threshold

- 6,962 meters sheet pile
- 42,000 meters pipe pile

Design Shapes

- Project Bridge Piers
- Project Design

N
W E
S

0 6,600 13,200
Feet

Columbia River CROSSING

Analysis by J. Robson; Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound_MG246_3.mxd

Steel Casings

Vibration may also be used to install the 10-foot-diameter steel casings for the drilled shafts of the permanent structures in the Columbia River and North Portland Harbor. No data were available regarding the initial SPLs generated by installation of steel casings of this size. Therefore, the design team extrapolated from published values, assuming that vibratory driving of 10-foot casings would generate noise at levels of up to 10 dB RMS (an order of magnitude) higher than the highest value for vibratory installation of a 72-inch pile (Exhibit 5-37).That is, vibratory installation of 10-foot diameter steel casing may yield a maximum value of 190 dB RMS at 5 m from the pile.

Therefore, it is assumed that vibratory installation of 10-foot-diameter steel pile would exceed the 190 dB RMS injury threshold for sea lions at 5 m from the source (Exhibit 5-41). Exhibit 5-41 also shows the distance within which noise is calculated to attenuate to the 120 dB RMS vibratory pile driving disturbance threshold, as per the Practical Spreading Model.

Exhibit 5-41. Distance to Underwater Noise Thresholds from Source for Vibratory Driving of Steel Casings

	Distance from Source (m)
Estimated Noise Level (dB RMS)	Initial SPL 190 dB RMS at 5 m
190 (injury threshold)	5
120 (disturbance threshold)	233,000

Landforms in the Columbia River and North Portland Harbor would completely block underwater noise well before it reaches the 233,000-m distance calculated for the 120 dB RMS disturbance threshold. Exhibit 5-42 shows site-specific values for the maximum distance at which noise is likely to exceed the injury and disturbance thresholds.

Exhibit 5-42. Distance to Underwater Noise Thresholds for Vibratory Driving of Steel Casings – Site-Specific Values

	Distance from Source Distance from Source (m)	
Estimated Noise Level (dB RMS)	Columbia River	North Portland Harbor
190 (injury threshold)	5	5
120 (disturbance threshold)	20,166 Upstream 8,851 Downstream	3,058 Upstream 5,632 Downstream

Without a precise estimate of initial SPLs, the values shown in Exhibit 5-42 are rough estimates. To refine these estimates, the CRC team proposes to perform hydroacoustic monitoring during vibratory installation of the first steel casing in order to verify: 1) the initial SPLs generated by this activity and 2) the potential injury zone for sea lions. Additionally, hydroacoustic monitoring is likely to be required under the terms of a Letter of Authorization issued by NMFS under the Marine Mammal Protection Act.

Airborne Noise

Exhibits 5-43 and 5-44 summarize the extent, timing, and duration of airborne impact pile-driving noise above disturbance thresholds for sea lions and seals, respectively. Airborne noise effects would occur on the same schedule as those described for impact pile driving above.

Exhibit 5-43. Summary of Impact Pile Driving Noise Above 100 dB RMS Airborne Disturbance Threshold for Sea Lions

Location	Distance from Source (m)	Mins/Day	No. Days
Columbia River	196	≤45	138
North Portland Harbor	196	≤45	134

Note: Elevated noise levels will occur throughout the approximately 4-year in-water work period. Potential exposure may only occur from approximately September through May, the range of months when seals and sea lions have been observed at Bonneville Dam and could be present in the project area.

Exhibit 5-44. Summary of Exposure to Impact Pile Driving Noise Above 90 dB RMS Airborne Noise Disturbance Threshold for Harbor Seals

Location	Distance from Source (m)	Mins/Day	No. Days
Columbia River	650	≤45	138
North Portland Harbor	650	≤45	134

Note: Elevated noise levels will occur throughout the approximately 4-year in-water work period. Potential exposure may only occur from approximately September through May, the range of months when seals and sea lions have been observed at Bonneville Dam and could be present in the project area.

PRELIMINARY

Exhibit 5-45. Extent of airborne impact pile-driving noise exceeding 100 dB RMS disturbance threshold for California and Steller sea lions.

Distance to Exceedance of Threshold

- 195 meters - single pile driver
- 274 meters - multiple pile drivers

Bathymetry

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Design

N
W E
S

0 540 1,080
Feet

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: 20 May 2011; File Name: F:\Transfer051111\ESY\HydroSound_MG246_3.mxd

5.2.3.1 Effects of Noise on Pinnipeds in the CRC Project Area

Steller and California sea lions and harbor seals are likely to be exposed to elevated noise levels in the project area. Exposure is likely to occur from November through May when primarily adult and subadult male Steller and California sea lions typically forage at Bonneville Dam. Sea lions are known to migrate through the project area between the dam and the ocean during this time period, often making multiple round-trip journeys. Individual sea lions also are occasionally present from September to November (Tackley et al. 2008). Harbor seals are also observed at the dam between February and May, and may be present in the river during the fall and winter. Therefore exposure during this time is possible, but less likely.

It is not certain how many sea lions would be exposed to elevated noise levels. Since counts at the dam began in 2002, numbers of Steller sea lions have ranged from 3 to 75 individuals; numbers of California sea lions have ranged from 30 to 104 individuals; numbers of harbor seals have ranged from 1 to 3 individuals (Stansell et al. 2010). Based on trends in the number of pinnipeds identified at Bonneville Dam in recent years, we estimate up to 89 California sea lions, 225 Steller sea lions, and six harbor seals may travel through the project area, annually, in future years. These figures account for animals making round-trips between Astoria and Bonneville Dam more than once in a given year.

There are no pinniped haulouts or breeding sites in areas likely to be exposed to elevated noise. The nearest known sea lion haulout is located approximately 32 miles upstream of the project area (Tennis 2009 pers. comm.). The nearest sea lion breeding site is located more than 200 miles from the project area (NMFS 2008b). The nearest known harbor seal haulout is located at Carroll Slough at the confluence of the Cowlitz and Columbia Rivers, approximately 45 miles west of the western-most edge of the project area. Therefore, elevated noise levels would have no effect on individuals at breeding or haulout sites.

Sea lions use the project area primarily for transiting only and are expected to be highly mobile when present in portions of the project area exposed to noise above the threshold levels for injury and disturbance. Additionally, Lambourn (2010 pers. comm.) notes that sea lions are likely to avoid unfamiliar noises unless there is a particular attraction keeping them in the area. As the CRC project area does not contain any such attractions (e.g., an especially rich food source, breeding area, or haulout site), sea lions would presumably avoid portions of the project area exposed to high levels of elevated noise (for example, noise generated by impact pile driving). Therefore, they would likely experience only brief, temporary behavioral disturbance or harassment as a result of impact pile-driving noise. Lambourn (2010) also added that Steller sea lions could become habituated to noises that are continuous and occurring over longer periods of time (such as vibratory pile-driving noise).

Exposure to Underwater Impact Pile-driving Noise

Exhibit 5-46 and Exhibit 5-47 below quantify the extent, timing, and duration of impact pile-driving noise that would exceed threshold levels for disturbance and injury to sea lions. Impact pile driving is expected to take place over the 4-year in-water construction period. During each year, work would likely occur within a 31-week in-water work window, ranging from week 38 of one year to week 16 of the next (or approximately from September 15 to April 15). There would be a total of about 138 days of impact pile driving in the Columbia River and 134 days of impact pile driving in North Portland Harbor over the 4-year construction period (Exhibit 5-23). Impact pile driving would be restricted to approximately 40 minutes per 12-hour work day. During most of this 40-minute period, pile driving would occur only with the use of a noise attenuation device; however, for a short duration (about 7.5 minutes per week in the Columbia River and roughly 2.5 to 5 minutes per week in North Portland Harbor), unattenuated pile driving may occur either during routine testing of the attenuation device or accidentally in the case of equipment failure. Each work day would include a period of at least 12 consecutive hours with no impact pile driving in order to minimize disturbance to aquatic animals. Likewise, each 7-day work week would include a 2-day pile-driving recess. Impact pile driving would occur only during daylight hours.

Exhibit 5-46. Summary of Extent, Timing, and Duration of Impact Pile-Driving Noise above 190 dB RMS Underwater Injury Threshold[a]

	Columbia River			North Portland Harbor		
Pile Size and Number	Distance (m)	Duration	No. Days	Distance (m)	Duration	No. Days
Without Attenuation Device						
18- to 24-inch pile	9	7.5 min/week	38	9	2.5 – 5 min/week	18
36- to 48-inch pile	54	7.5 min/week	38	54	2.5 – 5 min/week	31
With Attenuation Device						
18- to 24-inch pile	2	40 min/day	138	2	40 min/day	72
36- to 48-inch pile	12	40 min/day	138	12	40 min/day	62

Note: Elevated noise levels would occur throughout the 4-year in-water construction period. Potential exposure may only occur from approximately September to May, when Steller sea lions are typically present in the project area.

a Sea lions would actually not be exposed to injurious levels of noise, because impact pile driving would stop when sea lions are present in the injury zone.

Exhibit 5-47. Summary of Extent, Timing, and Duration of Impact Pile-Driving Noise above 160 dB RMS Underwater Disturbance Threshold

	Columbia River			North Portland Harbor		
Pile Size and Number	Distance (m)	Duration	No. Days	Distance (m)	Duration	No. Days
Without Attenuation Device						
18- to 24-inch pile	858	7.5 min/week	38	858	2.5 – 5 min/week	18
36- to 48-inch pile	5412	7.5 min/week	38	3058 – u 5412 - d	2.5 – 5 min/week	31
With Attenuation Device						
18- to 24-inch pile	185	40 min/day	138	185	40 min/day	72
36- to 48-inch pile	1166	40 min/day	138	1166	40 min/day	62

Note: Elevated noise levels would occur throughout the 4-year in-water construction period. Potential exposure may only occur from approximately September to May, when Steller sea lions are typically present in the project area.

u = upstream, d = downstream

Exposure to Underwater Vibratory Pile-driving Noise

Pipe Pile and Sheet Pile

Exhibit 5-48 summarizes the extent, timing, and duration of noise above the 120 dB RMS disturbance threshold generated by vibratory pile driving during installation of pipe pile and sheet pile. Vibratory driving of pipe pile and sheet pile is not expected to exceed the 190 dB RMS injury threshold, but it is likely to exceed the 120 dB RMS disturbance threshold.

Vibratory driving of pipe pile is likely to occur intermittently throughout the entire in-water project area at all new in-water piers or bents. Vibratory driving of sheet pile would occur along the same timeline, but only at pier complexes 2 and 7 in the Columbia River. These activities would occur continually throughout the 4-year in-water construction period over approximately 49 to 54 months. These activities are not restricted to an in-water work window, and therefore may take place during any of the 52 weeks of the year.

Vibratory driving of pipe pile and sheet pile is also likely to occur during demolition of the existing Columbia River bridge piers to install barge moorings and cofferdams. Pipe piles for barge moorings would be installed and removed continuously throughout the entire 18-month demolition period, during any of the 52 weeks of the year. Cofferdams would each require about 10 days to install and would likely be installed during the last 13 months of the 18-month demolition period. Exhibit 5-48 shows the estimated extent, timing, and duration of noise above the 120 dB RMS disturbance threshold.

Exhibit 5-48. Summary of Exposure to Vibratory Pile-driving Noise Above 120 dB RMS Disturbance Threshold – Pipe Pile and Sheet Pile

		Columbia River			North Portland Harbor		
Pile Type	Timing	Distance (m)	Hours/ Day	No. Days	Distance (m)	Hours/D ay	No. Days
Pipe Pile	Year-round	20166 – u 8851 –d	Up to 5	1470 - 1620	3058 – u 5632 - d	Up to 5	1470 – 1620
Sheet Pile	Year-round	6962 to 15000 – u 6962 to 8851 – d	Up to 24	99	N/A	N/A	N/A

Note: Elevated noise levels would occur throughout the four-year in-water construction period. Potential exposure may only occur from approximately September to May when sea lions are typically present in the project area.

u = upstream, d = downstream

Steel Casings

Exhibit 5-49 summarizes the extent, timing, and duration of noise above the injury and disturbance thresholds during vibratory installation of steel casings. The design team estimates that vibratory installation of 10 foot casings would take approximately 90 days in the Columbia River and 31 days in North Portland Harbor. Vibratory installation of 10-foot casings is not restricted to the in-water work window and therefore may take place any time during the four-year in-water construction period.

Exhibit 5-49. Summary of Exposure to Vibratory Pile Driving Noise above Disturbance and Injury Thresholds – Steel Casings

		Columbia River		North Portland Harbor	
Threshold	Timing	Distance (m)	No. Days	Distance (m)	No. Days
120 dB RMS	Year-round	20,166 – u 8,851 - d	90	3,058 – u 5,632 - d	31
190 dB RMS	Year-round	5	90	5	31

Note: Elevated noise levels would occur throughout the four-year in-water construction period. Potential exposure may only occur from approximately October to May when Steller sea lions are typically present in the project area.

u = upstream, d = downstream

As stated earlier, hydroacoustic monitoring would be conducted to field verify the distances within which noise exceeds these thresholds and to satisfy the conditions of the Incidental Harassment Authorization.

Exposure to Airborne Impact Pile-driving Noise

Exhibit 5-50 summarizes the extent, timing, and duration of airborne impact pile-driving noise. Airborne noise effects would occur on the same schedule as those described for underwater impact pile driving.

Exhibit 5-50. Summary of Exposure to Airborne Impact Pile-Driving Noise above 100 dB RMS Disturbance Threshold Generated by Impact Pile Driving

Location	Distance from Source (m)	Mins/Day	No. Days
Columbia River	195	≤40	138
North Portland Harbor	195	≤40	134

Note: Elevated noise levels would occur throughout the 4-year in-water construction period. Potential exposure may only occur from approximately September to May, when Steller sea lions are typically present in the project area.

Injury

The CRC project is not likely to injure pinnipeds. Although impact pile driving noise is likely to exceed the injury threshold, this effect will be limited to a distance of 2 to 54 m from the noise source, depending on the number and size of the piles. Vibratory installation of steel casings may also exceed the injury threshold within 5 m of the source. Additionally, as impact pile driving noise will be sporadic, occurring only about 45 minutes per day, pinnipeds will likely avoid it as an unfamiliar source of disturbance. Similarly, installation of the steel casings will be very limited. Pinnipeds are expected to avoid the injury zone rather than becoming habituated, thus reducing the potential for exposure.

The CRC project will further limit the potential for injury to pinnipeds through the implementation of a monitoring plan. Marine mammal monitors will ensure that the CRC project curtails impact pile driving if seals and sea lions approach the 2- to 54-meter injury isopleth, known as the safety zone, for impact pile driving. For added protection, the safety zone will be a minimum of 50 meters even though the injury isopleth may actually be smaller. Additionally, if vibratory installation of 10-foot diameter steel casings produces noise above the injury threshold, this activity will cease before seals or sea lions enter the potential safety zone for vibratory pile driving. The project will perform hydroacoustic monitoring to confirm injury zone isopleths. Monitoring zones may be refined accordingly, but will never be less than 50 meters.

Measures to avoid injury to seals and sea lions, including details of the monitoring plan and shut-down procedures, are described in Section 6. Because injurious noise levels will extend only a short distance and marine mammals will be monitored approaching these areas, it is reasonable to expect that qualified marine mammal monitors will be able to detect seals and sea lions within these areas. Impact pile driving will not occur at night, making the probability of detection very high. Vibratory installation of 10-foot-diameter steel casings may occur at night; however, marine mammal monitors will use night-vision/night-detection equipment to ensure detection of seals or sea lions within the safety zone while this activity is taking place. For these reasons, avoidance of injury through implementation of a monitoring plan would be attainable. While injury is theoretically possible, it is not probable. Therefore, CRC project-generated noise is not likely to injure seals and sea lions.

Behavioral Effects

The project is likely to create noise above threshold levels for airborne and underwater behavioral disturbance to pinnipeds. Exhibit 46 through Exhibit 49 outline the extent, timing, and duration of this effect.

Studies on behavioral effects to seals and sea lions are limited (Southall et al. 2007), and because the few available studies show wide variation in response to underwater and airborne noise, it is difficult to quantify exactly how pile driving noise will affect pinnipeds. The literature shows that elevated underwater noise levels could prompt a range of effects, including no obvious visible response, brief visual orientation towards the noise, curiosity (or movement towards the source), or habituation to the sound (Southall et al. 2007). For underwater noise, Southall et al. (2007) note that there is little evidence that high levels of pulsed noise, ranging between 150 and 180 dB RMS relative to 1 μPa, will prompt avoidance of an area. For airborne noise Southall et al. (2007) note there is extremely limited data suggesting very minor, if any, observable behavioral responses by pinnipeds exposed to airborne pulses of 60 to 80 dB relative to 20 μPa; however, given the paucity of data on the subject, we cannot rule out the probability that avoidance of noise in the project area could occur.

In an effort to gauge potential sea lion response to disturbance, CRC reviewed reports of sea lion response to harassment from hazing techniques just below Bonneville Dam. The deterrence efforts below Bonneville Dam began in 2005 and have used Acoustic Deterrent Devices (ADDs), boat chasing, above-water pyrotechnics (cracker shells, screamer shells or rockets), rubber bullets, rubber buckshot, and beanbags (Stansell et al. 2009). Review of deterrence activities by the West Coast Pinniped Program noted "USACE observations from 2002 to 2008 indicated that increasing numbers of California sea lions were foraging on salmon at Bonneville Dam each year, salmon predation rates increased, and the deterrence efforts were having little effect on preventing predation" (Scordino 2010). In the USACE status report through May 28, 2010, boat hazing was reported to have limited, local, short term impact in reducing predation in the tailrace, primarily from Steller sea lions. ODFW and WDFW reported that sea lion presence did not appear to be significantly influenced by boat-based activities and several "new" sea lions (initially unbranded or unknown from natural markings) continued to forage in the observation area in spite of shore- and boat-based hazing. They suggested that hazing was not effective at deterring naïve sea lions if there were large numbers of experienced sea lions foraging in the area (Brown et al. 2010). Observations on the effect of ADDs, which were installed at main fishway entrances by mid-June of 2007, noted that pinnipeds were observed swimming and eating fish within 20 feet of some of the devices with no deterrent effect observed (Tackley et al. 2008a, Tackley et al. 2008b, Stansell et al. 2009, Stansell et al. 2010). Many of the animals returned to the area below the dam despite hazing efforts (Stansell et al. 2009, Stansell and Gibbons 2010). Relocation efforts to Astoria and the Oregon coast were tried in 2007; all but 1 of 14 relocated animals returned to Bonneville Dam within days (Scordino 2010).

No information on in-water noise levels of hazing activities at Bonneville Dam has been published other than ADDs produce underwater noise levels of 205 dB in the 15 kHz range (Stansell et al. 2009). Durations of boat-based hazing events were reported at less than 30 minutes for most of the 521 boat-based events in 2009, but ranged up to 90 minutes (Brown et al. 2009). Durations of boat-based hazing events were not reported for 2010. However, 280 events occurred over 44 days during a 5-month period using a total of 4,921 cracker shells, 777 seal bombs, and 97 rubber buckshot rounds (Brown et al. 2010). Based on knowledge of in-water noise from construction activities, the CRC project assumes that pinniped exposure to project-related in-water noise (e.g., in-water construction and demolition) will be less than that of exposure to hazing techniques.

In addition, sea lions are expected to traverse through and not remain in the project area. Tagging studies of California sea lions indicate they pass hydrophones upriver and downriver of the CRC project site quickly. Wright et al. (2010a) reported minimum upstream and downstream transit times between the Astoria haul-out and Bonneville Dam (river distance ~20 km) were 1.9 and 1 day, respectively, based on 14 trips by 11 sea lions. The transit speed was calculated to be 4.6 km/hr in the upstream direction and 8.8 km/hr in the downstream direction. Graphics of the six individuals acoustically tagged in 2009 show they made a combined total of 11 upriver or downriver trips quickly through the CRC project site to or from Bonneville Dam and Astoria (Brown et al. 2009). Graphics from four acoustically tagged California sea lions in 2010 also indicate that the animals move though the area below Bonneville Dam down to the receivers located below the CRC project site rapidly both in the upriver or downriver directions (Wright draft report graphics from pers. comm. 2010b). Although the data apply to California sea lions, Steller sea lions and harbor seals have no incentive to stay near the CRC project area and have no haul-outs near the project area, and are expected to also pass the project area quickly. Therefore, sea lions and seals are not expected to be exposed to a long duration of construction noise.

Underwater noise generated by impact pile driving may cause minor disruption of movement through the area and feeding activities, but based on travel data and haul-out locations, exposure is expected to be brief. Additionally, because many of the individuals transiting the area are already habituated to high ambient disturbance levels from existing commercial and recreational vessel traffic and to hazing at Bonneville Dam, it is expected that they would not be sensitive to pile driving noise. Although brief, temporary, behavioral harassment would occur within the disturbance threshold areas, elevated noise levels from impact pile driving are expected to have only a negligible effect on foraging and transiting of individual seals and sea lions, and no effect on the overall populations.

Safe passage concerns during pile installation and removal at more than one pier complex were raised by NMFS. Given the 800-meter width of the Columbia River and the rarity of impact pile driving on opposite sides of the river (approximately 1 or 2 days total throughout the approximately 4-year construction period), passage should not be hindered. Vibratory installation or removal of piles at more than one pier complex will likely occur at the same time on occasion during construction and demolition. During construction and demolition, space limitations due to barge size and limitations on the amount of equipment available are anticipated to be limiting factors for the contractor. Vibratory installation of steel casings, pipe piles, and sheet piles are calculated to exceed behavioral disturbance thresholds at between 6,962 and over 50,000 meters. In this case, the entire width of the channel will be affected by noise above the disturbance threshold even if only one pier complex was being worked on. As stated above, not enough information on Columbia River pinniped reaction to vibratory driving is available to determine whether individuals will alter their movement patterns in this industrial area and some seals or sea lions may not pass the construction site due to noise and general construction activity. However, the safety of the animals would not be compromised by these noise levels.

If in-water work for pile installation or removal occurs simultaneously on both sides of the river and results in changes to pinniped behavior so they do not pass the project site, it would be due to behavioral harassment from incidental exposure to a short duration of non-injurious noise levels and general construction activity. Sea lions would be expected to traverse through the area and not be exposed to a long duration of noise. Also, based on observations from the Bonneville Dam sea lion removal program over 6 years, many individual sea lions appear motivated to reach the Bonneville Dam tailrace to forage, undeterred by directed noise hazing techniques. Many individual sea lions return repeatedly, even after being exposed to hazing and being captured, herded, and branded. Therefore, it is anticipated that the less intense, short duration, non-injurious noise levels from installation and removal of pipe piles, casings, and cofferdams will not affect the behavior of many of the individual sea lions in the project area.

Harbor seals occur sporadically in low numbers in the project area, so they are less likely to be exposed to the short periods when impact or vibratory installation and removal noise could occur on both sides of the Columbia River simultaneously.

Temporary Threshold Shift

Temporary Threshold Shift (TTS) is reversible hearing loss caused by fatigue of hair cells and supporting structures in the inner ear. Technically, TTS is not considered injury, as it consists of fatigue to auditory structures rather than damage to them. Impact pile driving would produce maximum underwater source pulsed noise levels estimated at 210 dB peak and 176 dB SEL with 10 dB of attenuation from an attenuation device (214 dB peak and 186 dB SEL without an attenuation device). Summarizing existing data, Southall et al. (2007) assumed that pulses of underwater noise result in the onset of TTS in pinnipeds when levels reach 212 dB peak or 171 dB SEL. They did not offer criteria for non-pulsed sounds. Although these suggested criteria have not been adopted by any regulatory body, they are presented as a starting point to discuss the likelihood of TTS occurring during the CRC project. The literature has not drawn conclusions on levels of underwater non-pulsed noise (e.g., vibratory pile installation) likely to cause TTS. With a noise attenuation device, TTS is not likely to occur based on our estimated source levels. Without a noise attenuation device, we estimate that the extent of the area in which underwater noise levels could potentially cause TTS is somewhere in between the extent of where the injury threshold occurs (2 to 54 m from the noise source) and the extent of where the disturbance threshold occurs (74 FR 63724).

Although underwater noise levels produced by the CRC project may exceed levels produced in studies that have induced TTS in pinnipeds (Southall et al. 2007), there is a general lack of controlled, quantifiable field studies related to this phenomenon. Existing studies have had varied results (Southall et al. 2007). Therefore, it is difficult to extrapolate from these data to site-specific conditions on the CRC project. For example, because most of the studies have been conducted in laboratories, rather than in field settings, the data are not conclusive as to whether noise will cause seals and sea lions to avoid the project area, thereby reducing the likelihood of TTS, or whether noise will attract seals and sea lions, increasing the likelihood of TTS. In any case, there are no universally accepted standards for the amount of exposure time likely to induce TTS. Lambourne (2010 personal communication) posits that, in most circumstances, free-roaming Steller sea lions are not likely to remain in areas subjected to high noise levels long enough to experience TTS unless there is a particularly strong attraction, such as an abundant food source. While we may infer that TTS could conceivably result from the CRC project, it is impossible to exactly quantify the magnitude of exposure, the duration of the effect, or the number of individuals likely to be affected.

Impact pile driving would produce initial airborne noise levels of approximately 112 dB peak at 160 feet from the source, as compared to the level suggested by Southall et al. (2007) of 143 dB peak referenced to 20 μPa for onset of TTS in pinnipeds from multiple pulses of airborne noise. It is not expected that airborne noise levels will prompt TTS in individual seals and sea lions. Exposure is likely to be brief because seals and sea lions use the project area for transiting, rather than breeding or hauling out. In summary, it is expected that elevated noise would have only a negligible probability of causing TTS in individual seals and sea lions.

5.2.3.2 Conclusion

Injury to California and Steller sea lions is avoidable through the implementation of a monitoring plan that requires a cessation of impact pile driving before individuals enter the underwater injury zone, defined as from 2 to 54 meters from impact pile driving. Additionally, if vibratory installation of 10-foot-diameter steel casings produces noise above the injury threshold, this activity would cease before sea lions enter the potential injury zone (anticipated to be 5 meters from the activity).

Noise above the behavioral disturbance threshold is probably unavoidable during both impact and vibratory pile driving, but effects to sea lions are expected to be brief and temporary, impacting only a small number of adult and sub-adult sea lions transiting the project area. No noise disturbance would occur at breeding areas or haulouts. Noise is not expected to significantly interfere with foraging, transiting, breathing, or other essential life functions.

5.2.4 Noise from Underwater Debris Removal

Debris removal may occur in North Portland harbor at the location of each of the new piers where there is anecdotal evidence that riprap occurs within the pier footprints. Debris removal in the North Portland Harbor, if it occurs, would be likely to create noise at or above the 120 dB RMS disturbance threshold for continuous noise in underwater portions of the project area.

Few studies have been conducted on noise emissions produced by underwater debris removal. A review of the literature indicates that underwater debris removal will produce noise in the range of 135 dB to 147 dB RMS at 10 m (Dickerson et al. 2001; OSPAR 2009; Thomsen et al. 2009), i.e., greater than the 120 dB RMS disturbance threshold for non-pulsed noise.

Underwater debris removal is not expected to generate significant airborne noise. The air-water interface creates a substantial sound barrier and reduces the intensity of underwater sound waves by a factor of more than 1,000 when they cross the water surface. The above-water environment is, thus, virtually insulated from the effects of underwater noise (Hildebrand 2005). Therefore, underwater debris removal is not expected to measurably increase ambient airborne noise.

Exhibit 5-51 shows the calculated distance at which underwater debris removal noise attenuates to the underwater disturbance threshold for continuous noise (120 dB RMS).

Exhibit 5-51. Underwater Noise Attenuation for Debris Removal Noise – Calculated Values

	Distance from Source (m)
Noise Level (dB RMS)	Bucket Dredge Source Sound Pressure Level 147 at 10 m
150	7
140	30
130	136
120	631

5.2.4.1 Potential Exposure of Steller and California Sea Lions to Underwater Debris Removal Noise

Exhibit 5-52 summarizes potential exposure of pinnipeds to underwater debris removal noise in the North Portland Harbor. Exposure is presented as an overlap of the areal extent of noise at or above the disturbance threshold, combined with the duration and timing of the impact and the time periods when seals and sea lions are likely to be present in the project area.

Debris removal is not certain to occur, but is included to present the fullest disclosure of effects. It is possible that debris removal would occur in North Portland harbor at the location of each of the new piers where there is anecdotal evidence that riprap occurs within the pier footprints. The exact quantity of this material is unknown, but as a worst-case scenario, this activity would remove approximately 90 cubic yards of material over an area of approximately 2,433 square feet from all piers combined.

Exhibit 5-52. Summary of Debris Removal Noise Above 120 dB RMS Underwater Disturbance Threshold

Noise Source	Location[a]	Underwater Distance (m)	Hours/ Day	No. Days	Timing[b]
Bucket dredge	Potentially at all new NPH piers	631	≤12	7 days	Nov 1 – Feb 28

a NPH = North Portland Harbor

b Over the course of in-water construction period in the North Portland Harbor: 2013 to 2017.

5.2.4.2 Effects of Exposure to Debris Removal Noise

The reactions of pinnipeds to debris removal noise have received virtually no study. Previous studies indicate that dredging noise has resulted in avoidance reactions in marine mammals; however, the number of studies is few, limited to only a handful of locations. Thomsen et al. (2009) caution that, given the limited number of studies, the existing published data may not be representative and that it is therefore impossible to extrapolate the potential effects from one area to the next.

In a review of the available literature regarding the effects of dredging noise on marine mammals, Richardson et al. (1995) found studies only related to whales and porpoises, and none related to pinnipeds. The review did, however, find studies related to the response of pinnipeds to "other construction activities," which may be applicable to dredging noise. Three studies of ringed seals during construction of artificial islands in Alaska showed mostly mild reactions ranging from negligible to temporary local displacement. Green and Johnson (1983, as cited in Richardson et al. (1995)) observed that some ringed seals moved away from the disturbance source within a few kilometers of construction. Frost and Lowry (1988, as cited in Richardson et al. [1995]) and Frost et al. (1988, as cited in Richardson et al. 1995) noted that ringed seal density within 3.7 km of construction was less than seal density in areas located more than 3.7 km away. Harbor seals in Kachemak Bay, Alaska, continued to haulout despite construction of hydroelectric facilities located 1,600 m away. Finally, Gentry and Gilman (1990) reported that the strongest reaction to quarrying operations on St. George Island in the Bering Sea was an alert posture when heavy equipment occurred within 100 m of northern fur seals.

In their study about sea lion hazing at Bonneville Dam, Stansell et al. (2009) note that sea lions showed only temporary behavioral responses to underwater loud noises, such as ADDs and seal bombs, and above-water pyrotechnics, which did not cause any measurable interference with foraging or transiting. Sea lions quickly habituated to the noise, some foraging within 20 feet of intense noise. The results suggest that some of individuals that transit through the project area either are already habituated to some loud noises or could readily become habituated.

5.2.1 Effect of Exposure to Debris Removal Noise

There are no established levels of underwater debris removal noise shown to cause injury to seals and sea lions. However, since the maximum expected debris removal noise levels on the CRC project are below any known injury thresholds (190 dB RMS, for impulsive noises), it is unlikely that this activity would produce noise levels that are injurious to seals and sea lions. Additionally, the limited body of literature does not include a single report of injuries caused by noise from underwater excavation.

Debris removal noise is likely to exceed the disturbance threshold (120 dB RMS for non-pulsed continuous noises) for only a short distance from the source (approximately 631 m). Specific responses to noise above this level may range from no response to avoidance to minor disruption of migration and/or feeding. Alternatively, seals and sea lions may become habituated to elevated noise levels (NMFS 2005; Stansell 2009). This is consistent with the literature, which reports only the following behavioral responses to these types of noise sources: no reaction, alertness, avoidance, and habituation. NMFS (2005) posits that continuous noise levels of 120 dB RMS may elicit responses such as avoidance, diving, or changing foraging locations.

Debris removal is only estimated to occur for up to 7 days over the 4-year construction period in North Portland Harbor. If this activity overlaps with pinniped presence, behavioral disturbance is expected to be brief and temporary, restricted to individuals that are transiting the North Portland Harbor portion of the project area. Because many of the individual sea lions transiting the project area are already habituated to hazing at Bonneville Dam and to high levels of existing noise throughout the lower Columbia River, we expect that they would not be especially sensitive to a marginal increase in existing noise. Thus, due to the short duration of this noise, its location only in North Portland Harbor and the high level of existing disturbance throughout the lower Columbia River, noise generated from debris removal is not expected to result in behavioral disturbance that would rise to the level of harassment.

5.2.2 Vessel Noise

Various types of vessels, including barges, tug boats, and small craft, will be present in the project area at various times. Vessel traffic will continually traverse the in-water CRC project area, with activities centered on Piers 2 through 7 of the Columbia River and the new North Portland Harbor bents. Such vessels already use the project area in moderately high numbers; therefore, the vessels to be used in the project area do not represent a new noise source, only a potential increase in the frequency and duration of these noise types.

There are very few controlled tests or repeatable observations related to the reactions of pinnipeds to vessel noise. However, Richardson et al. (1995) reviewed the literature on reactions of pinnipeds to vessels, concluding overall that seals and sea lions showed high tolerance to vessel noise. One study showed that, in water, sea lions tolerated frequent approach of vessels at close range, sometimes even congregating around fishing vessels. Because the project area is heavily traveled by commercial and recreational craft, it seems likely that seals and sea lions that transit project area are already habituated to vessel noise, thus the additional vessels that will occur as a result of CRC project activities will likely not have an effect on these pinnipeds. Therefore, CRC project vessel noise in the project area would be unlikely to rise to the level of harassment.

5.2.3 Physical Disturbance

Vessels, in-water structures, and over-water structures have the potential to cause physical disturbance to seals and sea lions, although in-water and over-water structures will cover no more than 20 percent of the entire channel width at one time (CRC 2010). As previously mentioned, various types of vessels already use the project area in high numbers. Tug boats and barges are slow moving and follow a predictable course. Seals and sea lions will be able to easily avoid these vessels while transiting through the project area, and they are probably already habituated to the presence of numerous vessels, as the lower Columbia River and North Portland Harbor receive high levels of commercial and recreational vessel traffic. Therefore, vessel strikes are extremely unlikely and, thus, discountable. Potential encounters will likely be limited to brief, sporadic behavioral disturbance, if any at all. Such disturbances are not likely to result in a risk of harassment of seals and sea lions transiting the project area.

5.2.4 Effects on Prey

Fish are the primary dietary component of all of the pinniped species in the project area. The Columbia River and North Portland Harbor provides migration and foraging habitat for sturgeon and lamprey, migration and spawning habitat for eulachon, and migration habitat for juvenile and adult salmon and steelhead, as well as some limited rearing habitat for juvenile salmon and steelhead.

There are no physical barriers to fish passage within the project area, nor are there fish passage barriers between the project area and the Pacific Ocean. The proposed project will not involve the creation of permanent physical barriers and, thus, long-term changes in seal and sea lion prey species distribution are not expected to occur.

Any adverse effects to prey species will occur during project construction and are temporary. All project activities will be conducted using the BMPs and minimization measures outlined in Section 6. Given the large numbers of fish in the Columbia River, the short-term nature of effects to fish populations, and extensive BMPs and minimization measures to protect fish during construction, as well as conservation and habitat mitigation measures that will continue into the future, the project is not expected to have measurable effects on the distribution or abundance of potential prey species in the long term. Therefore, temporary habitat impacts are expected to have a negligible impact to habitat for pinniped prey species. These effects to prey species are summarized below and are outlined in more detail in Sections 6.1 to 6.3 of the CRC project BA.

Noise from pile installation may harm (impact driving) or cause behavioral disturbance to fish (impact or vibratory installation of steel pipe pile, vibratory installation of steel pipe pile, sheet pile, and steel casings for drilled shaft placement). Avoidance and minimization measures will be implemented to limit effects to fish due to noise from impact pile-driving. These measures include: use of drilled shafts for bridge foundation rather than impact driving of 8-foot-diameter steel pipe piles, minimization of the number of in-water piers or bents, restricting impact pile driving to the amount needed for proofing of load-bearing piles only, timing windows for in-water impact pile driving to avoid the majority of fish runs, use of a noise attenuation devices, vibratory installation of piles to the extent practicable, a hydroacoustic performance measure to monitor and limit the extent of potential incidental fish take, and on-site biological monitors. Nevertheless, impact pile-driving will likely create a temporary migration barrier to all life stages of fish using the Columbia River and North Portland Harbor, although this would be localized. Cofferdams and temporary in-water work structures also may create partial barriers to the migration of juvenile fish in shallow-water habitat. Impacts to fish species distribution will be temporary during in-water work and hydroacoustic impacts from impact pile driving will only occur for limited periods during the day and only during the in-water work window established for this activity in conjunction with ODFW, WDFW, and NMFS. The overall effect to the prey base for seals and sea lions would be insignificant.

Prey may be affected by turbidity, contaminated sediments, or other contaminants in the water column. The CRC project will minimize, avoid, or contain all potential sources of contamination, minimizing the risk of exposure to prey species of seals and sea lions. The CRC project involves several activities that could potentially generate turbidity in the Columbia River and North Portland Harbor, including pile installation, pile removal, installation and removal of cofferdams, installation of steel casings for drilled shafts, and debris removal. Turbidity would not be expected to cause mortality in the fish species using the project area, and effects would probably be limited to temporary avoidance of the discrete areas of elevated turbidity (no more than 300 feet from the source) for approximately 4 to 6 hours at a time (CRC 2010). Therefore, turbidity will have only insignificant effects to fish and, thus, insignificant effects on seals and sea lions.

In-water work is extremely unlikely to mobilize contaminated sediments (CRC 2010). Well in advance of in-water work, the CRC project team will perform an extensive search for evidence of contamination, pinpointing the location, extent, and concentration of the contaminants. Then, BMPs will be implemented to ensure that the CRC project: 1) avoids areas of contaminated sediment or 2) enables responsible parties to initiate cleanup activities for contaminated sediments occurring from construction activities within the project area. These BMPs will be developed and implemented in coordination with regulatory agencies. Because the CRC project will identify the locations of contaminated sediments and use BMPs to ensure that they do not become mobilized, there is little risk that the prey base of seals and sea lions will be greatly affected by or exposed to contaminated sediments.

In-water and near-water construction will employ numerous BMPs and will comply with numerous regulatory permits to ensure that contaminants do not enter surface water bodies. In the unlikely event of accidental release, numerous BMPs and a Pollution Control and Contamination Plan (PCCP) will be implemented to ensure that contaminants are prevented from spreading and are cleaned up quickly. Therefore, contaminants are not likely to significantly affect fish and, thus, effects on the seal and sea lion prey base would also be insignificant.

5.3 Physical Loss of Prey Species Habitat

The project would lead to temporary physical loss of approximately 20,700 square feet of shallow-water habitat. Project elements responsible for temporary physical loss include the footprint of the numerous temporary piles associated with in-water work platforms, work bridges, tower cranes, oscillator support piles, cofferdams, and barge moorings in the Columbia River and North Portland Harbor.

The in-water portions of the new structures would result in the permanent physical loss of approximately 250 square feet of shallow-water habitat at pier complex 7 in the Columbia River. Demolition of the existing Columbia River structures will permanently restore about 6,000 square feet of shallow-water habitat. Overall, there would be a net permanent gain of at least 5,945 square feet of shallow-water habitat in the Columbia River (CRC 2010). At North Portland Harbor, there will be a permanent net loss of about 2,435 square feet of shallow-water habitat at all of the new in-water bridge bents. Note that all North Portland Harbor impacts are in shallow water.

Physical loss of shallow-water habitat is of particular concern for rearing or subyearling migrant salmonids. In general, in-water structures that completely block the nearshore may force these juveniles to swim into deeper-water habitats to circumvent them. Deep-water areas represent lower quality habitat because predation rates are higher there. Numerous studies show that predators such as walleye and northern pikeminnow occur in deepwater habitat for at least part of the year (Johnson 1969; Ager 1976; Paragamian 1989; Wahl 1995; Pribyl et al. 2004). In the case of the CRC project, in-water portions of the structures will not pose a complete blockage to nearshore movement anywhere in the project area. Although these structures will cover potential rearing and nearshore migration areas, the habitat is not rare and is not of particularly high quality. These juveniles will still be able to use the abundant shallow-water habitat available for miles in either direction. Neither the permanent nor the temporary structures will force these juveniles into deeper water, and therefore pose no added risk of predation.

Physical loss of shallow-water habitat will have only negligible effects on foraging, migration, and holding of salmonids that are of the yearling age class or older. These life functions are not dependent on shallow-water habitat for these age classes. Furthermore, the lost habitat is not of particularly high quality. There is abundant similar habitat immediately adjacent along the shorelines of the Columbia River and throughout North Portland Harbor. The lost habitat represents only a small fraction of the remaining habitat available for miles in either direction. There will still be many acres of habitat for yearling or older age-classes of salmonids foraging, migrating, and holding in the project area. Physical loss of shallow-water habitat will have only negligible effects on eulachon and green sturgeon for the same reason as above. The effects to these elements of seal and sea lion habitat would, thus, be minimal.

The CRC project would cause a temporary physical loss of approximately 16,635 square feet of deep-water habitat, consisting chiefly of coarse sand with a small proportion of gravel. CRC project elements responsible for temporary physical loss include the cofferdams and numerous temporary piles associated with in-water work platforms and moorings. The in-water portions of the new structures will result in the permanent physical loss of approximately 6,300 square feet of deep-water habitat at pier complexes 2 through 7 in the Columbia River. Demolition of the existing Columbia River piers will permanently restore about 21,000 square feet of deep-water habitat. Overall, there will be a net permanent gain of about 15,000 square feet of deep-water habitat in the Columbia River.

Although there will be a temporary net physical loss of deep-water habitat, this is not expected to have a significant impact on listed fish. The lost habitat is not rare or of particularly high quality, and there is abundant similar habitat in immediately adjacent areas of the Columbia River and for many miles both upstream and downstream. The lost habitat will represent a very small fraction (far less than 1 percent) of the remaining habitat available. Additionally, the in-water portions of the permanent and temporary in-water structures will occupy no more than about 1 percent of the width of the Columbia River. Therefore, the structures will not pose a physical barrier to fish migration.

In addition, compensatory mitigation for direct permanent habitat loss to jurisdictional waters from permanent pier placement will occur in accordance with requirements set by USACE, Oregon Department of State Lands (DSL), Washington Department of Ecology (Ecology), ODFW, and WDFW. To meet these requirements, CRC is proposing to restore habitat in the lower Lewis River and lower Hood River. At the Hood River site, 1 mile of a historic side channel will be reconnected to the lower Hood River and an existing 21-acre wetland resulting in habitat benefits to salmonids and eulachon. At the Lewis River site, restoration of 18.5 acres of side channels will occur between the lower Lewis River and the lower Columbia River resulting in habitat benefits to salmonid and other native species. Therefore, permanent habitat loss is expected to have a negligible impact to habitat for pinniped prey species.

Due to the small size of the impact relative to the remaining habitat available, and the permanent benefits from habitat restoration, both temporary and permanent physical habitat loss will be insignificant to fish and, thus, to the habitat and foraging opportunities of seals and sea lions.

5.3.1 Work-area Isolation and Fish Salvage

The project would use cofferdams to isolate the in-water work area from active flow during construction in the Columbia River. Cofferdams would be used during demolition of the existing bridge in the Columbia River if a wire saw is not used to cut the existing piers into pieces. The purpose of the cofferdams is to avoid contaminating the Columbia River with work materials or wastes, to contain re-suspended sediments, and to minimize disturbance and injury to fish. Cofferdams would be installed in a manner that minimizes fish entrapment. Sheet piles would be installed from upstream to downstream and lowered slowly until contact with the substrate.

Up to eleven cofferdams are anticipated. The two cofferdams used during construction of Piers 2 and 7 in the Columbia River would cover a combined area of approximately 15,750 square feet. The nine cofferdams used during demolition of the existing in-water Columbia River bridge piers 2 through 10 would each encompass an area of 7,500 square feet (for a total area of 67,500 square feet). Cofferdams would likely be installed and removed at any time of year, pending approval from USFWS and NMFS. ODFW and WDFW have both agreed that performing this activity outside of the standard work window would not cause significant harm to fish. Installation would use low impact methods such as vibrating or pressing into place.

Cofferdams used for construction would each require 10 days to install, be in place for approximately 330 to 470 calendar days apiece, and would require 15 days for removal.

Each cofferdam used for demolition would require 10 days to install, be in place for approximately 20 additional work days apiece, and require approximately 10 work days to remove.

Installation of the cofferdams is likely to generate low-level noise and visual disturbance. For this reason, fish are likely to actively avoid the work area during the construction of cofferdams. Nevertheless, due to the large size of the cofferdams, it is impossible to guarantee that no fish would become trapped inside. To minimize impacts to fish, the project would perform measures to remove fish from the work area during and after the installation of the cofferdams. Fish salvage would be conducted by qualified biologists in compliance with protocols outlined in Section 6. Methods may include seining, electrofishing, trapping, and encouraging volitional movement of fish away from the work area. Captured fish would be released outside of the work area. To avoid entrainment of fish, pump intakes would be screened according to ODFW and WDFW standards and ODOT and WSDOT protocols outlined in Section 6.

The salvage involves capture, direct handling, and transporting of fish; therefore, there is a reasonable risk that the operation may harass, injure, or kill fish. If fish remain trapped in a cofferdam during construction, they would likely perish.

Because the fish salvage operation may take place year round, individuals from any life stage of the fish species using the Columbia River and North Portland Harbor may be exposed to this effect. Exhibit 5-53 shows the species and life stages of fish SOI that may potentially be present within the project area during work-area isolation.

Exhibit 5-53. Species of Interest and Life Stages Expected to be Present in the Project Area during Work Isolation

	Life Stage					
Species	**Spawning**	**Incubation**	**Rearing**	**Outmigrating Juveniles**	**Migrating/ Holding Adults**	**Transiting**
Chinook						
Lower Columbia River ESU			X	X	X	
Upper Columbia River Spring-Run ESU			X	X	X	
Snake River Fall-Run ESU			X	X	X	
Snake River Spring/Summer-Run ESU				X	X	
Steelhead						
Lower Columbia River DPS			X	X	X	
Middle Columbia River DPS				X	X	
Upper Columbia River DPS				X	X	
Snake River Basin DPS				X	X	
Sockeye						
Snake River ESU				X	X	
Coho						
Lower Columbia River ESU			X	X	X	
Chum						
Columbia River ESU			X	X	X	
Bull trout						
Columbia River DPS					X	
Green sturgeon						
Southern DPS					X	
White sturgeon	X	X	X	X	X	X
Eulachon						
Southern DPS	X	X		X	X	
Lamprey Species			X	X	X	X
Resident fish (e.g., sculpin, dace, threespine stickleback, sucker, shiner)	X	X	X			

Adult sea lions are likely to be in the Columbia River during installation and removal of cofferdams. However, they would only use the river for transiting between the Bonneville Dam foraging area and haul-out sites further downstream. Sea lions are unlikely to swim near these construction activities and would probably actively avoid them (see discussion in 5.2.2 above regarding effects of noise on sea lions). Given the project's marine mammal monitoring efforts and sea lions' ability to avoid areas of high noise and disturbance, the project would not create a barrier to normal transit through the project area. Sea lions would not be trapped within cofferdams. Although sea lions would probably be aware of the construction, their avoidance of the area means that the disturbance would be insignificant. The likelihood of exposure to harmful levels of disturbance is discountable. This element of the project is not likely to significantly impact sea lions.

5.3.2 Increase in Overwater Coverage and Shading

The project would create several temporary sources of new overwater coverage in the Columbia River and North Portland Harbor and would increase the overall shade footprint in the project area. Temporary overwater structures include work platforms, work bridges, tower cranes, oscillator support platforms, and barges.

Studies have shown that fish communities under overwater structures differ from those in adjacent areas, in part due to the effect of shading (Southard et al. 2006). In general, shade may affect listed fish by increasing habitat for predators, causing visual disorientation, and decreasing primary productivity.

5.3.2.1 General Effects of Shading on Fish

Overwater coverage increases the amount of shade in the water column. Fish rely on visual cues when performing life functions such as foraging, schooling, avoiding predators, and migration. The literature shows that changes in light conditions can alter fish behavior (Simenstad et al. 1999; Simenstad and Nightingale 2001). Overwater structures that alter the existing light regime may limit the ability of fish to perform essential life functions (Southard et al. 2006). Shade may also affect the productivity of underwater plants, the basis of the food web for many juvenile fish (Simenstad and Nightingale 1999). Finally, shade may affect fish by providing cover for predators (Carrasquero 2001).

Predation

Shade attracts and provides cover for many species of predatory fish, including northern pikeminnow, smallmouth bass, and largemouth bass (Pribyl et al. 2004; Celedonia et al. 2008). The literature does not draw a clear, consistent relationship between an increase in predation and an increase in shade; predation rates have been shown to both increase and decrease with increasing light (Carrasquero 2001). In a review of the available literature, researchers concluded that the effect of shading on predation is "inconclusive" (WSF 2009). However, a literature review conducted by Carrasquero (2001) shows that largemouth and smallmouth bass have a strong affinity for piers and overwater structures, potentially using the cover of darkness to ambush fish. In a study in the Columbia River, Beamesderfer and Riemen (1991, as cited in Celedonia et al. 2008) noted that northern pikeminnow selected low-velocity microhabitats created by in-water structures, where juvenile salmonids were congregating. In a study conducted in the lower Columbia River, Zimmerman (1999) found that smallmouth bass consumed salmonids averaging 119 mm in length, and pikeminnow consumed salmonids averaging 167 mm in length. Relatively few salmonids consumed by pikeminnow were greater than 250 mm in length (Zimmerman 1999). This indicates that predation risks are greater for juvenile salmonids and for other small fish such as dace, threespine stickleback, redside shiners, suckers, and sculpin.

Migration and Orientation

The literature provides empirical evidence that juvenile salmonids, and presumably other fish, may become disoriented beneath overwater structures or other shaded areas with sharp contrast between light and dark. Heiser and Finn (1970), Weitkamp (1982), and Pentec (1997) reported that fish were reluctant to enter shadow zones under docks and or other sources of intense shade. Pentec (1997), Taylor and Willey (1997), Simenstad et al. (1999), Williams et al. (2003), and Toft et al. (2004) reported observing fish movement along the shadow zone boundary without penetration into the shadow. Shreffler and Moursund (1999) found that juvenile Chinook ceased directional movement at the shadow line rather than immediately continuing under an overwater structure. Juvenile salmon consistently swam from the shadow line into the light, then immediately darted down and back into the light-dark transition area again.

Other literature suggests that a sharp light/dark interface caused by overwater structures may interfere with migration in juvenile salmonids. Response of fish to overwater structures is complex, as some fish will readily pass under structures, and others will not. Schools may either disband upon encountering an overwater structure, or they may pause and proceed as a group (Southard et al. 2006). A study conducted by Pacific Northwest National Laboratory (PNNL) (Williams et al. 2003) concluded that overwater structures are likely to be impediments to juvenile migration, depending on numerous factors such as light levels, angle of the sun, cloud cover, current velocity and direction, and tidal stage. For example, the study indicated that effects of shading were reduced during low tide when more light can dissipate beneath overwater structures. The same study also observed that juvenile chum would not cross into shade when the decrease in light level was 85 percent over a horizontal distance of approximately 5 meters. Acoustic tagging at Port Townsend revealed that juvenile Chinook and coho passed under overwater structures more quickly in the evening when the light dark interface is indistinct (Southard et al. 2006). On the other hand, Weitkamp (1982) found that juvenile salmonids will readily swim under overwater structures. Williams et al. (2003) found that salmon fry were not inhibited by the 33 foot-wide shadow cast by an overwater structure at the Mukilteo Ferry Terminal, even though light levels under the structure were 97 percent lower than ambient levels.

Thus, although the literature is not in agreement regarding the effects of a shade on orientation, there appears to be some evidence that a shadow line under overwater structures could interfere with the migration of salmonid juveniles during some daylight hours. Studies have suggested that this may prompt fish to enter deeper water, where they could presumably be exposed to predation from birds, mammals, and other fish (WSF 2009). Additionally, juveniles may congregate at the edge of the shadow line, making them more vulnerable to predation (Southard et al. 2006).

Primary Productivity

Shading may result in decreased productivity of underwater vegetation. Macrophytes, benthic algae, and phytoplankton contribute to aquatic habitat complexity and form the basis of the food web for many species of fish. Carrasquero (2001) notes that lowered light levels may reduce or eliminate macrophyte beds, algae, and other aquatic vegetation beneath overwater structures. This may, in turn limit the amount of prey available to fish (Simenstad and Nightingale 2001). Epibenthic crustaceans are of most concern because they are typically associated with nearshore plants (Simenstad et al. 1999). Loss of underwater vegetation may also reduce cover for juvenile fish, potentially increasing exposure to predation (Carrasquero 2001). Furthermore, shading underneath overwater structures may reduce primary production in phytoplankton. However, this relationship is complex and poorly understood (Carrasquero 2001). For example, there is evidence that primary productivity of phytoplankton may be greater at the edge of overwater structures than in areas outside of the structure (White 1975, as cited in Carrasquero 2001). On the other hand, Mulvihill et al. (1980, as cited in Carrasquero 2001) report that pilings and piers beneath overwater structures may provide substrate for algal growth where bottom depths are below the photic zone or where bottom substrates are unstable. The increase in algal growth may potentially compensate for loss of phytoplankton primary productivity.

5.3.2.2 Sources of Shade on the CRC Project

The CRC project would create several temporary sources of in-water shade: barges, in-water work platforms, work bridges, tower cranes, and oscillator support platforms. There would be a net increase in temporary shade Exhibit 5-54.

Exhibit 5-54 Summary of Temporary Shade Sources in the Columbia River and North Portland Harbor

	Columbia River		North Portland Harbor	
Type	Area (sq. ft.)	Duration in Water (days)	Area (sq. ft.)	Duration in Water (days)
Work platforms/bridges for drilling shafts	148,000	120	29,640	up to 42
Tower cranes	2,400	600	N/A	N/A
Oscillator support platforms	N/A	N/A	27,900	Up to 33
Barges for construction	106,432	Varies	1,085,000	up to 42
Barges for demolition	42,000	~1	N/A	N/A
Total	**256,432**	---	**1,142,540**	---

Construction Barges

Barges would be anchored in the Columbia River and North Portland Harbor to serve as in-water work platforms during construction of in-water and overwater bridge elements. Stationary barges would be used at each of the in-water piers or bents. The shade footprint of moving barges (such as materials and spoils barges) was not included in this analysis. These barges move more or less constantly and on an unpredictable schedule, so it is impossible to quantify the extent or duration of shade cast by these sources.

Although the project would use numerous barges, there would be a limited number of barges in place at any one time. During construction in the Columbia River, there would likely be one to four stationary barges operating in the Columbia River at one time, casting no more than 120,000 square feet of shade at once. In North Portland Harbor, there would likely be no more than six crane barges operating at one time, creating a maximum of approximately 105,000 square feet of shade at one time.

In-Water Structures

The project would use temporary in-water work platforms, work bridges, tower cranes, and oscillator support platforms to support the equipment used to drill shafts in the Columbia River and North Portland Harbor.

In the Columbia River, there would be six temporary work platforms/bridges, one at each of the in-water pier complexes. At pier complexes 2 and 7, the work bridges would be L-shaped, approximately 17,500 square feet and 18,500 square feet in size, respectively. At pier complexes 3 through Pier 6, each work platform would cover an area of approximately 29,000 square feet (Exhibit 5-54). Up to four platforms would be in place at one time. Once drilled shafts are completed, the platforms would be removed. Six temporary tower cranes would be installed, one for each in-water pier complex. Each would shade an area of approximately 400 square feet Including the work platforms, work bridges, and the tower cranes, roughly 125,000 square feet would be shaded at one time in the Columbia River.

In North Portland Harbor, the project would use nine work bridges of different sizes to build the nine bents nearest the shorelines. Only one or two work bridges would be in place at any given time. Additionally, the project would use 31 oscillator support platforms (900 square feet), one for each in-water shaft in North Portland Harbor. Only one to three oscillator support platforms would be in place at once. At any one time, in-water structures in North Portland Harbor would shade no more than 7,180 square feet altogether.

Demolition in the Columbia River would not require shade-producing in-water structures.

Demolition Barges

Demolition of the existing structures in the Columbia River would require one to three stationary barges at any one time, with a maximum shade footprint of approximately 21,000 square feet at once.

There would be no demolition or demolition barges in North Portland Harbor.

5.3.2.3 Potential Effects of Shading on Fish in the CRC Project Area

Temporary overwater structures, including the barges, work platforms, work bridges, oscillator support platforms, and tower cranes, are located at the water line and therefore could create new, high-intensity shade, potentially generating the type of intense light-dark contrast that could attract predators or cause visual disorientation to fish in the Columbia River and North Portland Harbor. This impact would be temporary, limited to the time that these structures are in the water (Exhibit 5-54).

Temporary shading would not be uniform over all of the in-water construction years. In the Columbia River, shading would be limited to the first three pier complexes during the first year, expand to all six in the second, and taper off to three or fewer during the last two years. In North Portland Harbor, temporary shade would be distributed more or less evenly over the first two years of the in-water construction periods with more shade-producing activities concentrated in the last in-water construction year. Temporary shading would be evenly dispersed over the in-water demolition period.

Effects to Predation

The existing Columbia River and North Portland Harbor bridges likely attract predators, such as largemouth bass, smallmouth bass, and northern pikeminnow. The project increases the amount of shade in the project area compared to existing levels, but chiefly on a temporary basis.

It is impossible to quantify the extent to which increased shade may affect predation rates on juveniles. However, it is probable that an increase in predator habitat would increase predation pressure on juvenile salmonids and larval eulachon in the project area during daylight hours. Project related sources of shade likely to attract predators (barges, temporary overwater structures, and shaft caps) are located in juvenile migration routes, creating an opportunity for predators to forage on juveniles during migration. Additionally, rearing juvenile salmonids are present in the project area and could experience increased predation pressure as a result of increased shade. Green sturgeon and bull trout are unlikely to be subjected to increased predation pressure, because only adult and subadults may use the project area and the risk of predation is extremely low for fish of this size (Zimmerman 1999). Likewise, adult salmonids are unlikely to be exposed, for the same reason.

The increase in shade along the nearshore may have particularly adverse effects on certain life stages of juvenile salmonids. In general smaller, rearing and subyearling migrant salmonids are highly dependent on the nearshore. Overwater structures that create a shadow line completely blocking the nearshore may force these runs into deeper water where they could be subjected to higher levels of predation. (It should be noted that the literature does not show widespread agreement on this effect, and therefore this result is not certain to occur). This scenario could occur in several locations: at the temporary work bridges at Columbia River pier complexes 2 and 7, the permanent new shaft cap at pier complex 7 in the Columbia River, and at all of the temporary work bridges in the North Portland Harbor. While all runs of juvenile salmonids could be exposed to increased predation, species that rear in this portion of the project area (LCR Chinook, UCR spring run Chinook, UWR Chinook, LCR coho, and LCR steelhead) and species that migrate as subyearlings through this portion of the project area (CR chum and a portion of the LCR Chinook run) are generally more vulnerable to this effect both because they are dependent on the nearshore and because they are of a small size more easily captured by predators. It is not possible to quantify how many of these individuals would be exposed to increased predation in shallow water.

Effects to Orientation and Migration

As stated earlier, the literature is not in agreement as to whether the light dark interface definitively causes visual disorientation or interference with migration in juvenile salmonids. This analysis assumes a worst case scenario, that is, that all new intense shade sources in the project area may result in visual disorientation during the day time. Assuming this is true, juvenile salmonids could be exposed to this effect during daylight hours when they are present in the Columbia River and North Portland Harbor portions of the project area.

For juvenile salmonids, visual disorientation could presumably lead to delayed migration and increased vulnerability to predation. The literature indicates that these effects are not certain to occur, and in any case, it is impossible to quantify the magnitude of these effects. The project would not create a swath of dense shade that completely spans either the Columbia River or North Portland Harbor stream channel. Therefore, even if the light dark interface does prompt avoidance of the shadow zone, it is not likely to completely block migration. Nighttime migration would be unaffected.

Eulachon larvae do not have volitional movement (Langness 2009 pers. comm.), and are therefore not subject to disorientation.

Green sturgeon are bottom feeders (NMFS 2008e) that inhabit portions of the stream channel with low light levels. Shade effects (particularly, a sharp light/dark interface) are not likely to extend to the depths that green sturgeon inhabit. In addition, their presence in the project area is extremely limited. Therefore, green sturgeon are not likely to experience visual disorientation as a result of increased shade in the project area.

Because bull trout abundance is extremely low in the project area and because the proportion of the project area likely to be exposed to increased shade is very limited, the risk of exposure to this effect is discountable. Additionally, only adult and subadult bull trout could potentially occur in this portion of the project area, and these age classes are not subject to visual disorientation from shade.

The increase of shade in shallow-water habitat may have particularly adverse effects to species that are highly dependent on the nearshore for migration: CR chum and the portion of the LCR run that migrates as subyearlings. Shade may completely overlap shallow-water habitat at the temporary work bridges at Columbia River pier complexes 2 and 7 and at all of the temporary work bridges in the North Portland Harbor, potentially prompting these salmonids to swim into deeper water to circumvent the shadow line. It is not possible to quantify how many individuals may experience delayed migration due to the presence of shade in the nearshore.

Effects to Primary Productivity

The project is not expected to cause significant impacts to primary productivity or the food web for any of the fish species using the project area. The project may reduce the productivity of plants, algae, and phytoplankton occurring both within the photic zone and beneath overwater structures. However, shade would be limited to localized, discrete areas, measuring no more than several hundred to several thousand square feet Barges, work platforms, tower cranes, and oscillator support platforms are temporary sources of shade on the CRC project.

Although the project may result in loss of primary production in shaded areas, this loss is not likely to significantly impact the food web. The project area does not contain habitats that are known to support high primary and secondary productivity for fish. In northwest estuaries, such habitats include areas that produce and retain high levels of detritus: floodplains, vegetated riparian areas with overhanging vegetation, shallow marshes, tidal creeks, dendritic channel networks, low intertidal and subtidal eelgrass beds, emergent vegetation in tidal wetlands, and macroalgal beds (such as mudflats and sandflats). In the Columbia River estuary, detritus is concentrated in low velocity peripheral bay habitats (Bottom et al. 2005). These habitats are completely lacking in the project area, which is dominated by high-velocity open water that is severed from the historical floodplain and lacks emergent vegetation, structural complexity, and riparian areas with overhanging vegetation. In areas of the upper estuary that lack these habitat features, there has been a shift from detritus-based primary production to production dominated by phytoplankton. This has led to widespread loss of food webs supporting epibenthic feeders such as juvenile salmonids (Bottom et al. 2005). This type of food web also favors production of a microdetrital food web dominated by simple celled plants and organic particles (NMFS 2005b), as well as calanoid copepods and other organisms that are not consumed by juvenile salmon (Bottom et al. 2005). Because of the shift in the food web, the suspension/deposit feeder *Corophium salmonisis* is now the most abundant prey item of juvenile salmonids in the estuary. This species is a poor food source because it is low in protein and high in chitin (NMFS 2005b). Because the project area lacks detritus rich habitat types and harbors a microdetrital food web, it provides only limited, low quality foraging habitat and food web support for salmonids.

In shallow-water areas of the lower Columbia River, the large majority of primary productivity is driven by benthic algae, with some contribution from filamentous algae and flowering grasses. Within the water column, primary productivity is driven by phytoplankton (NMFS 2005b). Because shallow water habitat is limited in the project area, the majority of primary productivity is likely driven by phytoplankton.

There have been no known surveys of underwater vegetation or periphyton in the project area. However, in the lower Columbia, small diatoms (*Achnanthes*, *Cocconeis*, and some filamentous blue greens) are expected to be present. Other grazing resistant algae are expected to be present on the riprap along shorelines and on bridge piers, together with filamentous green algae (such as *Cladophora*) and its associated epiphyton (for example, *Rhoicosphenia*, *Cocconeis*, and *Epithemia*). Red algae are also probably very common (Carpenter 2010 pers. comm.).

Typical macrophytes in the lower Columbia River include *Potomogeton crispus*, *Elodea* (*cascadensis*, *nuttallii*, and others), *Ceratophyllum*, and possibly *Hetheranthera dubia*. However, macrophytes are likely not present or are very limited in the project area, as they typically occur in backwater areas (Carpenter 2010 pers. comm.). Because underwater portions of the project area are characterized by high current velocity and an armored streambank, backwater areas are generally lacking, and thus, macrophytes are limited. Additionally, substrate is unstable sand, and the underwater topography slopes off steeply, reducing the size of the photic zone.

Because the project area lacks high-productivity, detritus-based plant communities and is dominated by plankton and periphyton, shading would not impact habitats of particularly high quality. Additionally, outside of the areas potentially influenced by shading, the surrounding area contains dozens of square miles of water available for primary production both upstream and downstream. Shading would only impact a tiny fraction of the remaining area available for primary production, such that there is no measurable reduction in baseline levels of production. All of the listed species that forage in the project area are highly mobile and can readily move to these nearby areas in response to localized impacts to vegetation or the food web. Because the impact is small relative to the amount of habitat present in the surrounding area, this effect would be insignificant.

Beneficial Effects of Shade

Shade may also confer benefits to salmonids using the project area. Salmonids require cool water to perform life history functions. Temperatures of 50 to 57°F are considered adequate to support spawning, migration, and rearing (Bjornn and Reiser 1991). The 303(d) listings for the Columbia River portion of the project area indicate that temperature exceeds standards for spawning, migrating, and rearing salmonids during summer months in the Columbia River and North Portland Harbor (DEQ 2009), with measured temperatures ranging as high as 72°F (USGS 2007). Overwater structures may create shade, resulting in localized areas of cooler water. The temporary overwater structures would create new areas of dense shade that could potentially provide an increase in summertime cool-water refugia compared to the current condition. These increases in shade may confer a benefit to migrating and rearing salmon, although it is impossible to quantify to what extent.

Pacific lamprey are light-sensitive and migrate primarily at night. Lights that have been used at the Columbia River dams for night video migration counts have been shown to repel Pacific lampreys (Ocker et al 2001, NPCC 2004). Therefore, shading would not affect Pacific lamprey but could be affected by artificial lights used at night during construction.

Increased shade would have little or no effect on sea lions since predation rates of salmon and sturgeon, two prey species, are not anticipated to change in a way that would affect population size. Furthermore, Steller sea lions have been shown to rely more on white sturgeon as a food source than salmon (Tackley et al 2008).

5.3.3 Artificial Lighting over Water

The project would require several new sources of overwater artificial lighting to be used during nighttime construction. The following sections outline the general effects of lighting on fish and provide an analysis of the likely effects on fish in the CRC project area.

5.3.3.1 General Effects of Artificial Lighting on Fish

Artificial light sources associated with overwater structures or construction activities may attract fish. Because salmon rely on vision for capturing prey, the artificial lights may improve both prey detection and predator avoidance (Tabor et al. 1998, as cited in Carrasquero 2001). During a study of the Columbia River at Bonneville Pool, Collis et al. (1995) observed that juvenile salmon were attracted to work lights directed at the water surface. In Lake Washington, juvenile Chinook have been observed congregating at night near streetlights on the SR 520 bridge (Celedonia et al. 2008). Tabor et al. (2004) observed sockeye fry in the Cedar River, noting that they were significantly more abundant under city street lights than at nearby sites that were not illuminated. Light levels as low as 0.22 lux (0.020 foot candle) appeared to influence fry behavior. In one location, turning off the streetlights resulted in a significant decrease in the number of sockeye fry present.

Artificial lights may create sharp boundaries between dark and light areas under water. This, in turn, may cause juvenile fish to become disoriented or avoid crossing the light-dark interface, as outlined in detail in Section 5.3.2.1. Williams and Thom (2001) noted that artificial lighting on docks may change nighttime movement patterns in juvenile salmon. Numerous other studies (Fields 1966, Prinslow et al. 1979, Weitkamp 1982, Ratte and Salo 1985, Pentec 1997, Taylor and Willey 1997, and Johnson et al. 1998; as cited in Southard et al. 2006) corroborate these findings, noting behavioral changes in juvenile salmon in response to artificial lighting. McDonald (1960, as cited in Tabor et al. 2004) found that sockeye fry will stop swimming downstream upon encountering artificial lighting, and was able to completely stop nightly migration of sockeye salmon fry with artificial lighting kept on all night at 30 lux (2.8 foot candles). A USFWS (1998) literature review noted that sockeye fry moved through experimental streams more quickly in complete darkness than under bright lights (Tabor et al. 1998). Increased light appeared to inhibit migration of sockeye fry, with significant effects to migration when light levels reached 2.0 lumens/ft^2 (2.0 foot candles). A later study (Tabor et al. 2004) corroborated the finding that fewer sockeye moved through illuminated artificial streams than in darkness, and those that did move, moved more slowly. In this study, light intensity levels from 1.08 to 5.40 lux (0.1 to 0.5 foot candle) appeared to inhibit migration. The same study noted that the delay in outmigration in sockeye fry increased their vulnerability to predation.

Another USFWS study (Tabor and Piaskowski 2001) observed juvenile Chinook in nearshore habitat in Lake Washington, noting that individuals became active when light levels reached 0.08 to 0.21 foot candle and were scarce in the study area when light levels were between 2.2 to 6.5 foot candles. A review of the impact of ferry terminals on juvenile migration in Puget Sound (Simenstad and Nightingale 1999) cites Ali (1958, 1960, and 1962) as stating that light is tremendously important for numerous life functions of chum, coho, sockeye, and pink salmon, noting that feeding, minimum prey capture, and schooling are dependent on light levels lower than 10^{-4} foot candles (similar to a clear, moonless night) and that maximum prey capture for chum and pink fry occurs when the light level is 1.0 foot candle (similar to light levels at dawn and dusk).

Artificial light sources may provide an advantage to predators such as smallmouth bass, largemouth bass, northern pikeminnow, and salmonids. Rainbow trout predation on sockeye fry in artificial streams increased with increased lighting at levels of less than 1.1 lux (Ginetz and Larkin 1976, as cited in Tabor et al. 2004). Northern pikeminnow are attracted to areas where juvenile salmonids congregate, such as hatchery release sites and dams (Collis et al. 1995; Beamesderfer and Rieman 1991). If light sources attract congregations of juvenile salmonids, this could cause an increase in predation by northern pikeminnow. Celedonia et al. (2008) found that smallmouth bass may feed at night in the vicinity of artificial light or under moonlight.

Largemouth bass have been shown to forage efficiently at light levels ranging from low-intensity daylight to full moonlight, with less foraging at light levels equivalent to a starlit, moonless night (McMahon and Holanov 1995).

Tabor et al. (2004) observed the effect of light intensity on cottid predation of sockeye fry in artificial streams, noting that cottids consumed 45 percent of the fry under intense illumination (5.4 lux or 0.50 foot candle), 28 percent under dim light (0.22 lux or 0.020 foot candle), and 5 percent in complete darkness (0 lux or 0 foot candle). The study also observed that fewer fry emigrated in illuminated streams and did so at a faster rate when predators were present than in lighted streams where predators were not present, indicating that the presence of predators may inhibit migration in some individuals. In a field study in the Cedar River, Washington, Tabor et al. (2004) further noted that the number of shoreline fry and rates of predation by cottids increased with an increase in light levels. At one site, shielding the lights to levels of 0.1 to 0.32 lux (0.013 to 0.030 foot candle) substantially reduced predation.

The literature is not in complete agreement about light levels that are likely to impede migration or increase predation on juvenile fish. However, data from Tabor et al. (2004) may present a worst-case scenario. That is, light levels as low as 0.22 lux (0.20 foot candle) may delay migration or increase predation on juvenile salmonids.

5.3.3.2 Effects of Lighting on Fish in the CRC Project Area

Temporary overwater lighting sources would include the cofferdams, barges, work platforms/bridges, oscillator platforms, and tower cranes. Temporary lighting would not be uniform over all of the in-water construction years. During the Columbia River in-water construction period, temporary lighting would be limited to the first three pier complexes during the first year, expand to all six in the second, and taper off to three or fewer during the last 2 years. In North Portland Harbor, temporary lighting would be distributed more or less evenly over the first 2 years of the in-water construction periods with illumination-producing structures concentrated in the last in-water construction year. Temporary lighting would be distributed evenly across the Columbia River in-water demolition period.

The barges and temporary in-water structures would cast light at the water surface during construction and demolition in the Columbia River and North Portland Harbor. At this stage in the project design, the intensity of light likely to be cast on the water surface is not known. However, to the extent practicable, the project would implement conservation measures that minimize the effects of lighting on fish. Measures may include using directional lighting with shielded luminaries to control glare and to direct light onto work areas instead of surface waters.

It is impossible to quantify how many fish would be exposed to increased lighting; however, all of the juvenile fish that use the project area could be exposed to this effect when they are rearing in or migrating through the project area.

It is possible that the increase in lighting in the project area could cause some interference with juvenile salmonid migration. Overwater structures would be limited to discrete locations measuring from several hundred to several thousand square feet and would only span a fraction of the entire channel. While lighting may prompt juvenile fish to avoid the illuminated area, it would not constitute a complete barrier to migrating juvenile fish.

It is also possible that rearing and migrating juvenile salmonids could congregate under light sources, potentially becoming exposed to an increased risk of predation than they are currently. As with effects to migration, it is impossible to quantify the extent to which predation would increase. However, it seems likely that an increase in the conditions that confer an advantage to visual predators could increase levels of predation. Rearing juveniles (LCR Chinook, coho, and steelhead) are present in the area for a relatively long proportion of the year, and therefore could be especially vulnerable to this effect.

Illumination in shallow water may place subyearling migrants (LCR Chinook and CR chum) at particular risk, as these individuals are highly dependent on nearshore areas. This effect is discussed in greater detail in Section 5.3.2.3.

The project would implement BMPs during in-water and upland construction activities to avoid and minimize impacts to water quality. Without implementation of BMPs, water quality could be impacted in a number of ways. Chemical contamination could potentially occur through the accidental release of construction materials or wastes. Upland excavation could lead to erosion, causing turbidity in adjacent water bodies. In-water work (such as pile driving, demolition, debris removal, barge use, and installation of bridge piers) could generate turbidity directly in waterways. The implementation of BMPs would help ensure that these effects would be localized and temporary, limited to the duration of the project, and would result in minimal impacts to water quality.

This section describes the sources of effects to water quality, outlines the BMPs that would be used to contain them, and analyses the potential effects to listed fish. Section 6 outlines the BMPs in further detail.

5.3.3.3 Chemical Contamination

There are numerous potential sources of chemical contamination associated with in-water work in the Columbia River and North Portland Harbor. Potential contamination sources include the following:

- Equipment located in or over water (such as barges or equipment operating on barges, temporary work platforms, the existing structure, or the new structure) are potential sources of contamination.
- Uncured concrete would be used in numerous locations both in and over water for the construction of the piers and superstructure for the new bridges.
- Construction of the superstructure would involve the use of numerous other potential contaminants, including various petroleum products, adhesives, metal solder, concrete and metal dust, asphalt, and others.
- Bridge demolition would occur both in and over water and may release contaminants such as concrete debris, concrete dust created by saw cutting, lead paint, creosote-treated wood, and others.
- There are a total of approximately 1,800 timber piles at the nine existing Columbia River bridge piers. It is assumed that these piles have been chemically treated, based on their age and intended purpose. Contaminants from the piles could be mobilized during demolition of the piers.

Although there are several sources of chemical contaminants, there is a low risk that chemicals would actually enter the Columbia River and North Portland Harbor. A spill prevention, control, and countermeasures (SPCC) plan would be implemented to completely contain sources of chemical contamination such as equipment leaks, uncured concrete, and other pollutants.

During construction of the drilled shafts, uncured concrete would be poured into water-filled steel casings, creating a mix of concrete and water. As the concrete is poured into the casing, it would displace this highly alkaline mixture. The project would implement BMPs to contain the mixture and ensure that it does not enter any surface water body. Once contained, the water would be treated to meet state water quality standards and either released to a wastewater treatment facility or discharged to a surface water body.

In-water bridge demolition would take place only in the Columbia River. All demolition activities would be completely contained within cofferdams. The contractor is required to prepare a demolition plan according to ODOT and WSDOT standard specifications. The plan would be submitted to ODOT and WSDOT and would not be implemented without being approved and stamped by a registered professional engineer. The demolition plan would specify containment methods to ensure that bridge elements and wastes do not enter the Columbia River. Breaking up the concrete piers with an excavator or saw cutter could potentially introduce concrete dust into the water; however, because of the containment proposed, there is minimal risk that dust or debris would enter the Columbia River during demolition. Any concrete wastes would be allowed to settle in the cofferdams before the cofferdams are disassembled. During removal of the cofferdams, released water would meet state water quality standards.

Removal of the timber piles that are deemed navigational hazards and located beneath the existing Columbia River piers would be contained within cofferdams during the demolition of the rest of the piers. There may be, however, some piles that must be removed and are located outside of the cofferdam footprint. These would likely be cut off at or below the mudline. No containment is proposed for the removal of these pilings. However, given the high flow in the Columbia River, dilution of contamination is likely to be high, and the extent of the contamination is expected to be minimal.

The project would obtain several regulatory permits that include terms and conditions for controlling and containing chemical releases to surface water bodies. These permits include: Ecology's 401 Water Quality Certification, WDFW hydraulic project approval (HPA), DEQ's 401 Water Quality Certification, DSL's Removal/Fill Permit, and USACE's 404 Removal/Fill Permit. The project would adhere to the terms and conditions of all of these permits, further minimizing risks to water quality in the Columbia River and North Portland Harbor.

In general, construction equipment operating on land poses a low risk of releasing chemical contaminants (such as petroleum fuel or other fluids) that could enter surface water bodies by way of stormwater inlets, ditches, or other forms of conveyance. Implementation of a Pollution Control Plan would minimize the risk of landward contaminants entering water, to ensure that the risk of contaminant release is discountable. These measures are outlined in greater detail in Section 6. Overall, this aspect of the project is not likely to appreciably impact fish.

5.3.3.4 Turbidity and Suspended Sediment

The project is likely to generate turbidity during the course of in-water work in the Columbia River and North Portland Harbor. Exhibit 5-55 lists the activities that could potentially generate turbidity downstream of each activity and summarizes the effect to the environmental baseline in the Columbia River and North Portland Harbor.

Exhibit 5-55. Potential Sources of Turbidity

Activity	Timing[a]	Location[b]	Likely Extent of Downstream Turbidity	Duration of Effect (hr/day)	Number of Work Days
Install temporary piles, impact methods	9/15 – 4/15	Adjacent to P2 – P7 in CR Adjacent to new NPH shafts	~25 feet	0.66	138 in CR 134 in NPH
Install temporary piles and cofferdams, vibratory methods	Year-round	Adjacent to P2 – P7 in CR Adjacent to new NPH shafts	~25 feet	Up to 24	Continually over ~1015 days in CR ~334 in NPH
Remove temporary piles and cofferdams, direct pull or vibratory	Year-round	Adjacent to P2 – P7 in CR Adjacent to new NPH shafts	Minimal	Up to 24	Continually over ~1015 days in CR ~334 days in NPH
Install steel casings to drill permanent shafts – vibratory hammer, oscillator, or rotator	Year-round	P2 – P7 in CR New NPH shafts	~25 feet	8 – 10	250 / CR pier <1 / NPH shaft
Drill and excavate permanent shafts	Year-round	P2 – P7 in CR New NPH shafts	Minimal (contained)	n/a	100 / CR pier ≤8 / NPH shaft
Operate stationary and moving barges in shallow water	Year-round	P2 – P7 in CR new NPH shafts	<300 feet	Varies	Continually over ~1015 days (CR) ~640 in NPH
Debris removal (clamshell)	11/1 – 02/28	Potentially at 31 locations in NPH.	~300 feet (or as prescribed by permits)	4-6 hr/day, ≤ 4x/day	Less than 7 days
Demolish existing Columbia River bridge piers (includes installation of cofferdams)	Year-round	Existing Piers 2 - 11 in CR	Minimal	8 – 10	~266

a All activities likely to take place within the 4-year in-water construction period.

b CR = Columbia River; NPH = North Portland Harbor, P = pier complex.

Potential Effects to the Environmental Baseline

The project would employ numerous BMPs to minimize the extent and duration of turbidity. These BMPs may include (but would not be limited to) a Spill Prevention/Pollution Control Plan, an Erosion Control Plan, and others as outlined in Section 6. The exact BMPs have not yet been determined. However, these BMPs would ensure that the amount and extent of turbidity would meet the terms and conditions of the two Section 401 Water Quality Certifications that would be obtained from DEQ and Ecology. The certifications would specify a mixing zone for turbidity: that is, a specified distance beyond which turbidity may not exceed ambient levels downstream of the source. We anticipate that the permits would specify a mixing zone of 300 feet downstream of turbidity-generating activities, as this is typical for water bodies the size of the Columbia River and North Portland Harbor (that is, with flows of 300 cubic feet per second [cfs] or greater). Typically, these permits allow exceedance of ambient levels of turbidity for a period of 4 hours within the mixing zone and 2 hours outside of the mixing zone, after which the applicant must stop work until the turbidity dissipates to ambient levels. The project would implement regular water quality monitoring in accordance with the permits to ensure that the project adheres to the permit conditions, with cessation of work if conditions are not met.

In actuality, many of the activities listed in Exhibit 5-55 are not expected to generate large amounts of turbidity. The following activities are expected to generate turbidity at far shorter distance than the anticipated 300-foot mixing zone: installation of piles and cofferdams using impact or vibratory methods, removal of piles and cofferdams using direct pull or vibratory methods, installation of large diameter steel casings using an oscillator, rotator, or vibratory hammer, and demolition activities contained within a cofferdam. These activities do not involve in-water excavation and disturb relatively small amounts of material; therefore, the potential for generating turbidity is greatly reduced.

EPA advises that turbidity extends no more than 25 feet from the source during impact or vibratory pile installation (WSF 2009). Assuming that this is an average value observed over a range of substrate types and flow levels, we expect this threshold distance to be achievable on the CRC project. The Columbia River and North Portland Harbor are large water bodies, providing very high levels of dilution, and reducing size of the potential mixing zone. Additionally, substrates in these water bodies are coarse sand, which settles in relatively short distances compared to finer sediments. Given these mitigating circumstances, we expect that turbidity levels in the CRC project area would be similar to average conditions in other streams, or at least not exceed them. Therefore, we expect that the turbidity would extend to no more than 25 feet from installation of piles, cofferdams, and the steel casings for drilled shafts.

Few studies document the magnitude or extent of turbidity resulting from pile removal. Roni and Weitkamp (1996) reported that pile removal in Manchester, Washington, generated turbidity at less than 1 Nephelometric Turbidity Unit (NTU) above background levels. Washington State Ferries (WSF) performed water quality monitoring during pile removal at Friday Harbor Ferry Terminal; they reported that turbidity levels did not exceed 1 NTU above background levels and were less than 0.5 NTU above background for most of the samples. WSF also performed water quality monitoring during pile removal at Eagle Harbor Maintenance Facility in 2005, reporting that removal of steel and creosote pile resulted in turbidity levels of no more than 0.2 NTU. These values represent extremely small increases above background turbidity levels. Given that the Columbia River and North Portland Harbor have very high dilution capacity and given that substrate in the project area is coarse sediment that settles readily, it is expected that turbidity generated by removal of piles and cofferdams would dissipate within a minimal distance Specifically, it is assumed that this distance would be less than that for pile installation (25 feet), as pile removal displaces less sediment than pile installation.

Drilling and cleaning the permanent shafts would introduce only minimal amounts of sediment into the water. All of the drilling and excavation would occur within the closed steel casings. To the extent practicable, excavated materials would not be allowed to enter the water, but would be stored in contained areas on the barges or work platforms and transported to a permitted upland disposal site.

Debris removal is the only aspect of in-water work likely to generate significant amounts of turbidity. Debris removal could potentially occur at discrete locations in North Portland Harbor. While debris removal is not certain to occur, this information is presented as a worst-case analysis.

There are anecdotal reports that remnant pieces of the original North Portland Harbor bridge (including riprap used as scour protection), still remain on the stream floor. The exact location of the material is not known, but the design team believes that it occurs in several scattered locations, potentially within the footprint of any of the new North Portland Harbor bridge shafts. If this is the case, the material must be removed before drilled shafts can be installed in these locations. Before debris removal begins, divers would pinpoint the locations of the material.

Debris removal would be performed only in the precise locations where the material occurs within the footprint of the new bents, greatly minimizing the areal extent of the activity. As stated previously, the amount of material in this location is not known. Assuming a worst-case scenario, that the area of the material is the same as the footprint of the drilled shafts, the project would remove debris at each of the 31 new bridge shafts (encompassing an area of roughly 2,433 square feet, total). The design team estimates that no more than 90 cubic yards of material would be removed.

Due to the large size of the North Portland Harbor, the design team anticipates that it would not be possible to install physical BMPs to contain turbidity during debris removal in these locations. Regardless, the project would comply with the terms of all permits related to in-water turbidity, and turbidity would not exceed the levels, distance, or duration specified by the permits. Depending on the permit specifications, the turbidity plumes are expected to reach no more than 300 feet downstream of the source for a duration of no more than 4 to 6 hours. In all cases, debris removal would be performed using a clamshell and at a slow, controlled pace to minimize turbidity.

Barges operating in shallow water have the potential to produce turbidity at Pier Complexes 2 and 7 in the Columbia River and at all of the new North Portland Harbor bents. Barges would have a draft depth of about 13 feet and would operate in water as shallow as 20 feet deep. Therefore, barge propellers may produce turbulence that causes sediments to become suspended. Additionally, tug boats that position barges may also have propellers that generate suspended sediment. Tug boats would operate only during discrete time periods to 1) position the work barges at each of the shallow-water piers (Pier Complex 7 in the Columbia River and all North Portland Harbor bents) and 2) to remove them when work is completed. These barges would remain stationary for the duration of the work, and therefore have little potential to produce turbidity. Additionally, there would be one or two barges at each of the shallow-water piers used to store and move materials and dredge spoils. These barges would make numerous trips, as needed, operating on a sporadic schedule. Because the schedule is unknown, it is not possible to predict the timing and duration of the turbidity plumes. In any case, the size of the plumes is expected to be much smaller than the typical plume created by dredging (estimated to be no more than 300 feet). Given that sediment in this portion of the project area consists mainly of coarse material with only minor amounts of fines, suspended sediment is expected to settle quickly, further restricting the size of the potential turbidity plume. Additionally, compared with the existing energy generated by high velocity flow in this portion of the project area, disturbance of sediment by tug and work boat propellers is expected to be minimal. Because little aquatic vegetation is present in this portion of the project area, turbidity generated by barges and tug boats is not expected to have a significant impact on underwater vegetation. In any case, turbidity would not exceed the levels, distance, or duration specified by the permits. Construction barges would not be grounded.

Demolition would involve cutting, breaking, and removing the nine existing Columbia River bridge piers. Exact demolition methods are unknown at this time and would be determined by the contractor at a later date. However, the CRC team anticipates that all demolition work would be performed from barges and would be completely contained inside of enclosed cofferdams. Installation and removal of the cofferdams is the only aspect of bridge demolition likely to cause turbidity. Turbidity is likely to extend only a minimal distance from the source (Exhibit 5-55) and could potentially be present for the duration of the time it takes to install or remove each cofferdam. Installation of the cofferdam, demolition of the pier, and removal of the cofferdam is expected to take 40 days throughout the 18-month in-water demolition period. In any case, turbidity would not exceed the levels, distance, or duration specified by the permits.

In general, upland excavation has the potential to cause erosion, which in turn may introduce suspended sediments into water bodies by way of stormwater inlets, ditches, or other forms of conveyance. However, it is not likely that upland construction would cause turbidity in the CRC project area water bodies. To prevent the introduction of sediments into waterways from upland excavation, the project would adhere to an erosion control plan that specifies the type and placement of BMPs, mandates frequent inspections, and outlines contingency plans in the event of failure. Additionally, in many cases, there would likely be numerous other barriers between the potential sources and the project area water bodies. Therefore, there is only a discountable risk that upland excavation would generate turbidity in project area water bodies. Erosion control specifications are outlined in further detail in Section 6.

General Effects of Turbidity on Fish

Turbidity is a naturally occurring phenomenon; however, turbidity above background levels may harm fish. Several factors contribute to turbidity levels in water, including suspended sediments, dissolved particles, finely divided organic and inorganic matter, chemicals, plankton, and other microscopic organisms. Not all of these materials are necessarily harmful, meaning that turbidity levels alone may not accurately indicate the effect on fish. TSS a direct measure of particles transported in the water column, may be a more useful indicator of the effect to fish. However, due to the ease of taking turbidity measurements, turbidity is in widespread use throughout the literature as an indicator of the effect of suspended sediments on fish (Bash et al. 2001).

The response of fish to turbidity is complex. High levels of turbidity may be fatal to salmonids, but salmonids may also be affected by turbidity at relatively low levels (Lloyd 1987). Juvenile salmonids have been observed in naturally turbid estuaries and highly turbid glacial streams, which indicates that that salmon are able to cope with elevated turbidity during certain life stages (Gregory and Northcote 1993, as cited in Bash et al. 2001). In contrast, salmonids not normally exposed to elevated turbidity levels may be appreciably impacted at relatively low levels (Gregory 1992, as cited in Bash et al. 2001). The severity of effect depends on a variety of factors, such as the turbidity level, extent of the turbidity plume, the duration and frequency of exposure, the toxicity and angularity of the particles, life stage of the fish, and access to "turbidity refugia" (Bash et al. 2001). Depending on the amount of exposure, turbidity above background levels may prompt the following effects: direct mortality, gill tissue damage, physiological stress, and behavioral effects.

Numerous studies document that direct mortality for juvenile salmonids occurs at a 96-hour median sediment concentration of 6,000 mg/L (Stober et al. 1981 as cited in Bash et al. 2001; Salo et al. 1980; LeGore and DesVoigne 1973 as cited in WSF 2009).

Suspended sediments have been shown to damage gill structure (Noggle 1978). When the filaments of salmonid gills are clogged with sediment, fish attempt to expunge the sediment by opening and closing their gills excessively, in a physiological process known as "coughing." In response to the irritation, the gills may secrete a protective layer of mucus. Although this may interfere with respiration, it is not a lethal effect (Berg 1982, as cited in Bash et al. 2001). Servizi and Martens (1992) noted a significant increase in coughing in subyearling coho when turbidity measured 30 NTU. Berg (1982, as cited in Bash et al. 2001) observed a significant increase in coughing in juvenile coho at 60 NTU, with a decline or return to pre-exposure levels of coughing at 10 NTU. This indicates that turbidity somewhere between 10 and 30 NTUs may cause onset of coughing. Servizi and Martens (1987) found that gill trauma occurred in subyearling sockeye at suspended sediment concentrations of 3,148 mg/L.

The literature indicates that exposure to suspended sediments may cause stress response in both adult and juvenile salmonids. Physiological stress generally manifests itself as elevated blood sugar, plasma glucose, and plasma cortisol (Bash et al. 2001). Redding et al. (1987) observed physiological stress in subyearling coho after exposure to sediment concentrations of 2,000 mg/L for 7 to 8 days. Servizi and Martens (1987) observed elevated blood glucose levels in adult and juvenile sockeye after contact with fine sediment. In adults, this response occurred at concentrations of 500 to 1,500 mg/L after exposure for 2 to 8 days. At levels of 150 to 200 mg/L, no stress response was observed (Redding et al. 1987; Servizi and Martens 1987). At the individual level, stress may reduce growth, increase the likelihood of disease, inhibit the development from parr to smolt, disrupt osmotic balance, impair migration, and reduce survival (Wedermeyer and McLeay 1981, as cited in Bash et al. 2001). At the population level, stress may reduce spawning success, increase larval mortality, and decrease overall population abundance (Bash et al. 2001).

Turbidity may also prompt behavioral responses in fish, including avoidance, migration delays, and changes in foraging and predation. Numerous studies document salmonids avoiding suspended sediments and migrating to less turbid areas (Berg 1982; Sigler et al. 1984). Lloyd et al. (1987) showed that juvenile salmonids avoid streams that are chronically turbid unless they cannot avoid these areas on their migration path. Cederholm and Salo (1979) showed that the upstream migration of salmonids in the lower Columbia River may be delayed when water clarity is reduced. On the other hand, adult male Chinook experienced no disruption in migration to spawning grounds after exposure to sediment concentrations of 650 mg/L over 7 days.

The literature is not in complete agreement as to whether or not turbidity increases the rate of prey capture in salmonids. Some studies reveal that fish have decreased foraging success in response to increased turbidity (Berg 1982; Berg and Northcote 1985; Redding et al. 1987; Gardner 1981 as cited in Bash et al. 2001; Boehlert and Morgan 1985 as cited in Bash et al. 2001; Vogel and Beauchamp 1999 as cited in Bash et al. 2001). One study showed decreased foraging at levels as low as 20 NTU (Berg 1982). In contrast, other studies show that juvenile coho, steelhead, and Chinook have increased foraging success in "slightly to moderately turbid" water (Sigler at al. 1984; Gregory and Levings 1998). There is also evidence that suspended sediments may offer cover from predators (Gregory 1993; Gregory and Levings 1996; Davies-Colley and Smith 2001), which may both enhance survival and increase foraging success.

Turbidity and concurrent sedimentation may negatively affect survival of eggs and emergence of fry or larvae. After being deposited in spawning areas, high levels of fines may become embedded in the substrate, reducing the permeation of oxygen into eggs, potentially resulting in mortality. Additionally, deposition of sediment may physically block the emergence of fry or larval fish (Cederholm and Salo 1979).

Effects on Fish in the CRC Project Area

There are few water-quality monitoring studies that cite turbidity levels encountered during installation and removal of piles, cofferdams, and steel casings. Due to the lack of data, the analysis of the effects of turbidity on fish is based on turbidity levels observed during dredging, for which there are numerous monitoring studies. Havis (1988, as cited in WSF 2009)), Salo et al. (1979, as cited in WSF 2009), and Palermo et al. (1990, as cited in WSF 2009) note that typical samples collected within 150 feet of dredging contain sediment concentrations between 50 and 150 mg/L. LaSalle (1988, as cited in WSF 2009) concluded that maximum sediment concentrations resulting from dredging range between 700 and 1,100 mg/L at a distance of approximately 300 feet from the source, based on monitoring data from seven clamshell dredging operations. These levels would be expected for dredging of fine sediments such as silt or clay.

Much lower concentrations, 50 to 150 mg/L, would be expected for dredging in coarser substrates (LaSalle 1988). The CRC in-water project area contains a mixture of coarser sediments and silty sand. Therefore, the amount of turbidity encountered during debris removal is likely to be more than 50 to 150 mg/L but is not expected to exceed 700 to 1,100 mg/L. Turbidity levels for the other activities listed in Exhibit 5-55 (installation and removal of piles and cofferdams, installing large steel casings, barge use, and drilling shafts) are expected to be much lower than levels resulting from dredging.

Turbidity levels on the CRC project are not expected to reach levels that cause mortality in fish. The highest sediment concentrations expected to occur (1,100 mg/L) would be well below levels known to kill fish (6,000 mg/L). Likewise, turbidity levels on the CRC project are not likely to cause gill trauma, as gill trauma occurs at roughly 3,000 mg/L, well above the highest levels of turbidity expected on the project. However, turbidity would likely reach levels that could cause "coughing." Coughing may occur at 30 NTU, a value roughly estimated to be greater than 100 mg/L (Lloyd 1987). Actual exposure to these levels is expected to be minimal, however. Regulatory permits would require restricting the size of the plumes (probably to about 300 feet from the source) and their duration (about 4 to 6 hours). Additionally, because of the large size and the high dilution capacity of the Columbia River and North Portland Harbor, there are abundant turbidity refugia, and listed fish should not become trapped in turbid water. The turbidity would be localized in areas downstream of specific activities (Exhibit 5-55) and would not extend across the entire width of the Columbia River or North Portland Harbor. Therefore, it would not cause a complete barrier to movement. Thus, while turbidity levels are theoretically high enough to prompt coughing in fish, it is unlikely that the duration and extent of exposure would be great enough to cause gill damage.

The project may produce turbidity at levels that could cause physiological stress in fish. Of the studies available, the data indicate that stress may occur at a minimum level of 500 mg/L after several days of exposure. The project may generate a maximum of 1,100 mg/L of sediment concentration, but most activities would generate levels more in the order of 50 to 150 mg/L. On the CRC project, the actual duration of exposure to elevated turbidity is likely to be quite low, as regulatory permits would restrict the size and duration of the turbidity plumes, probably to about 300 feet and to about 4 to 6 hours at a time. Additionally, because of the large size and the high dilution capacity of the Columbia River and North Portland Harbor, listed fish would be able to avoid the turbidity plumes and not become trapped in turbid water. The turbidity would not cause a complete migration barrier. Thus, while turbidity levels are theoretically high enough to prompt stress in fish, it is unlikely that the duration and extent of exposure would be great enough to cause stress.

It is highly likely that turbidity generated by the project would cause both adult and juvenile fish to avoid discrete portions of the work area (Exhibit 5-55), as avoidance has been documented at very low turbidity levels. Turbidity-generating activities would be ongoing for the duration of the 4-year in-water construction period, and, therefore, these activities are likely to intersect up to four migration periods of juvenile salmon and steelhead. The exception is debris removal, which would likely intersect only about 7 days of one juvenile migrational period. Fish would likely circumvent the turbidity plumes and swim into less turbid areas. Whether this avoidance would result in a biologically significant effect is less clear. Although the literature shows that juvenile salmonids may delay migration in response to high turbidity, this may not necessarily be true in the CRC project area for two reasons. First, due to the large size of the Columbia River and North Portland Harbor, turbidity refugia would be abundant, and juvenile fish would probably circumvent the plumes with no significant delay to migration. Second, larger sediment plumes (anticipated to be no more than 300 feet) would occur in the project area for no more than roughly 4 to 6 hours at a time. Therefore, there is ample time for juveniles to migrate between sediment pulses, and even if there were a delay, it would only be for a matter of hours. Adults have not been shown to delay migration even after many days of exposure to high turbidity. Because the CRC project would cause only low exposure (due to the abundance of turbidity refugia) over a limited spatial extent and over short durations, delays to adult migration are not probable.

Turbidity would likely reach levels that have been shown both to enhance and impede foraging abilities in fish. Therefore, we can expect that turbidity generated by the project would cause fish in the project area to increase foraging in some circumstances and decrease foraging in others. There is also evidence that turbidity may provide cover from predators, creating a benefit to juvenile fish. However, due to the uncertainly in the literature, and due to the wide variations in the levels of turbidity shown to cause either of these outcomes, it is impossible to quantify this effect.

Turbidity and resulting sedimentation may affect spawning eulachon in the project area. (Other listed fish would not be exposed to this effect because none spawn in portions of the project area downstream of activities likely to generate turbidity). High levels of turbidity have the potential to smother eggs and block the emergence of larvae (Langness 2009 pers. comm.). There are no known eulachon spawning concentrations in portions of the project area likely to be exposed to elevated turbidity and sedimentation. Given the lack of precise spawning locations, it is assumed that spawning could potentially occur anywhere in the portions of the Columbia River and North Portland Harbor with water depths of 8 to 20 feet, and if spawning occurs in this area, it would likely be exposed to elevated turbidity. In other words, exposure could result from turbidity-generating activities at Pier 7 in the Columbia River and throughout North Portland Harbor. Actual exposure is expected to be quite low, as high levels of turbidity would be limited to approximately 300 feet downstream of the discrete areas where debris removal would occur and would be restricted to a much smaller area for other in-water activities (Exhibit 5-55). This represents a minuscule proportion of the channel and an insignificant fraction of the total available spawning habitat immediately surrounding the affected area for many miles upstream and downstream.

Exposure to eulachon eggs or larvae would be limited to the overlap of 1) the incubation and emergence period, approximately from January through June, with 2) the 4-year in-water construction period. Other resident fish that utilize habitat in the project area for their full life cycle (e.g., sculpins, threespine sticklebacks, suckers, dace, shiners) would also be exposed to turbidity and sedimentation. Exhibit 5-56 summarizes the effect of turbidity and sedimentation on various life functions of fish.

Exhibit 5-56. Summary of Effect of Turbidity and Sedimentation on Life Functions of Fish

Activity/ Timing[a]	Mortality[b]	Gill Damage[c]	Stress[c]	Avoidance	Migration Delay[c]	Foraging/ Predation[d]	Spawning[e]
Debris Removal 11/1 – 2/28	No	Not likely	Not likely	Likely (~300 ft, 4-6 hrs, ~4x/day)	Not likely	Likely	Likely (~300 feet)
Impact installation 9/15 – 4/15	No	Not likely	Not likely	Likely (25 ft, ~1 hr/day)	Not likely	Likely	Likely (~25 feet)
Vibratory installation year-round	No	Not likely	Not likely	Likely (25 ft, ≤24 hr/day)	Not likely	Likely	Likely (~25 feet)
Pile/cofferdam removal year-round	No	Not likely	Not likely	Likely (minimal, ≤24 hr/day)	Not likely	Likely	Likely (minimal)

Activity/ Timing[a]	Mortality[b]	Gill Damage[c]	Stress[c]	Avoidance	Migration Delay[c]	Foraging/ Predation[d]	Spawning[e]
Drilled shafts year-round	No	Not likely	Not likely	Not likely (contained)	Not likely	Likely	Not likely (contained)
Demolition year-round	No	Not likely	Not likely	Likely (minimal, ~8-10 hr/day)	Not likely	Likely	Likely (minimal)
Barges, shallow water year-round	No	Not likely	Not likely	Likely <300 feet	Not likely	Likely	Likely (<300 feet)

a All activities to occur within 4-year in-water constriction period.
b Turbidity would not reach levels known to cause mortality.
c Exposure unlikely due to avoidance, dilution, turbidity refugia, and limited extent and duration of effect.
d Effect likely but not quantifiable.
e Applies to eulachon only.

Exhibit 5-57 summarizes the species and life stages of fish that could potentially be exposed to turbidity and sedimentation in the Columbia River and North Portland Harbor.

Exhibit 5-57. Fish Species Potentially Exposed to Project-generated Turbidity in the Columbia River and North Portland Harbor

	Life Stage				
Species	Spawning	Incubation	Rearing	Juvenile Outmigration	Migrating/ Holding Adults
Chinook					
LCR ESU			X	X	X
UCR Spring-Run ESU			X	X	X
UWR ESU				X	X
SR Fall-Run ESU				X	X
SR Spring/Summer-Run ESU				X	X
Steelhead					
LCR DPS			X	X	X
MCR DPS				X	X
UWR DPS				X	X
UCR DPS				X	X
SR DPS				X	X
Sockeye					
SR ESU				X	X
Coho					
LCR ESU			X	X	X
Chum					
CR ESU			X	X	X
Bull Trout (exposure is discountable due to extremely low numbers in project area)					
CR DPS					X[a]
Green Sturgeon (exposure is discountable due to extremely low numbers in project area)					
Southern DPS					X[a]
Eulachon					
Southern DPS	X	X		X	X

Species	Life Stage				
	Spawning	Incubation	Rearing	Juvenile Outmigration	Migrating/ Holding Adults
Lamprey species			X	X	X
Resident fish (e.g., sculpin, dace, threespine stickleback, sucker, shiner)	X	X	X		

a Includes subadults.

Turbidity is not expected to have an effect on invertebrate distribution or abundance.

Summary of Effects to Aquatic Species

Bull trout and green sturgeon could potentially be exposed to turbidity effects, but due to extremely low numbers of these species in the very limited areas subject to elevated turbidity, exposure would be insignificant.

Adult and juvenile salmon and steelhead (Exhibit 5-57) are likely to be exposed to elevated turbidity, but not at levels likely to cause mortality, gill damage, stress, or migratory delay. Turbidity may reach levels that could cause temporary avoidance of the areas within the discrete mixing zones and timelines outlined in Exhibit 5-55 and 5-56. This is likely an adverse effect.

Adult and larval eulachon, as well as resident fish, are likely to be exposed to elevated turbidity in the same manner as described for salmon and steelhead. Additionally, turbidity and sedimentation may have adverse effects on spawning and potential spawning habitat, but these effects would be limited to discrete areas, representing a miniscule proportion of available spawning habitat. Turbidity is not expected to interfere with migration of larval eulachon, which do not have volitional movement.

The temporary turbidity that is likely to occur from project activities is not expected to reach a level that would impact sea lions. Sea lions in the Columbia River are known to habituate to very high levels of turbidity; for example, at the Bonneville Dam spillway, where they congregate to feed during maximum spring spill (Tennis 2010 pers. comm.). The level of turbidity resulting from project activities is not expected to interfere with sea lions' ability to navigate, respire, avoid predators, or find prey. Therefore, this element of the project is not likely to significantly impact sea lions.

Turbidity is not likely to measurably affect any life stages of lamprey.

5.3.3.5 Contaminated Sediments

State and federal databases have identified upland sites in the project area or immediate vicinity that are known or suspected to contain contaminated media (Parcel Insight 2009). Parcel Insight (2009) compiled information from all of the regulatory databases related to chemical contamination in the project area, including: the federal Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database, Oregon State Environmental Cleanup Site Information (ECSI) database, Oregon and Washington State Leaking Underground Storage Tank (LUST) database, and Oregon State Hazardous Materials (HAZMAT) database. DEQ suspects that four sites in the project area may contain contaminated sediments due to their proximity to the contaminated upland sites and due to available information about past activities on the sites (Parcel Insight 2009).

- Schooner Boat Works Pier 99 is a marine repair facility located on the south bank of North Portland Harbor, east of I-5. The facility appears in the ECSI and CERCLIS databases. Metals and petroleum products were detected in on-site soils. Groundwater and sediment at the site have not yet been analyzed. Considering the types of activities conducted at the site and the length of time that these activities occurred, other potential site contaminants may include: organotoxins, toxic metals (such as arsenic, lead, cadmium, chromium, mercury, and zinc), volatile organic compounds, semi-volatile organic compounds, and PCBs. Additionally, regulatory agencies have received complaints about this site releasing materials into the water (Parcel Insight 2009).
- Diversified Marine is a second marine repair facility located on the south bank of North Portland Harbor, west of the I-5 bridge. This facility also appears in the Oregon State HAZMAT and ESCI databases and in the federal CERCLIS database. As for Pier 99, regulatory agencies have received complaints about the Diversified Marine site releasing materials into the water. The record of Pollution Complaints and Spill Reports suggests that on-site activities could have contaminated the site soils and nearby sediments with any of a variety of contaminants used in boat building, maintenance, and repair. These contaminants may include paint chips, toxic metals (such as copper oxide, organotins, lead, cadmium, chromium, mercury, and zinc), petroleum constituents (such as benzene, toluene, ethylbenzene, and PAHs), and organic contaminants such as phthalates, pentachlorophenol, chlorinated solvents, and PCBs (Parcel Insight 2009).
- The site of a former landfill is located on Hayden Island near the Columbia River shoreline and to the west of I-5 at the current location of the Thunderbird Hotel. This unregulated landfill was located in a seasonal lake basin and probably operated between 1950 and 1970, after which it was covered with a 7- to 8-foot layer of clean fill. In 1989, an ARCO gas station that later opened on the eastern edge of the former landfill initiated a study and detected gasoline contamination in the groundwater. Borings also revealed a layer of landfill debris beneath clean fill. The DEQ LUST program (file #26-89-0149) requested a Corrective Action Plan from ARCO, leading to pump-and-treat remediation that began operating in August 1990. Groundwater samples from eight monitoring wells contained dissolved metals, which are most likely a result of leachate percolating through unknown solid wastes in the unsaturated zone (Parcel Insight 2009). Because there is a high connectivity between the groundwater and the Columbia River in this location, it is suspected that metals could be present in the river sediments immediately adjacent to the site.
- The former site of the Boise-Cascade Lumber Mill is located in Vancouver on the north shore of the Columbia River, about 1,500 feet to the west of the I-5 bridge and to the west of the Red Lion Hotel. Based on the industrial history and type of activities conducted on the site, it is possible that these contaminants may have impacted nearby sediments in the Columbia River. However, the USACE performed in-water sediment sampling near the site, but did not detect contaminated sediments (USACE 2008, 2009).

The project would implement several measures to prevent the mobilization of contaminated sediments in the project area. First, the project would complete a Phase I Environmental Site Assessment or each acquired property that could reasonably contain contaminated materials. The Phase I Environmental Site Assessment may identify possible contamination based on the site history, a visual inspection of the site, and a search of federal and state databases of known or suspected contamination sites. If there is evidence of contamination, a Phase II Environmental Site Assessment may be performed to pinpoint the location of the contaminated sediments as well as to measure the extent and concentration of the contaminants. The Phase II Environmental Site Assessment would also identify the specific areas recommended for remedial action.

The project would implement BMPs to ensure that the project either: 1) avoids areas of contaminated sediment or 2) enables responsible parties to initiate cleanup activities for contaminated sediments occurring within the project construction areas. The exact BMPs are not yet determined, but the contractor would be required to develop mitigation and remediation measures in accordance with ODOT and WSDOT standard specifications and all state and federal regulations. The plan would also comply with all regulatory criteria related to contaminated sediments. There would be coordination with regulatory agencies such as DEQ and Ecology on the assessment of site conditions and the cleanup of contaminated sediments. If contaminated sediments are removed from the site, they would be disposed of at a permitted upland disposal site.

Because the project would identify the locations of contaminated sediments and use BMPs to ensure that they do not become mobilized, there is little risk that aquatic species would be exposed to contaminated sediments. This aspect of the project is not likely to measurably affect any fish species.

5.3.4 Avian Predation

Project-related in-water and overwater structures may have an effect on avian predation in the CRC project area. Such structures may include the temporary work platforms/bridges, tower cranes, oscillator support platforms, barges, and cofferdams, as well as the permanent new bridge spans.

Avian predation is known to be a factor that limits salmon recovery in the Columbia River basin (NMFS 2008e). Throughout the basin, birds congregate near man-made structures and eat large numbers of migrating juvenile salmonids (Ruggerone 1986, Roby et al. 2003, and Collis et al. 2002 cited in NMFS 2008e). Basin wide, avian predation is high enough to constitute a substantial portion of the mortality rate of several runs of salmon and steelhead (Roby et al. 2003 cited in NMFS 2008e). Predation rates are particularly high in impoundments upstream of dams, dam bypass systems, and dredge spoil islands (NMFS 2008e). Additionally, local environmental factors may exacerbate avian predation. In particular, mainstem dams in the lower Columbia detain suspended sediments, a condition that has increased water clarity, potentially enhancing the foraging success of predaceous birds (NMFS 2008e).

The effects of overwater structures on interactions between salmonids and avian predators are widely recognized but have not been the subject of extensive study (Carrasquero 2001). In a 2001 literature review Carrasquero (2001) determined that there is no quantitative or qualitative evidence that docks, piers, boathouses, or floats either increase or decrease predation on juvenile salmonids. Additionally, the review found no studies related to predator-caused mortality specifically associated with overwater structures. Caspian terns, double-crested cormorants, and various gull species are the principal avian predators in the Columbia River basin (NMFS 2000 cited in NMFS 2008e). Populations in the basin have increased as a result of nesting and feeding habitats caused by the creation of dredge spoil islands, reservoir impoundments, and tailrace bypass outfalls (Roby et al. 2003). However, no studies have demonstrated the use of overwater structures by predaceous birds (Carrasquero 2001).

The overwater structures in the CRC project area are not likely to attract large concentrations of avian predators as do such features as nesting islands, impoundments, or tailraces. Nevertheless, because avian predators are known to congregate on overwater structures and because the project would increase the number of available perches, it is possible that the avian predation rates could increase to some extent within the project area. Specifically, the new bridges could create a permanent increase in the number of perches available. Additionally, the work platforms/bridges, tower cranes, oscillator support platforms, and barges would temporarily increase the number of perches available in the Columbia River and North Portland Harbor. Presumably, avian predation may occur during the overlap of: 1) when overwater structures are present in the project area and 2) when juvenile fish are present in the project area; however, it is impossible to quantify how many individual fish would be affected.

5.3.5 Effects to Aquatic Habitat

5.3.5.1 Shallow-water Habitat

The project would have temporary effects on shallow-water habitat in the Columbia River and North Portland Harbor. Temporary impacts to shallow water include: in-water and overwater structures (work platforms, work barges, tower cranes, oscillator support piles, cofferdams, and barges), turbidity, and elevated underwater noise. Section 4.1.2.1 outlines the role of shallow-water habitat in the life history of fish.

The following ESA-listed and SOI and life stages of fish could be exposed to these effects:

- Holding, feeding, and migration habitat for juveniles and holding and migration habitat for adults in several ESUs/DPSs: LCR coho; CR chum; SR sockeye; LCR, MCR, UCR, and SR steelhead; and LCR, UCR spring-run, SR fall-run, and SR spring/summer-run Chinook.
- Rearing habitat for juvenile Chinook (LCR, UCR spring-run, and UWR), LCR coho, CR chum, and LCR steelhead.
- Adult bull trout migration and holding habitat. Because of the extremely low numbers of bull trout in this portion of the project area, risk of exposure to this effect is discountable.
- Adult and subadult green sturgeon feeding and migration habitat. Because of the extremely low numbers of green sturgeon in this portion of the project area, risk of exposure to this effect is discountable.
- All life stages of white sturgeon.
- Adult and larval eulachon spawning and migration habitat.
- Lamprey ammocoetes may be present in the substrate within the project area. Project work would remove or disturb substrate that may contain ammocoetes. Therefore, ammocoetes may be injured or killed. Potential project impacts to this life stage should not be discounted, but because abundance and distribution data are so limited, impacts cannot be quantified at this time. Pacific lamprey are discussed in more detail in Appendix A.
- Impacts to shallow-water habitat would have no effect on sea lions.

Since shallow-water impacts would occur continually throughout the 4-year in-water construction period, as many as four migration cycles of salmon, steelhead, and eulachon could be exposed to these effects. Resident fish may be exposed to these effects year-round during the in-water construction period.

All of these species and life stages may use shallow-water habitat at some point during their presence in the project area. Of these life stages, rearing juvenile salmonids and subyearling migrant salmonids (CR chum and LCR Chinook) may be closely dependent on shallow-water habitat, and therefore are more vulnerable to these effects.

This section outlines the project's short-term effects on fish in shallow-water portions of the CRC project area. These effects include physical loss of habitat, increase in the area of overwater coverage, turbidity, and underwater noise.

Physical Loss of Shallow-Water Habitat

Exhibit 5-58 and Exhibit 5-59 quantify the area affected by short-term physical loss of shallow-water habitat. The project would lead to temporary physical loss of approximately 20,700 square feet of shallow-water habitat. Project elements responsible for temporary physical loss include the footprint of the numerous temporary piles associated with in-water work platforms, work bridges, tower cranes, oscillator support piles, cofferdams, and barge moorings in the Columbia River and North Portland Harbor. Note that all North Portland Harbor impacts are in shallow water.

Exhibit 5-58. Physical Impacts to Shallow-water Habitat in the Columbia River

Structure	Area	Time in Water
Work Platforms – construction (P2 & 7)	728 sq. ft.	150 - 300 days each
Barge moorings – construction (P7)	25 sq. ft.	120 days each
Cofferdams – construction (P7) (about ¼ is in shallow water)	2,000 sq. ft.	240 days each
Barge moorings - demolition (existing Pier 10, 11)	200 sq. ft.	30 days each
Coffer dams – demolition (existing Pier 10, 11)	15,000 sq. ft.	45 days each
Total	**17,753 sq. ft.**	---

Exhibit 5-59. Physical Impacts to Shallow-water Habitat in North Portland Harbor

Structure	Area	Time in Water
Temporary		
Work Platforms – construction (9 locations)	400 to 710 sq. ft.	Up to 42 days each
Oscillator Platforms (31 locations)	1,200 to 1,560 sq. ft.	Up to 34 days each
Barge moorings – construction (8 locations)	318 to 678 sq. ft.	Up to 34 days each
Total	**1,970 to 2,940 sq. ft.**	---

The effect of physical loss of shallow-water habitat is described in detail in Section 4.1.2.1.

In the case of the CRC project, in-water portions of the structures would not pose a complete blockage to nearshore movement anywhere in the project area. Although these structures would cover potential rearing and nearshore migration areas, the habitat is not rare and is not of particularly high quality. These juveniles would still be able to use the abundant shallow-water habitat available for miles in either direction. Neither the permanent nor the temporary structures would force these juveniles into deeper water, and therefore pose no added risk of predation. Additionally, northern pikeminnow and walleye tend to avoid high-velocity areas during the spring juvenile salmonid outmigration (NMFS 2000; Gray and Rondorf 1986; Pribyl et al. 2004). The high velocities present in deep-water portions of the CRC project area may limit the potential for actual predation in deep-water areas.

Physical loss of shallow-water habitat would have only negligible effects on foraging, migration, and holding of salmonids that are of the yearling age class or older. These life functions are not dependent on shallow-water habitat for these age classes. Furthermore, the lost habitat is not of particularly high quality. There is abundant similar habitat immediately adjacent along the shorelines of the Columbia River and throughout North Portland Harbor. The lost habitat represents only a small fraction of the remaining habitat available for miles in either direction. There would still be many acres of habitat for foraging, migrating, and holding.

Physical loss of shallow-water habitat would have only negligible effects on eulachon and green sturgeon for the same reason as above. Resident fish such as dace, threespine stickleback, redside shiners, suckers, and sculpin would be impacted by localized loss of shallow-water habitat, but as is noted above, the lost habitat is not of particularly high quality, and there is abundant similar habitat immediately adjacent along the shorelines of the Columbia River and throughout North Portland Harbor. The lost habitat represents only a small fraction of the remaining habitat available for miles in either direction.

Increase in Overwater Coverage

The project would place several temporary overwater structures in shallow water in the Columbia River and North Portland Harbor. Temporary overwater structures include temporary work platforms, work bridges, oscillator support platforms, and stationary barges. Exhibit 5-60 and Exhibit 5-61 quantify the area and duration of project-related overwater structures in the CRC project area.

Exhibit 5-60. Temporary Overwater Coverage in Shallow-water Habitat in the Columbia River

Structure Type	Area	Duration in Water (days)
Work bridges (P2, P7)	36,000 sq. ft.	150–300 days/pier complex
Barges for Demolition (Existing Piers 10 & 11)	14,350 sq. ft.	Varies up to 30 days/barge
Total Temporary Impact	**50,350 sq. ft.**	---

Exhibit 5-61. Temporary Overwater Coverage in Shallow-water Habitat in North Portland Harbor

Structure Type	Area	Duration in Water
Temporary		
Work Bridges (8 locations)	29,640 sq. ft.	Up to 42 days each
Oscillator Support Platforms (31 locations)	27,900 sq. ft.	Up to 34 days each
Barges for Construction (31 locations)	64,164 sq. ft.	Up to 34 days each
Total Temporary Impact	**108,164 sq. ft.**	---

Temporary structures would not all be present in the project area at the same time. The maximum amount of shade from temporary overwater structures in shallow water in the Columbia River would be no more than about 18,500 square feet at one time. In North Portland Harbor, the maximum amount of shade in shallow water at one time would be about 112,180 square feet.

Effects of overwater coverage on fish and fish habitat are discussed in Section 5.3.2.

Turbidity

The project would also temporarily degrade shallow-water habitat by creating turbidity. Turbidity would pose fairly limited impacts to shallow-water habitat, as the project would restrict the extent of turbidity to distances specified by regulatory permits (anticipated to be 300 feet). The turbidity may make discrete areas temporarily unavailable for foraging, rearing, holding and migration, but only for short periods of time (as specified by the regulatory permits). Fish would be able to use the abundant, similar-quality shallow-water habitat outside of the areas subject to high turbidity.

Underwater Noise

Underwater noise would temporarily degrade shallow-water habitat, creating disturbance in the Columbia River from RM 101 to 118 and in North Portland Harbor 3.5 miles downstream of the project area and 1.9 miles upstream. In these areas, behavioral disturbance is likely to occur. Additionally, underwater noise is expected to cause significant, though temporary, effects to shallow-water habitat, making these areas unsuitable for foraging, rearing, and holding because fish entering this area would be killed or injured. Underwater noise may also create a temporary barrier to migration for both adults and juveniles in these areas during this time period (Caltrans 2009).

5.3.5.2 Deep-water Habitat

Deep-water habitat occurs only in the Columbia River portion of the project area. Aquatic SOI have mixed use of this deep-water habitat.

Fish Distribution in Deep-Water Habitat

Typically, yearling and subyearling migrant salmonids (CR chum and some LCR Chinook) are restricted to shallow-water habitat in the upper estuary (including the project area) (Carter et al. 2009); however, we cannot discount the possibility that some would occasional stray into the surface layer of deeper waters (Bottom et al. 2005). Larger juveniles commonly use deep-water portions of the navigation channel in high numbers during outmigration, taking advantage of higher velocities there (Carter et al. 2009).

Adult salmonids do not show any specific preference for deep-water habitat over shallow-water habitat (Bottom et al. 2005). While they generally migrate at mid-channel, they may be found at depths of 1 to 50 feet (NMFS 2005b). They commonly use deep-water portions of the project area for foraging and hold in low-velocity areas of deep-water habitat (such as behind bridge piers).

Eulachon adults and juveniles are known to forage at depths of greater than 50 to 600 feet and could be present in deep-water portions of the project area (Hay and McCarter 2000).

Adult and subadult green sturgeon use waters at a depth of 30 feet or less and also could be present in deep-water portions of the project area (73 FR 52084).

Effects to Fish in the CRC Project Area

Impacts to deep-water habitat would affect the following species and life stages of fish:

- Feeding, holding and migration habitat for juveniles and holding and migration habitat for adults of the following ESUs/DPSs: LCR coho; CR chum; SR sockeye; LCR, MCR, UCR, and SR steelhead; and LCR, UCR spring-run, SR fall-run, and SR spring/summer-run Chinook.
- Rearing habitat for juvenile Chinook (LCR, UCR spring-run, and UWR), LCR coho, LCR steelhead, and CR chum.
- Adult and subadult bull trout migration and holding habitat. (Because of the extremely low numbers of bull trout in this portion of the project area, risk of exposure to this effect is discountable).

- Adult and subadult green sturgeon feeding and migration habitat. (Because of the extremely low numbers of green sturgeon in this portion of the project area, risk of exposure to this effect is discountable).
- All life stages of white sturgeon.
- Adult and larval eulachon spawning and migration habitat.
- Lamprey ammocoetes may be present in the substrate within the project area. Project work would remove or disturb substrate that may contain ammocoetes. Therefore, ammocoetes may be injured or killed. Potential project impacts to larval, juvenile, or adult lamprey in deep water portions of the project area should not be discounted, but because data are lacking, impacts cannot be quantified at this time. Pacific lamprey are discussed in more detail in Appendix A.

The project would have temporary impacts on deep-water habitat in the Columbia River. These impacts include: physical loss of habitat, increase in overwater coverage, turbidity, and in-water noise.

Physical Loss of Deep-water Habitat

A summary of temporary physical impacts to deep-water habitat in the Columbia River is in Exhibit 5-62.

Exhibit 5-62. Physical Impacts to Deep-water Habitat in the Columbia River

Structure Type	Area	Time in Water
Work platforms – construction (P3 – P6) [a]	3,870 sq. ft.	150-300 days each
Tower cranes – construction (P2 – P7)	603 sq. ft.	350 days/crane
Barge moorings – construction (P2 – P6)	226 sq. ft.	120 days /pier complex
Barge moorings - demolition (existing Piers 2 – 9)	754 sq. ft.	40 days/pier complex
Coffer dams – demolition (existing Piers 2 – 9)	52,500 sq. ft.	~317 days
Total	**57,953 sq. ft.**	---

P = Pier Complex

The structures shown in Exhibit 5-62 would not all be in place at the same time. During construction, temporary structures would occupy no more than 1,080 square feet of substrate in deep water at one time. During demolition, temporary structures would occupy no more than 15,100 square feet of substrate in deep water at one time.

Although there would be a temporary net physical loss of deep-water habitat, this is not expected to have a significant impact on fish. None of the fish SOI are particularly dependent on deep-water habitat. The lost habitat is not rare or of particularly high quality, and there is abundant similar habitat in immediately adjacent areas of the Columbia River and for many miles both upstream and downstream. The lost habitat would represent a very small fraction (far less than 1 percent) of the remaining habitat available. Additionally, the in-water portions of the permanent and temporary in-water structures would occupy no more than about 1 percent of the width of the Columbia River. Therefore, the structures would not pose a physical barrier to migration. Due to the small size of the impact relative to the remaining habitat available, this effect would be insignificant.

Increase in Overwater Coverage

The project would place several temporary overwater structures in deep-water portions of the Columbia River including work platforms, tower cranes, and stationary barges. Exhibit 5-63 quantifies the area and duration of temporary overwater structures in deep-water portions of the project area, showing that there would be a net temporary increase in shade in the project area.

Exhibit 5-63. Overwater Coverage in Deep-water Habitat in the Columbia River

Structure Type	Area	Duration in Water (days)
Work Platforms for Drilling Shafts (P 3 – 6)a	112,000 sq. ft.	260 – 315 / platform
Tower Cranes (P 2 – 7)	2,400 sq. ft.	150 – 200 /crane
Barges for Construction (P 3 – 6)	106,432 sq. ft.	300 – 480 / complex
Barges for Demolition (Existing Piers 2 – 9)	14,350 sq. ft.	~320
Total	**235,182 sq. ft.**	

P = Pier Complex

General effects of overwater coverage on fish are described in detail in Section 5.3.2.1. In summary, overwater coverage creates dense shade that may attract predators and may cause visual disorientation to juvenile fish, which may in turn result in delayed migration and increased vulnerability to predators. Of the juvenile fish that use the project area, rearing juveniles and subyearling-migrant salmonids are highly dependent on shallow-water habitat and therefore are less vulnerable to these effects in deep water. However, as these individuals are not restricted to the nearshore (Bottom et al. 2005), they may stray into deeper water, and there is a small chance of exposure to these effects. Larger juveniles of the yearling age class or older commonly use deep-water habitat during migration, and therefore are likely to be exposed to these effects.

The temporary structures would not create a swath of dense shade completely spanning deep-water habitat. Therefore, even if these structures were to create a shadow line that juvenile salmonids avoid crossing during daylight hours, juveniles could simply circumvent the shadow, resulting in no measurable delay to migration. Nighttime migration would be unaffected. Larval eulachon do not have volitional movement and are therefore not subject to visual disorientation or migration delays.

The increase in the shade footprint increases the amount of suitable habitat for predators and therefore could presumably increase the number of predators in this portion of the project area. This could potentially cause a temporary and/or permanent increase in predation rates on juveniles, although it is not possible to quantify the extent of this effect. All of the juveniles fish SOI that use this portion of the project area could potentially be exposed to this effect, although it is impossible to quantify the number of fish that could be affected.

Turbidity

The project would temporarily degrade deep-water habitat by creating turbidity. Exhibit 5-64 summarizes the activities likely to generate turbidity in deep water.

Exhibit 5-64. Activities Likely to Generate Turbidity in Deep Water in the Columbia River

Activity	Timing[a]	Location[b]	Likely Extent of Turbidity	Duration of Effect (hr/day)	Number of Work Days
Install temporary piles, impact methods	9/15 – 4/15	Adjacent to P 2 – 7	~25 feet	0.66	~138
Install temporary piles, vibratory methods	Year round	Adjacent to P 2 – 7	~25 feet	up to 24	continually over ~928
Remove temporary piles, direct pull or vibratory	Year round	Adjacent to P 2 – 7	Minimal	up to 24	continually over ~928
Install steel casings to drill permanent shafts – vibratory hammer, oscillator, or rotator	Year round	Adjacent to P 2 – 7	~25 feet	8 – 10	60 – 80 days / pier complex
Drill and excavate permanent shafts	Year round	Adjacent to P 2 – 7	None (contained)	N/A	60 – 80 days / pier complex
Demolish existing Columbia River bridge piers (includes installation and demolition of cofferdams)	Year round	Existing Piers 2 – 9	Minimal	8 – 10	~320

a All activities likely to take place throughout the 4-year in-water construction period.

b P = Pier Complex

General effects of turbidity are described in detail in Section 5.3.3.4. In summary, turbidity would pose fairly limited impacts to deep-water habitat, as the project would restrict the extent of turbidity to distances specified by regulatory permits. It is anticipated that the regulatory permits would specify a mixing zone of no more than 300 feet. In actuality, many of the activities would restrict the turbidity plume to far shorter distances (Exhibit 5-56). Permits would also restrict the duration of each turbidity plume to approximately 4 to 6 hours at a time.

The turbidity plumes may make discrete areas temporarily unavailable for foraging, holding and migration, but only for short periods of time (as specified by the regulatory permits). Due to the high dilution capacity of the Columbia River, turbidity plumes are expected to disperse relatively quickly and within a short distance of the source. Due to the large size of the water body relative to the small size of the turbidity plume, fish are not likely to become trapped in turbid water. Fish would be able to use the abundant turbidity refugia in deep-water habitat outside of the areas subjected to high turbidity. Both adult and juvenile fish could be exposed to this effect.

Underwater Noise

Underwater noise and vibration would have the same effects on deep-water habitat as described for shallow-water habitat above.

5.4 Effects to Terrestrial Resources

5.4.1 Terrestrial Habitat

Terrestrial habitat is likely to be temporarily impacted for construction access along highway right-of-way. Terrestrial habitat that would be impacted by project construction is likely to be of low quality for terrestrial wildlife because it is likely to be within existing highway right-of-way and/or degraded by proximity to existing urban development. Erosion could occur from construction activities. Appropriate avoidance and minimization methods (silt fencing, no-work zones, erosion control BMPs) would reduce potential impacts to the riparian areas. Riparian habitat along the Oregon and Washington banks of the Columbia River would be impacted by construction activities including any of the following: deconstruction of existing structures, construction of new bridge elements, access to work areas, workers on foot, vehicles, survey crews, and other related construction presence along the banks. Riparian vegetation, including herbaceous plants, shrubs, and small trees, may be trampled or removed. Because the condition of the riparian area is currently fairly degraded due to the urban location, construction activities may further compromise riparian function and ability to provide habitat features for terrestrial species including mammals and migratory birds. Mitigation measures would address impacts to the riparian community and are likely to result in a net improvement in riparian function relative to current conditions.

5.4.2 Riparian Habitat

In North Portland Harbor and the Columbia River, effects to riparian habitat would be negligible, as there is very little functioning riparian vegetation in the project area. The project would revegetate disturbed shoreline areas, resulting in a net benefit to riparian habitat in the long term. It has not yet been determined exactly where replanting would take place. However, it is anticipated that replanting would occur on or adjacent to the current sites of the trees where practicable. In any case, the number, type, and size of the replanted trees would be selected to comply with standards outlined in the City of Portland and City of Vancouver tree ordinances.

In Oregon, the project would remove three deciduous trees, all with trunks less than 1 foot in diameter, from the riparian zone on the south bank of the Columbia River. The project would also remove two deciduous ornamental trees from the riparian zone adjacent to North Portland Harbor. These trees are located in a landscaped setting and have trunks of approximately 1 foot in diameter. In Washington, 10 trees with trunks less than 1 foot in diameter would be removed from the riparian zone on the north shore of the Columbia River.

In general, removal of trees from riparian areas results in a reduction of shade in the water column and a concurrent increase in water temperature. However, in the case of the CRC project, only approximately 15 trees would be removed from the Columbia River/North Portland Harbor riparian area. This represents an extremely small amount of shaded water (less than 10,000 square feet, patchily distributed among at least three locations) relative to the thousands of acres of unshaded water located immediately adjacent to the area from which trees would be removed. Because of the small size of the shaded area relative to the large volume of water and because of the high current velocity in these water bodies, it is unlikely that these fifteen riparian trees create enough shade to measurably decrease water temperatures in the water column. Thus, the loss of these trees is expected to cause only negligible effects to water temperature, if any.

Additionally, removal of trees from riparian areas may reduce the potential for large woody debris recruitment in a watershed over the long term. However, given the large size of the lower Columbia system and the thousands of remaining riparian trees in this area, removal of 15 trees would not measurably decrease the potential for long-term large woody debris recruitment in the project area or in the lower Columbia system overall.

There would be no excavation, vegetation clearing, or removal of trees from the Columbia Slough riparian area. Therefore, the project would have no effect on Columbia Slough riparian habitat.

The project would not remove any trees from the Burnt Bridge Creek riparian area. Temporary impacts from construction may include some clearing of, or temporary storage in, this area. However, after construction is complete, exposed soil would be revegetated with native vegetation, resulting in no long-term impact.

5.4.2.1 LPA with Highway Phasing

Should the project improvements at SR 500 be deferred under the LPA with highway phasing option, temporary riparian impacts near Burnt Bridge Creek would also be deferred.

5.4.3 Threatened, Endangered, and Proposed Species

Short-term effects to listed and proposed aquatic species are discussed throughout Section 5. No federally listed terrestrial species are known to occur in the project area. Effects to state listed terrestrial species are discussed in the sections below.

5.4.4 Species of Interest

Terrestrial resources, such as protected birds and other SOI, would be impacted because construction activity would create noise disturbance and disruption of potential nesting and/or roosting habitat as the bridge structures are deconstructed or retrofitted. Migratory bird nesting and roosting habitat (e.g., the structures of the existing bridge) would be permanently removed. Construction activities conducted during nesting season could cause excessive disturbance through noise and physical displacement of bridge structures, resulting in nest failure and/or the need to remove active nests.

Although the existing bridge does not provide ideal roosting habitat for bats, several bat species that may pass near the existing bridge and use it for temporary roosting may be affected by construction disturbance. Short-term effects to raccoons, bats, reptiles, and other terrestrial wildlife could result from high levels of noise, clearing/alteration of vegetation, potential impacts to water quality, and other disturbances that could affect breeding, foraging, and dispersal.

5.4.5 Acoustic Impacts to Terrestrial Species

Construction activities conducted during nesting season could cause excessive disturbance through noise and physical displacement of bridge structures, resulting in nest failure and/or the need to remove active nests. Peregrine falcons are known to use the existing bridge and would be directly impacted by noise disturbance if construction activities occurred during nesting and fledging season. Although no other state or federally protected birds (e.g., bald eagles) are known to nest in or near the project area, compliance with applicable regulations such as the federal MBTA would occur. In addition, construction activities would need to comply with city ordinances on noise production.

5.4.6 Wildlife Passage

Given the highly developed character of the project area, wildlife passage is degraded and severely limited in the project area. Passage is most likely to occur along river banks (particularly for waterfowl) and between vegetated areas that offer some cover. Wildlife passage may be even further impaired during construction as construction equipment is mobilized, stored, and used, and as construction activities occur on or near river banks. Effects to wildlife could include altered behavior to avoid construction activities (e.g., moving through more developed areas), and could increase the risks of human/wildlife conflicts and wildlife mortality.

5.5 Effects to Botanical Resources

Temporary impacts to vegetation are anticipated (see discussion above relevant to terrestrial habitat). No listed or otherwise rare plants are known to occur in the project area, and are therefore not expected to be impacted.

6. Proposed Mitigation for Adverse Effects

6.1 Introduction

Mitigation for impacts to aquatic, terrestrial, and botanical resources may include BMPs, conservation measures, and avoidance and minimization measures. Standard construction BMPs and conservation measures would be implemented to avoid or minimize impacts to ecosystem resources from construction activities. Discussions with agencies from both Washington and Oregon are ongoing to determine specific mitigation measures.

6.2 Proposed Mitigation for Long-term Adverse Effects

6.2.1 Aquatic Resources

Impacts to listed salmonids must be addressed through avoidance and minimization measures. The LPA would impact listed fish species through the presence of large piers in the river that could provide habitat for piscivorous fish and birds, lead to a physical loss of substrate, increase the amount of overwater coverage, affect local flow patterns, and impact streambed conditions through sediment deposition. Potential measures to address these impacts include discouraging piscivorous fish and other predator use of piers, promoting aquatic habitat conservation efforts, and ensuring adherence to water quality standards. Riparian fringe habitat may also be altered during construction and as a result of new bridge design. Revegetation of riparian areas and limited use of riprap would be employed to limit long-term effects. Bio-engineered bank protection may also be considered to address impacts to riparian areas and vegetation.

Impact avoidance and minimization are also addressed through project design alternatives that were considered but not advanced due to impacts to ecosystems and other resources. Certain design alternatives have also been modified to reduce impacts to resources. Examples of design alternatives that were not advanced include a dug tunnel between Vancouver and Portland; significant damming of the Columbia River during project construction; and placement of a park and ride facility on Cold Canyon (northwest of Burnt Bridge Creek). Examples of design alternatives that have been modified include minimization of piers in the river from 21 to 12, reducing the number of bridge spans in the Columbia River from 3 to 2, providing a high level of stormwater treatment, and avoiding Vanport wetlands and the Delta Park area.

The project would be required to offset impacts to aquatic habitat by performing compensatory mitigation as required by Section 404 of the Clean Water Act, a WDFW HPA, Oregon Removal/Fill law, and other regulations. Mitigation under City of Portland and City of Vancouver requirements have not yet been determined, but would also address impacts to aquatic habitat. The project proposes two mitigation sites: the Lower Hood River Powerdale Corridor Off-Channel Wetland Reconnection and the Lewis River Confluence Side Channel Restoration.

6.2.1.1 Lower Hood River Powerdale Corridor Off-Channel Wetland Reconnection

The Lower Hood River Powerdale Corridor Off-Channel Wetland Reconnection site contains the following species of fish: LCR Chinook, LCR steelhead, LCR coho, the Columbia River DPS of bull trout, native resident fish such as sculpins, sticklebacks, and suckers, and potentially Pacific lamprey. This action would remove an earthen berm that currently isolates a historic side channel of the Hood River from the main stem. Long-term beneficial effects of the action would include:

- Increased area of spawning and rearing habitat for salmon and steelhead.
- Native woody vegetation planted throughout the site would provide food chain support, cover, and shade. This would improve foraging, rearing, holding, and migrating habitat for adult and juvenile salmonids.
- Creation of high-flow refuges, improvement of base flows, attenuation of peak flows, and improvements to water quality would result in enhancement of rearing habitat for juvenile salmon and steelhead.
- Placement of large woody debris would create habitat complexity, improving rearing and holding conditions for salmonids.

6.2.1.2 Lewis River Confluence Side-Channel Restoration

The Lewis River Confluence Side-Channel Restoration site contains the following species of fish: LCR Chinook, LCR coho, LCR steelhead, and potentially CR chum, eulachon, green sturgeon, Pacific lamprey, and bull trout. This action would connect a historic side channel with the Lewis River. Long-term beneficial effects are likely to include:

- Increased area of spawning and rearing habitat for salmon and steelhead.
- Native woody vegetation planted throughout the site would provide food chain support, cover, and shade. This would improve foraging, rearing, holding, and migrating habitat for adult and juvenile salmonids.
- Creation of high flow refuges, improvement of base flows, attenuation of peak flows, and improvements to water quality would result in enhancement of rearing habitat for juvenile salmon and steelhead.
- Placement of large woody debris would create habitat complexity, improving rearing and holding conditions for salmonids.

6.2.2 Terrestrial Resources

In general, long-term impacts to terrestrial resources are fairly minimal (see Exhibit 4-18) and would not require extensive mitigation. Long-term impacts to terrestrial resources would be addressed through avoidance and minimization measures, replanting vegetation, and addressing habitat modification for protected birds.

Native migratory birds (e.g., swallows) are not known to consistently utilize the existing bridge structures for nesting or other life stages. Current habitat conditions for migratory birds in the project area, especially along the river banks, are fairly poor and are dominated by urban built environment, with ornamental shrubs and trees providing habitat structure. Opportunities to replant riparian vegetation and to incorporate shrub and tree plantings with improved habitat structure in the project area to improve natural habitat conditions would be identified through ongoing discussions with the regulatory agencies.

Riparian habitat in the project area on both the Oregon and Washington banks is fairly degraded and provides limited habitat for terrestrial wildlife for passage, cover, breeding, feeding, and dispersal. To address the current condition of much of the riparian vegetative community in the project area, as well as the impacts to riparian vegetation from project construction, opportunities to incorporate the improvement of riparian function and habitat, either on-site or off-site within the basin, would be addressed through ongoing discussions with the regulatory agencies. Mitigation for effects to riparian habitat would meet all applicable local, state, and federal requirements.

Impacts to wildlife passage would be addressed through avoidance and minimization measures. Placement of new structures or replacement of existing structures along the I-5 alignment creates obstructions to movement of wildlife. This is particularly true along riparian zones. Although little intact riparian habitat suitable for passage is currently present along the Columbia River and North Portland Harbor, placement of obstructions would create an additional passage obstacle for several decades, thereby limiting potential future connectivity projects. Efforts to improve riparian conditions through replanting riparian vegetation would be considered and discussed with the regulatory agencies, and would potentially be achieved through local jurisdiction requirements.

6.2.3 Botanical Resources

No long-term impacts requiring mitigation are anticipated for botanical resources. No sensitive, listed, or otherwise rare plant species are known to occur in the project area. Vegetation removal, including riparian vegetation, would be temporary and these areas would be replanted (Section 6.3).

6.3 Proposed Mitigation for Adverse Effects during Construction

6.3.1 Aquatic Resources

The LPA would impact listed fish species through in-water work that could result in increased turbidity and suspended sediments, underwater noise, temporary localized dewatering, potential contaminant spills, loss of substrate, increase in overwater coverage, increase in artificial lighting, increased predation by birds and fish, and an increase in hydraulic shadowing. Avoidance and minimization measures to address these impacts would apply to all phases of construction. Impact avoidance would be addressed to the extent possible by redesigning project components with adverse impacts. Impact minimization would be addressed by implementing BMPs (e.g., sediment and erosion control, no-work zones, appropriate flagging and fencing), and using cofferdams around in-water work sites. Measures to minimize turbidity would be implemented any time that work on the streambed occurs. Monitoring would likely be required to assess impacts to fish from in-water work. Avoidance, minimization, and conservation measures are discussed in more detail below.

6.4 Summary of Avoidance, Minimization, and Conservation Measures

6.4.1 General Measures and Conditions

- A biologist shall re-evaluate the project for changes in design and evaluation methods not previously employed in the BA to assess potential impacts associated with those changes, as well as the status and location of listed species, every 6 months until project construction is completed. Re-initiation of consultation with the Services is required if new information reveals project effects that may affect listed species or critical habitat in a manner or to an extent not previously considered. Re-initiation of consultation is also required if the identified action is modified in a manner that causes an effect to species that was not considered in the BA or if a new species is listed or critical habitat is designated that may be affected by the action.

- All work shall be performed according to the requirements and conditions of the regulatory permits issued by federal, state, and local governments. Seasonal restrictions, e.g., work windows, would be applied to the project to avoid or minimize potential impacts to listed or proposed species based on agreement with, and the regulatory permits issued by DSL, WDFW, and USACE in consultation with ODFW, USFWS, and NMFS.
- Drilled shafts would be installed while water is still in the cofferdam. The drilled shaft casing would function to contain and isolate the work. Cofferdams would be installed to minimize fish entrapment. Sheet piles would be installed from upstream to downstream, lowering the sheet piles slowly until contact with the substrate. When cofferdams are used, fish salvage would be conducted according to protocol approved by ODFW, WDFW, and NMFS (see Appendix E of the BA) (CRC 2010).
- Contractor shall provide a qualified fishery biologist to conduct and supervise fish capture and release activity as to minimize risk of injury to fish, in accordance with ODOT Standard Specification 00290.31(i) or its equivalent; and/or the 2009 WSDOT Fish Exclusion Protocols and Standards, or its equivalent.
- The contractor shall prepare a Water Quality Sampling Plan for conducting water quality monitoring for all projects occurring in-water in accordance with the specific conditions issued in the Oregon and Washington 401 Water Quality Certifications. The Plan shall identify a sampling methodology as well as method of implementation to be reviewed and approved by the engineer. If, in the future, a standard water quality monitoring plan is adopted by ODOT and/or WSDOT, this plan, with the agreement of NMFS and USFWS, may replace the contractor plan.
- State DOT policy and construction administration practice in Oregon and Washington is to have a DOT inspector on site during construction. The role of the inspector would ensure contract and permit requirements. ODOT/WSDOT environmental staff would provide guidance and instructions to the onsite inspector to ensure the inspector is aware of permit requirements.
- If in-water dredging is required outside of a cofferdam, a clamshell bucket shall be used. Dredged material shall be disposed of in accordance with relevant permits and approvals.
- Piles that are not in an active construction area and are in place 6 months or longer would have cones or other anti-perching devices installed to discourage perching by piscivorous birds.
- All pumps must employ a fish screen that meets the following specifications:
    - An automated cleaning device with a minimum effective surface area of 2.5 square feet per cubic foot per second, and a nominal maximum approach velocity of 0.4 foot per second, or no automated cleaning device, a minimum effective surface area of 1 square foot per cubic foot per second, and a nominal maximum approach rate of 0.2 foot per second; and
    - a round or square screen mesh that is no larger than 2.38 millimeters (mm) (0.094") in the narrow dimension, or any other shape that is no larger than 1.75 mm (0.069") in the narrow dimension; and
- Each fish screen must be installed, operated, and maintained according to NMFS fish screen criteria.

6.4.2 Spill Prevention/Pollution Control

- The contractor shall prepare a Spill Prevention, Control, and Countermeasures (SPCC) Plan prior to beginning construction. The SPCC Plan shall identify the appropriate spill containment materials; as well as the method of implementation. All elements of the SPCC Plan would be available at the project site at all times. For additional detail, consult ODOT Standard Specification 00290.00 to 00290.90 and/or WSDOT Standard Specification 1-07.15(1). For transit construction in Oregon, consult TriMet Standard Specification 01450{1.04}).
- The contractor would designate at least one employee as the erosion and spill control (ESC) lead. The ESC lead would be responsible for the implementation of the SPCC Plan. The contractor shall meet the requirements of and follow the process described in ODOT Standard Specifications 00290.00 through 00290.30 and/or WSDOT Standard Specification 8-01.3(1)B. The ESC lead shall be listed on the Emergency Contact List as part of ODOT Standard Specification 00290.20(g) and/or WSDOT Standard Specification 1-07.15(1).
- All equipment to be used for construction activities shall be cleaned and inspected prior to arriving at the project site, to ensure no potentially hazardous materials are exposed, no leaks are present, and the equipment is functioning properly. Identify equipment that would be used below OHW. Outline daily inspection and cleanup procedures that would insure that identified equipment is free of all external petroleum-based products. Should a leak be detected on heavy equipment used for the project, the equipment shall be immediately removed from the area and not used again until adequately repaired. Where off-site repair is not practicable, the implemented SPCC Plan would prevent and/or contain accidental spills in the work/repair area to insure no contaminants escape containment to surface waters and cause a violation of applicable water quality standards.
- Operation of construction equipment used for project activities shall occur from on top of floating barge or work decks, existing roads or the streambank (above OHW). Any equipment operating in the water shall use only vegetable-based oils in hydraulic lines.
- All stationary power equipment or storage facilities shall have suitable containment measures outlined in the SPCC Plan to prevent and/or contain accidental spills to insure no contaminants escape containment to surface waters and cause a violation of applicable water quality standards.
- Process water generated on site from construction, demolition or washing activities would be contained and treated to meet applicable water quality standards before entering or re-entering surface waters.
- No paving, chip sealing, or stripe painting would occur during periods of rain or wet weather.
- For projects involving concrete, the implemented SPCC Plan shall establish a concrete truck chute cleanout area to properly contain wet concrete as part of ODOT Standard Specification 00290.30(a)1 and/or WSDOT Standard Specification 1-07.15(1).

6.4.3 Site Erosion/Sediment Control

- The contractor shall prepare a Temporary Erosion and Sediment Control (TESC) Plan and a Source Control Plan and implemented for the project requiring clearing, vegetation removal, grading, ditching, filling, embankment compaction, or excavation. The BMPs in the plans would be used to control sediments from all vegetation removal or ground-disturbing activities. The engineer may require additional temporary control measures beyond the approved TESC Plan if it appears pollution or erosion may result from weather, nature of the materials or progress on the work. For additional detail, consult ODOT Standard Specifications 00280.00 to 00280.90 and/or WSDOT Standard Specification 1-07.15. For transit construction, consult TriMet Standard Specification 02276.

- As part of the TESC Plan, contractor shall delineate clearing limits with orange barrier fencing wherever clearing is proposed in or adjacent to a stream/wetland or its buffer and install perimeter protection/silt fence as needed to protect surface waters and other critical areas. Location would be specified in the field, based upon site conditions and the TESC Plan. For additional silt fence detail, consult ODOT Standard Specification 00280.16(c) and/or WSDOT Standard Specification 8-01.3(9)A.
- The contractor shall identify at least one employee as the ESC lead at preconstruction discussions and the TESC Plan. The contractor shall meet the requirements of and follow the process described in ODOT Standard Specifications Section 00280.30 and/or WSDOT Standard Specification 8-01.3(1)B. The ESC lead shall be listed on the Emergency Contact List as part of ODOT Standard Specification 00290.20(g) and/or WSDOT Standard Specification 1-05.13(1). The ESC lead would also be responsible for ensuring compliance with all local, state, and federal erosion and sediment control requirements.
- All TESC measures shall be inspected on a weekly basis. Contractor shall follow maintenance and repair as described in ODOT Standard Specifications 00280.60 to 00280.70 and/or WSDOT Standard Specification 8-01.3(15). Inspect erosion control measures immediately after each rainfall, and at least daily during for precipitation events of more than 0.5 inches in a 24-hour period.
- For landward construction and demolition, project staging and material storage areas shall be located a minimum of 150 feet from surface waters, in currently developed areas such as parking lots or managed fields, unless a site visit by an ODOT/WSDOT biologist determines the topographic features or other site characteristics allow for site use closer to the edge of surface waters. Excavation activities (dredging not included) shall be accomplished in the dry. All surface water flowing towards the excavation shall be diverted through utilization of cofferdams and/or berms. Cofferdams and berms must be constructed of sandbags, clean rock, steel sheeting, or other non-erodible material.
- Bank shaping shall be limited to the extent as shown on the approved grading plans. Minor adjustments made in the field would occur only after engineer's review and approval. Bio-degradable erosion control blankets would be installed on areas of ground-disturbing activities on steep slopes (1V:3H or steeper) that are susceptible to erosion and within 150 feet of surface waters. Areas of ground-disturbing activities that do not fit the above criteria shall implement erosion control measures as identified in the approved TESC Plan. For additional erosion control blanket detail, consult ODOT Standard Specification 00280.14(e) and/or WSDOT Standard Specification 9-14.5(2)A.
- Erodible materials (material capable of being displaced and transported by rain, wind or surface water runoff) that are temporarily stored or stockpiled for use in project activities shall be covered to prevent sediments from being washed from the storage area to surface waters. Temporary storage or stockpiles must follow measures as described in ODOT Standard Specification 00280.42 and/or WSDOT Standard Specification 8-01.3(1).
- All exposed soils would be stabilized as directed in measures prescribed in the TESC Plan. Hydro-seed all bare soil areas following grading activities, and re-vegetate all temporarily disturbed areas with native vegetation indigenous to the location. For

additional detail, consult ODOT Standard Specifications 01030.00 to 01030.90 and/or WSDOT Standard Specification 8-01.3(1).

- Where site conditions support vegetative growth, native vegetation indigenous to the location would be planted in areas disturbed by construction activities. Re-vegetation of construction easements and other areas would occur after the project is completed. All disturbed riparian vegetation would be replanted. Trees would be planted when consistent with highway safety standards. Riparian vegetation would be replanted with species native to geographic region. Planted vegetation would be maintained and monitored to meet regulatory permit requirements. For additional detail, consult ODOT Standard Specifications 01040.00 to 01040.90 and/or WSDOT Standard Specification 8-01.3(2)F.

6.4.4 Work Zone Lighting

- Site work shall follow local, state and federal permit restrictions for allowable work hours. If work occurs at night, temporary lighting should be used in the night work zones. The work area and its approaches shall be lighted to provide better visibility for drivers to travel safely travel through the work zone and illumination shall be provided wherever workers are present to make them visible.
- During overwater construction contractor would use directional lighting with shielded luminaries to control glare and direct light onto work area; not surface waters.

6.4.5 Hydroacoustics

6.4.5.1 Minimization Measure 1 – Drilled Shafts for Foundations

Permanent foundations for each in-water pier would be installed by means of drilled shafts. This approach significantly reduces the amount of impact pile driving, the size of piles, and amount of in-water noise.

6.4.5.2 Minimization Measure 2 – Piling Installation with Impact Hammers

Installation of piles using impact driving may only occur between September 15 and April 15 of the following year. On an average work day, six piles could be installed using vibratory installation to set the piles; then impact driving to drive the piles to refusal per project specifications to meet load-bearing capacity requirements. No more than two impact pile drivers may be operated simultaneously within the same waterbody channel.

In waters with depths more than 0.67 meters (2 feet) deep, a bubble curtain or other sound attenuation measure would be used for impact driving of pilings. If a bubble curtain or similar measure is used, it would distribute small air bubbles around 100 percent of the piling perimeter for the full depth of the water column. Any other attenuation measure (e.g., temporary noise attenuation pile) must provide 100 percent coverage for the full depth of the pile.

A performance test of the noise attenuation device in accordance with the approved hydroacoustic monitoring plan shall be conducted prior to any impact pile driving. If a bubble curtain or similar measure is utilized, the performance test shall confirm the calculated pressures and flow rates at each manifold ring.

6.4.5.3 Minimization Measure 3 – Impact Pile Installation Hydroacoustic Performance Measure

Sound pressure levels from an impact hammer would be measured in accordance with the hydroacoustic monitoring plan. Recording and calculation of accumulated sound exposure levels shall be performed. Exposure factors shall be calculated using the NMFS moving fish model, based on a fish of over 2 grams with a movement rate of 0.1 meter per second (see Appendix K of the CRC BA [2010]). Exposure factors shall account for all attenuated and unattenuated impact pile driving in both the Columbia River and North Portland Harbor. The accumulated sound exposure level shall be recorded.

The following thresholds must not be exceeded:

1. The maximum weekly exposure factor shall not exceed 0.18649, based on one calendar week. The weekly exposure factor is defined as the proportion of channel affected by impact pile driving as measured by accumulated sound exposure level multiplied by the proportion of a 24-hr day affected multiplied by the proportion of calendar week affected.

2. The maximum yearly (calendar year) total exposure factor shall not exceed 0.202181. The maximum yearly exposure factor is the sum of all weekly exposure factors in one calendar year.

3. The average yearly exposure factor must not exceed 0.120090 per calendar year of construction. The average yearly exposure factor is the mean value of all yearly total exposure factors.

4. A total exposure factor of 0.480359 shall not be exceeded throughout the construction period of the project. The total exposure factor equals the sum of all weekly exposure factors throughout the project.

One 12-hour rest period would occur each work day in which no impact pile driving would occur. In addition, to limit the exposure of migrating fish that may be present in the behavioral disturbance zone,[7] impact striking of piles that produce hydroacoustic levels over 150 dB_{RMS} would not occur for more than 12 hours per work day. Unattenuated pile striking may occur to meet the requirements of the hydroacoustic monitoring plan or account for malfunction of the noise attenuation device, but would not occur more than 300 impact pile strikes per week in the Columbia River and no more than 150 impact pile strikes per week in North Portland Harbor. To ensure that this measure is not being exceeded, an approved hydroacoustic monitoring plan would be in place to test a representative number of piles installed during the project (see Minimization Measure 5).

If the predicted accumulated sound exposure level exceeds the levels described above, then the Services would be contacted within 24 hours to determine a course of action, so that incidental take estimates are not exceeded. Necessary steps may include modifications to the noise attenuation system or method of implementation.

6.4.5.4 Minimization Measure 4 – Hydroacoustic Monitoring

The project would conduct underwater noise monitoring to test the effectiveness of noise attenuation devices. Testing would occur based on an underwater noise monitoring plan based on

[7] Behavioral disturbance is expressed in dB_{RMS} (root mean square) re: 1 μPa.

the most recent version of the Underwater Noise Monitoring Plan Template (http://www.wsdot.wa.gov/Environment/Air/Noise.htm). This template has been developed in cooperation with NMFS, USFWS, and WSDOT and has been approved by NMFS and USFWS for use in Section 7 consultation for transportation projects in Washington.

Testing would occur according to protocols outlined in an Underwater Noise Monitoring Plan (WSDOT 2008). Underwater noise monitoring would occur as follows:

- Hydroacoustic monitoring would occur for a representative number of piles per structure (minimum of five piles installed with an impact hammer).
- Monitoring would occur for piles driven in water depths that are representative of typical water depths found in the areas where piles would be driven.
- Ambient noise would be measured as outlined in the template in the absence of pile driving.

A report that analyzes the results of the monitoring effort would be submitted to the Services as outlined in the monitoring plan template.

Unattenuated impact pile driving for obtaining baseline sound measurements would be limited to the number of piles necessary to obtain an adequate sample size for the project, as defined in the final Hydroacoustic Monitoring Plan.

6.4.5.5 Minimization Measure 5 – Biological Monitoring

A qualified biologist would be present during all impact pile driving operations to observe and report any indications of dead, injured, or distressed fishes, including direct observations of these fishes or increases in bird foraging activity.

6.4.5.6 Minimization Measure 6 – Temporary Pile Removal

Temporary piles shall be removed with a vibratory hammer and shall never be intentionally broken by twisting or bending. Except when piles are hollow and were placed in clean, sand-dominated substrate, the holes left by the removed pile shall be filled with clean native sediments immediately following removal. No filling of holes shall be required when hollow piles are removed from clean, sand-dominated substrates. At locations where hazardous materials are present or adjacent to utilities, temporary piles may be cut off at the mud line with underwater torches.

6.4.6 Marine Mammal Minimization Measures

6.4.6.1 Equipment Noise Standards

To mitigate noise levels and impacts to sea lions, all construction equipment would comply with applicable equipment noise standards of EPA, and all construction equipment would have noise control devices no less effective than those provided on the original equipment.

6.4.6.2 Sound Attenuation Measures

Specific to pile driving, the hydroacoustic minimization measures listed in Section 6.5.4 would be implemented to reduce impacts to sea lions to the greatest extent practicable.

6.4.6.3 Marine Mammal Monitoring

Establishment of Monitoring Zones

For impact pile driving, a safety zone (defined as where SPLs equal or exceed 190 dB RMS) and a disturbance zone (defined as where SPLs equal or exceed 160 dB RMS) would be established. The initial safety and disturbance zones would be established based on the worst-case underwater sound modeled from impact driving of 36- to 48-inch steel pile.

For vibratory pile or vibratory steel casing installation, an initial disturbance zone (defined as where SPLs equal or exceed 120 dB RMS) would be established based on the worst-case sound modeled from vibratory installation of 36- to 72-inch steel pile for pipe piles or the loudest value modeled for sheet piles. Noise levels for vibratory installation of steel sheet or pipe piles are not anticipated to be above the 190 dB RMS thresholds based on literature values; therefore, no safety zone for vibratory installation of steel pile is anticipated. If steel casings for drilled shafts are installed by a vibratory hammer, an initial safety zone of 5 meters would be established.

Once impact or vibratory installation begins, the safety and disturbance zones would either be enlarged or reduced based on actual recorded SPLs from the acoustic monitoring. The zones would be based on actual acoustic monitoring results collected at an approximate 10-meter distance. If new zones are established based on SPL measurements, NMFS requires each new zone be based on the most conservative measurement (i.e., the largest zone configuration).

Exhibit 6-1 and Exhibit 6-2 show initial monitoring distances for safety and disturbance zones in the Columbia River and North Portland Harbor, respectively.

Exhibit 6-1. Initial Underwater Distance to Safety and Disturbance Monitoring Zones in the Columbia River

		Calculated Distance to Monitoring Zones (meters)[a]		
Pile Type	Hammer Type	190 dB RMS[b] Safety Zone	160 dB RMS Disturbance Zone (impulse noise)	120 dB RMS Disturbance Zone (continuous noise)
18- to 24-inch steel pipe	Impact	9	858	N/A
36- to 48-inch steel pipe	Impact	54	5,412	N/A
48-inch steel pipe	Vibratory	N/A	N/A	20,166 upriver 8,851 downriver
120-inch steel casing	Vibratory	~5[c]	N/A	20,166 upriver 8,851 downriver
Sheet pile	Vibratory	N/A	N/A	6,962

a Monitoring zones based on worst case modeled values where the attenuation device is not operating. Upriver and downriver distances vary if a landform is encountered prior to noise attenuating to a threshold value.

b All values unweighted and relative to 1 μPa.

c No source value available. To obtain a worst case estimate, distance is based on extrapolation of vibratory sound values from 36- and 72-inch piles.

Exhibit 6-2. Initial Underwater Distance to Safety and Disturbance Monitoring Zones in North Portland Harbor

		Calculated Distance to Monitoring Zones (meters)[a]		
Pile Type	Hammer Type	190 dB RMS[b] Safety Zone	160 dB RMS Disturbance Zone (impulse noise)	120 dB RMS Disturbance Zone (continuous noise)
18- to 24-inch steel pipe	Impact	9	858	N/A
36- to 48-inch steel pipe	Impact	54	3,058 upriver 5,412 downriver	N/A
48-inch steel pipe	Vibratory	N/A	N/A	3,058 upriver 5,632 downriver
120-inch steel casing	Vibratory	~5[c]	N/A	3,058 upriver 5,632 downriver
Sheet pile	Vibratory	N/A	N/A	3,058 upriver 5,632 downriver

a Monitoring zones based on worst case modeled values where the attenuation device is not operating. Upriver and downriver distances vary if a landform is encountered prior to noise attenuating to a threshold value.

b All values unweighted and relative to 1 μPa.

c No source value available. To obtain a worst case estimate, distance is based on extrapolation of values from 36- and 72-inch piles.

Visual Marine Mammal Monitoring and Pile Driving Shutdown Procedure

The CRC project would develop a monitoring plan in conjunction with NMFS that would collect sighting data for marine mammals observed during activities that include impact or vibratory installation of steel pipe pile, sheet pile, or steel casings. A qualified biologist would be present on site at all times during impact or vibratory installation of steel pile or steel casings. In order to be considered qualified, the biologist would meet the following criteria for marine mammal observers:

- Visual acuity in both eyes (correction is permissible) sufficient for discernment of moving targets at the water's surface with ability to estimate target size and distance. Use of binoculars may be necessary to correctly identify the target.
- Advanced education in biological science, wildlife management, mammalogy, or related fields (Bachelors degree or higher is preferred).
- Experience and ability to conduct field observations and collect data according to assigned protocols (this may include academic experience).
- Experience or training in the field identification of marine mammals (cetaceans and pinnipeds), including the identification of behaviors.
- Sufficient training, orientation, or experience with the construction operation to provide for personal safety during observations.
- Writing skills sufficient to prepare a report of observations that would include information such as the number and type of marine mammals observed; the behavior of marine mammals in the project area during construction, dates and times when observations were conducted; dates and times when in-water construction activities were conducted; dates and times when marine mammals were present at or within the defined safety zone; dates and times when in-water construction activities were suspended to avoid incidental potential injury from construction noise within the defined safety zone; etc.

- Ability to communicate orally, by radio or in person, with project personnel to provide real-time information on marine mammals observed in the area as necessary.

The CRC project proposes the following marine mammal monitoring during any impact or vibratory pile driving:

- Monitoring of safety and disturbance zones would occur for all impact pile driving activities. Monitoring of the disturbance zone would occur for all vibratory pipe or sheet pile installation. No SPLs above 190 dB RMS are anticipated for vibratory installation of pipe or sheet piles; therefore, a safety zone would not be established. If hydroacoustic monitoring of vibratory installation of steel casings for drilled shafts indicates SPLs of 190 dB RMS or higher, then a safety zone would be established and monitored for vibratory installation of steel casings.
- Through acoustic monitoring, the CRC project would determine the actual distance to safety or disturbance zones and establish the new zones at that distance.
- Until determination of safety and disturbance zones is accomplished, monitoring would occur for the area within the calculated zones (Exhibit 6-1 and Exhibit 6-2).
- Safety and disturbance zones would be monitored from a work platform, barge, the existing bridge, or other vantage point or by driving a boat along and within the radius of the zones while visually scanning the area. For activities within a safety zone, full observation of the safety zone would occur. If a small boat is used for monitoring, the boat would remain 50 yards from swimming pinnipeds in accordance with NMFS marine mammal viewing guidelines (NMFS 2007a).
- If vibratory installation of steel pipe piles, sheet piles, or casings occurs after dark, the disturbance zone would be monitored with a night vision scope and/or other suitable device. Vibratory installation of steel pipe piles or sheet piles is not expected to produce SPLs at or above 190 dB RMS; therefore, no safety zone would be established or monitored for these activities. If hydroacoustic monitoring of vibratory installation of steel casings for drilled shafts indicates SPLs of 190 dB RMS or higher, then a safety zone would be established and monitored with a night vision scope and/or other suitable device.
- If the safety zone is obscured by fog or poor lighting conditions, pile driving would not be initiated until the entire safety zone is visible.
- The safety zone would be monitored for the presence of sea lions before, during, and after any pile driving activity.
- The safety zone would be monitored for 30 minutes prior to initiating the start of pile driving. If sea lions are present within the safety zone prior to pile driving, the start of pile driving would be delayed until the animals leave the safety zone.
- Monitoring of the safety zone would continue for 20 minutes following the completion of pile driving.
- Monitoring would be conducted using high-quality binoculars. When possible, digital video or still cameras would also be used to document the behavior and response of sea lions to construction activities or other disturbances.
- Each monitor would have a radio for contact with other monitors or work crews.
- A GPS unit or electric range finder would be used for determining the observation location and distance to sea lions, boats, and construction equipment.

Data collection would include a count of all sea lions observed by species, sex, age class, their location within the zone, and their reaction (if any) to construction activities, including direction of movement, and type of construction that is occurring, time that pile driving begins and ends, any acoustic or visual disturbance, and time of the observation. Environmental conditions such as wind speed, wind direction, visibility, and temperature would also be recorded.

Shutdown Procedure

The safety zone would also be monitored throughout the time required to drive a pile (or install a steel casing if applicable). If a sea lion is observed approaching or entering the safety zone (190 dB RMS isopleth for pinnipeds), piling operations would be discontinued until the animal has moved outside of the safety zone. Pile driving would resume only after the sea lion is determined to have moved outside the safety zone by a qualified observer or after 15 minutes have elapsed since the last sighting of the sea lion within the safety zone.

Acoustical Monitoring

Hydroacoustic monitoring would be conducted for impact driving of steel piles. Acoustic monitoring would be conducted on a representative number of piles as described in the monitoring plan template that has been developed with and approved by NMFS and USFWS for Section 7 consultations. The number, size, and location of piles monitored would represent the variety of substrates and depths, as necessary, in both the Columbia River and North Portland Harbor. Hydroacoustic monitoring would be condcuted during vibratory installation of at least one pile of the largest diameter used by the project to confirm the distance to the 120 dB RMS threshold level. If steel casings are installed with a vibratory hammer, hydroacoustic monitoring would occur for the first casing installed; this would represent a worst case for size, depth, and substate for vibratory installation of casings. For standard underwater noise monitoring, one hydrophone positioned at midwater depth and 10 meters from the pile is used. Some additional initial monitoring at several distances from the pile is anticipated to determine site-specific transmission loss and directionality of noise. This data would be used to establish the radii of the safety and disturbance zones for sea lions.

Marine Mammal Monitoring Reporting

Reports of the data collected during sea lion monitoring would be submitted to NMFS weekly. In addition, a final report summarizing all sea lion monitoring and construction activities would be submitted to NMFS annually.

6.4.7 Steller and California Sea Lion Minimization Measures[8]

6.4.7.1 Timing Windows

Timing restrictions are used to avoid in-water work when ESA listed species are most likely to be present. CRC would comply with all in-water timing restrictions as determined through the ESA Section 7 and included in permit provisions.

[8] Note: Because seal and sea lion species present in the Columbia River are protected under the Marine Mammal Protection Act (MMPA), an application for a Letter of Authorization under the MMPA section 101(a)(5)(A) is being submitted to NMFS Office of Protected Resources. The project will comply with any additional minimization measures issued for seals and sea lions as part of the authorization.

6.4.7.2 Equipment Noise Standards

To mitigate noise levels and impacts to sea lions, all construction equipment would comply with applicable equipment noise standards of the EPA, and all construction equipment would have noise control devices no less effective than those provided on the original equipment.

6.4.7.3 Sound Attenuation Measures

Specific to pile driving, the hydroacoustic minimization measures listed in Section 7.1.5 would be implemented to reduce impacts to sea lions to the greatest extent practicable.

6.4.8 Terrestrial Resources

The LPA would impact terrestrial resources, such as migratory birds and SOI, through noise impacts and removal or degradation of habitat. Mitigation measures to address these impacts include impact avoidance and impact minimization. Impact avoidance would be addressed through timing vegetation removal to occur outside of nesting season for migratory birds, and/or developing management plans to provide guidance on ways to meet project construction objectives and timeframes while avoiding violation of the MBTA.

Impact minimization would be addressed by implementing BMPs for erosion and sediment control to protect riparian buffers and sensitive terrestrial habitats (e.g., for riparian species such as pond turtles), appropriate flagging and signing, preservation of native plant species onsite, and other relevant conservation measures. Canada geese and swallows are known to nest on the concrete piers, but not on steel structure portions of the existing bridge; use of the new bridge structures would likely be similar. The I-5 bridge could be inspected at least one full year prior to commencement of construction activities to determine whether any SOI or migratory birds are using the bridge for nesting or roosting. If such species are present, exclusionary devices may be installed on the bridge during the non-nesting season to prevent the bridge from being used for nesting or roosting when demolition activities begin. If high disturbance activities must take place during nesting season, the CRC project team would coordinate with USFWS, ODFW, and WDFW to establish work buffer zones around the nest during nesting season.

To address temporary loss of riparian vegetation resulting from project impacts, mitigation measures could include streambank revegetation and reshaping to restore habitat function, removal of noxious weeds in certain areas, and revegetation of disturbed areas with native species.

6.4.9 Botanical Resources

No sensitive, listed, or otherwise rare plant species are known to occur in the project area. Vegetation removal, including riparian vegetation, is addressed above (Terrestrial Resources).

7. Permits and Approvals

7.1 Federal

The project activities described in this document will be subject to the following federal regulations relevant to protecting fish, wildlife, and their habitat:

- Endangered Species Act. 1973. 16 USC 1531-1544, as amended.
- Migratory Bird Treaty Act. 1936. 16 USC 703-712, as amended.
- Bald and Golden Eagle Protection Act. 1940. 16 USC 668a-d, as amended.
- Magnuson-Stevens Fishery Conservation Management Act. 1976. Public Law 94-265, as amended.
- Marine Mammal Protection Act. Title I. 1972. 16 USC 1361-1389, 16 USC 1401-1407, 1411-1417, and 1421-1421h, as amended.
- Clean Water Act. 1977. 33 USC 1251-1376, as amended.
- Fish and Wildlife Coordination Act. 16 U.S.C. 661-667e, as amended.

7.1.1 Endangered Species Act

The Endangered Species Act (ESA) prohibits the incidental take of any federally listed species. Take is defined in the law to include harass and harm; harm is further defined to include any act which actually kills or injures federally listed species, including acts that may modify or degrade habitat in a way that significantly impairs essential behavioral patterns of the species. Under Section 7 of the ESA, any federal agency that permits, funds, carries out, or otherwise authorizes an action is required to ensure that the action will not jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat.

An incidental take permit, obtained through a formal Section 7 consultation with NMFS and/or USFWS, is required if there is potential for the project to adversely impact federally listed species or their critical habitat. Informal consultations occur for projects that result in a "not likely to adversely affect" determination; formal consultations occur for projects that are "likely to adversely affect" listed species.

Formal consultation under Section 7 of the ESA is ongoing with NMFS to analyze effects to listed species and EFH. A Biological Opinion is expected to be issued in early 2011. Informal consultation with USFWS has been completed. A concurrence letter for a "not likely to adversely affect" determination for bull trout and designated critical habitat was issued by USFWS on August 27, 2010.

7.1.2 Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) regulates the unauthorized taking of migratory bird eggs, young, or adults. Under the MBTA, a permit is required from USFWS if active nests (i.e., those with eggs or young) of migratory birds are destroyed during the breeding season. The breeding season in the project area is approximately March through August, although some birds may breed outside this period. Taking the necessary steps to deter nesting, if possible, in order to preclude the need for a permit to remove active nests and/or eggs, is generally preferable to obtaining a permit.

7.1.3 Bald and Golden Eagle Protection Act

Administered by the USFWS, this law provides for the protection of the bald eagle and the golden eagle (*Aquila chrysaetos*) by prohibiting, except under certain specified conditions, the taking, possession and commerce of such birds. Golden eagles are not likely to occur within the project area.

Bald eagles, now delisted, are primarily protected under the Bald and Golden Eagle Protection Act (BGEPA). The BGEPA prohibits unregulated take and makes it illegal to kill, wound, pursue, shoot, shoot at, poison, capture, trap, collect, molest or disturb bald or golden eagles. If disturbance will occur in potential violation of the act, a permit to authorize take of eagles is required. This permit authorizes incidental take of bald and golden eagles, as well as incidental take of bald eagles that complies with the terms and conditions of a previously granted Section 7 incidental take statement. Projects permitted under the BGEPA do not need a permit under the MBTA.

There are no documented bald eagle nests within or near the project area; therefore, no permits under the BGEPA are expected to be necessary for this project.

7.1.4 Magnuson-Stevens Fishery Conservation Management Act

The Magnuson-Stevens Act (MSFCMA) affords protection to EFH, which may include streams, lakes, ponds, wetlands, other currently viable water bodies, and most of the habitat historically accessible to salmon. Under MSFCMA, NMFS is required to provide EFH conservation and enhancement recommendations to federal and state agencies for actions that adversely affect EFH. Consultation with NMFS on effects to EFH has been done in conjunction with the Section 7 ESA consultation.

7.1.5 Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) is administered by NMFS and provides for the protection of marine mammals by prohibiting, except under certain specified conditions, the taking, possession, and commercial use of such mammals. Under the MMPA, "take" includes to harass, hunt, capture, or kill, or attempt to harass, hunt, capture or kill any marine mammal. Previous analysis of the impact area suggests that marine mammals do utilize this portion of the Columbia River.

CRC submitted an application for a Letter of Authorization (LOA) to NMFS for authorization to incidentally "take" marine mammals (sea lions and harbor seals) over the course of the project. NMFS published the receipt for application in the Federal Register on December 15, 2010, thereby opening the 30-day public comment period (75 FR 78228). The LOA is expected to be issued in mid-2011.

7.1.6 Clean Water Act

Impacts to jurisdictional wetlands or other waters will require a Section 404 permit from the United States Army Corps of Engineers (USACE). For activities that may result in discharge to waters of the U.S., Section 401 of the CWA requires certification that the project will comply with water quality requirements and standards. Dredging, filling, and other activities that alter a waterway require a Section 404 permit and Section 401 certification. The appropriate state agency must also certify that the project meets state water quality standards and does not endanger waters or wetlands of the state or the United States. Certifications are issued by DEQ in Oregon and by Ecology in Washington.

7.1.7 Fish and Wildlife Coordination Act

This Act authorizes the Secretaries of Agriculture and Commerce to provide assistance to, and cooperate with, Federal and State agencies to protect, rear, stock, and increase the supply of game and fur-bearing animals, as well as to study the effects of domestic sewage, trade wastes, and other polluting substances on wildlife.

7.2 State

7.2.1 Oregon

Work associated with the CRC will be subject to the following Oregon state regulations relevant to protecting fish, wildlife, and their habitat:

- Oregon Endangered Species Act. 2003. Oregon Revised Statutes (ORS) 496.171-192 and Oregon Administrative Rule (OAR) 635-100. Salem, OR.
- Fish Passage; Fishways; Screen Devices; Hatcheries Near Dams. 2001. ORS 509.580-910 and OAR 635-412-0005 to 0040. Salem, OR.
- Goal 5: Natural Resources, Scenic and Historic Areas, and Open Spaces. 1973. OAR 660-15-0000 (5). Salem, OR.
- Oregon's Removal-Fill Law. 2002. ORS 196.800 to 990 and ORS 196.600 to 692. Issuance and Enforcement of Removal-Fill Authorizations, OAR 141-085-0005 to 141-089-0615 and Water Quality Standards, 340-041. Salem, OR.

7.2.1.1 Oregon Endangered Species Act

The Oregon ESA applies to actions of state agencies on state-owned or leased lands. In general, the Oregon ESA is much more limited in scope than the federal ESA. The ODFW is responsible for fish and wildlife protected under the Oregon ESA, and the ODA is responsible for plants. The ODFW or ODA may issue a permit to any person for the incidental take of a state-listed threatened or endangered species if it determines that such take will not adversely impact the long-term conservation of the species or its habitat. The department may issue the permit under such terms, conditions, and time periods necessary to minimize the impact on the species or its habitat. An incidental take permit may be issued for individuals of more than one state-listed species. An incidental take permit for state-listed species not covered under the federal ESA would be required from ODFW or ODA.

7.2.1.2 Fish Passage; Fishways; Screen Devices; Hatcheries Near Dams

Oregon's fish passage law has several triggers that initiate compliance requirements. All new culverts, bridges, and dams must meet the current ODFW guidelines for fish passage. If passage is not possible, the law allows for waivers or exemptions to be approved by the ODFW fish passage coordinator or the Oregon Fish and Wildlife Commission, depending on the amount of habitat that will be removed from fish usage. Waivers allow for fish passage to be accomplished off-site, but still within the watershed if a net benefit to fish is shown. Exemptions allow the applicant not to provide passage at the specific site, but passage could be required in the future if watershed conditions change.

A fish passage plan will be submitted to ODFW and approved when project designs are further advanced. The project will meet all fish passage criteria for the state of Oregon.

7.2.1.3 Goal 5: Natural Resources, Scenic and Historic Areas, and Open Spaces

Goal 5 requires local governments in Oregon to protect natural resources and conserve scenic and historic areas and open spaces by adopting programs to protect these resources. Permitting may be required through local government Goal 5 ordinances. Goal 5 planning related to ecosystem resources within the I-5 CRC project includes the following:

- Fish and wildlife areas and habitats should be protected and managed in accordance with the Oregon Fish and Wildlife Commission's fish and wildlife management plans. The nearest ODFW Wildlife Management Area is on Sauvie Island, adjacent to the downstream extent of the project area (ODFW 2010).
- Stream flow and water levels should be protected and managed at a level adequate for fish, wildlife, pollution abatement, recreation, aesthetics and agriculture.
- Significant natural areas that are historically, ecologically or scientifically unique, outstanding or important, including those identified by the State Natural Area Preserves Advisory Committee, should be inventoried and evaluated. The study area includes numerous "significant natural areas"; however, at this time it does not include any areas specifically identified by the Oregon Natural Heritage Advisory Council (ONHAC 2010).
- Plans should provide for the preservation of natural areas consistent with an inventory of scientific, educational, ecological, and recreational needs for significant natural areas.

7.2.1.4 Oregon's Removal-Fill Law

Impacts to jurisdictional wetlands or other waters of the state (e.g., fill or removal activities below the bankfull stage or the line of non-aquatic vegetation, whichever is higher) require a removal-fill permit from DSL. This permit would typically be obtained in conjunction with a federal Section 404 permit (Section 11.1.6) via a joint permit application for impacts to wetlands and jurisdictional waters; a wetland delineation and conceptual mitigation plan would also be required.

7.2.1.5 Wildlife Policy

It is the policy of the State of Oregon that wildlife would be managed to prevent serious depletion of any indigenous species. An in-water blasting permit is required from ODFW if the project alternatives include in-water blasting. This permit is required if explosives are used when removing any obstruction in any waters of this state, in constructing any foundations for dams, bridges or other structures, or in carrying on any trade or business. ODFW issues in-water blasting permits only if they contain conditions for preventing injury to fish and wildlife and their habitat.

No in-water blasting is expected to be necessary during the course of this project; therefore, no permit is likely to be required under this policy.

7.2.2 Washington

Work associated with the CRC will be subject to the following Washington state regulations relevant to protecting fish, wildlife, and their habitat:

- State Environmental Protection Act (SEPA). 1971. Revised Code of Washington (RCW) 43.21C, and Washington Administrative Code (WAC) 197-11 and WAC 468-12. Olympia, WA.
- Habitat buffer zones for bald eagles. 1984. RCW 77.12.655. Bald eagle protection rules. 1986. WAC 232-12-292. Olympia, WA.
- Shoreline Management Act of 1971. 1971. RCW 90.58, WAC 173-18-100 and WAC 173-22. Olympia, WA.
- Hydraulic Code. 1949. Chapter 77.55 RCW. Olympia, WA.
- Fishways, flow, and screening. 1949. RCW 77.57, as amended. Olympia, WA.
- Clean Water Act certification.

7.2.2.1 State Environmental Protection Act

SEPA requires all governmental agencies to consider the environmental impacts of a proposed action before making decisions. An environmental impact statement (EIS) must be prepared for all proposals with probable significant adverse impacts on the quality of the environment. State and local agencies may approve an EIS prepared under NEPA to fulfill the SEPA evaluation requirement.

7.2.2.2 Habitat Buffer Zones for Bald Eagles

Government agencies must notify the WDFW if a landowner is applying for a permit for a land-use activity that involves land containing or adjacent to an eagle nest or communal roost site. WDFW will determine whether the proposed activity would adversely affect bald eagle nests or communal roosts sites; if so, a site management plan is required.

7.2.2.3 Shoreline Management Act of 1971

Under the Shoreline Management Act (SMA), each city and county is required to adopt a shoreline master program that is based on state guidelines and that may be tailored to the specific geographic, economic, and environmental needs of the community (Ecology 2009c). A permit will be required from the City of Vancouver for project activities occurring along the shoreline of the Columbia River or Burnt Bridge Creek.

7.2.2.4 Hydraulic Code

The Hydraulic Code is intended to ensure that required construction activities are performed in a manner to prevent damage to the state's fish, shellfish, and their habitat. An HPA from WDFW will be required for work occurring within waters of the state (defined as all salt and fresh waters waterway of the OHW and within the territorial boundary of the state).

7.2.2.5 Fishways, Flow, and Screening

Washington's fish passage regulations describe requirements for fish screens or bypasses when a lake, river, or stream containing game fish will be diverted, and for fishways, if an obstruction will be placed in a stream. An HPA will be required (Hydraulic Code), and a permit from Ecology will be required if water is diverted.

7.2.2.6 Clean Water Act Certification

This certification would typically be obtained from Ecology in conjunction with a federal Section 404 permit and a 401 certification (Section 11.1.6) via a joint permit application for impacts to wetlands and jurisdictional waters; a wetland delineation and conceptual mitigation plan would also be required.

7.3 Local

7.3.1 Oregon

Work on the Columbia River Crossing will be subject to the following Oregon local regulations relevant to protecting fish, wildlife, and their habitat:

- Environmental Zones. 1994. City of Portland Code (CPC) 33.430, as amended. Portland, OR.
- Tree Cutting. 2002. CPC 20.42. Portland, OR.
- Nature in Neighborhoods. 2005. Metro Code Sections 3.07.130 - 3.07.1370) - Title 13.
- Floodplain Overlay District. 2009. City of Gresham Code 5.0120. Gresham, Oregon.
- Special Purpose Overlay District. 2006. City of Gresham Code 10.221. Gresham, Oregon.

7.3.1.1 Environmental Zones

Permits are required for development or disturbance within environmental zones. Applicable permits will be completed for the CRC project as project designs and timelines are finalized.

The environmental zones provide for fish habitat protection through the designation of environmental protection or conservation zones. Development within these zones requires a permit application and additional information. Natural resource management plans (NRMPs) may be developed and approved, and may contain regulations that supersede or supplement the environmental zone regulations. These regulations will apply when a building permit or development permit application is requested within the resource area of the environmental conservation zone and is subject to the Development Standards of Section 33.430.110-170. These regulations do not apply to building or development permit applications for development that has been approved through environmental review. Environmental review is overseen by the City of Portland Land Use Review process.

7.3.1.2 Tree Cutting

A permit to cut trees on private or public property within the project area may be required from the City of Portland. Urban Forestry also regulates the cutting and planting of trees on public property, including street trees located on the public right-of-way. Permits are required to plant, prune, remove, or cut the roots of any tree located on public property.

7.3.1.3 Nature in Neighborhoods

The purpose of Nature in Neighborhoods is to conserve, protect, and restore a continuous ecologically viable streamside corridor system that is integrated with upland wildlife habitat and the surrounding urban landscape.

7.3.1.4 Floodplain Overlay District

According to City of Gresham code, within the floodplain overlay district of Fairview Creek, proposed developments need to comply with the guidelines and recommendations of the Fairview Creek master storm drain plan and would need to be accompanied by documentation prepared by a registered civil engineer demonstrating that the development would not result in an increase in floodplain area on other properties, reduce natural flood storage volumes, or result in an increase in erosive velocity of the stream that may cause channel scouring or reduced slope stability downstream of the development.

7.3.1.5 Special Purpose Overlay District

Sites specified by the Inventory of Significant Natural Resources and Open Spaces as having particular importance as fish and wildlife habitat areas shall be designated on the Community Development Special Purpose District Map as Natural Resource (NR) districts. The NR districts shall function as a special purpose overlay district.

Measures shall be adopted in the Community Development Code and Standards document to restrict development proposed within or adjacent to an NR district site. These measures shall require any such development to take place in a manner which minimizes adverse impacts on the resource site. Findings of public need and lack of alternative sites shall be required in connection with any proposed development activity within an NR district site.

7.3.2 Washington

Work on the Columbia River Crossing will be subject to the following Washington local regulations relevant to protecting fish, wildlife, and their habitat:

- Critical Areas Protection Ordinance. 2005. City of Vancouver - Vancouver Municipal Code (VMC) 20.740; Fish and Wildlife Habitat Conservation Areas. 2005. VMC 20.740.110. Vancouver, WA.
- Shoreline Management Area. 2005. VMC 20.760. Vancouver, WA.
- Critical Areas and Shorelines. 2005. Clark County Code. Title 40.4. Vancouver, WA.
- SEPA Regulations. 2004. VMC 20.790.
- Street Trees. VMC 12.04; and Tree Conservation. VMC 20.770. Vancouver, WA.
- Water Resources Protection. VMC 14.26.

7.3.2.1 Critical Areas Protection Ordinance (City of Vancouver)

The CAO applies to habitat for any life stage of state or federally designated endangered, threatened, or sensitive fish or wildlife species, priority habitats and habitats of local importance, riparian management areas and riparian buffers, and water bodies. Critical Areas Protection also regulates development in the floodplain and in erosion hazard areas, both of which occur in the project area. A critical areas report will be required as part of the submittal for a Critical Areas Permit, which is required for project activities occurring on properties containing critical areas or buffers. A Critical Areas Report for a riparian management area or riparian buffer must include an evaluation of habitat functions using the Clark County Habitat Conservation Ordinance Riparian Habitat Field Rating Form or another habitat evaluation tool approved by the WDFW.

7.3.2.2 Shoreline Management (City of Vancouver)

A Substantial Development Permit will be required for project activities occurring within areas regulated by the Shoreline Management Master Program (see discussion above in the Washington state section).

7.3.2.3 Critical Areas and Shorelines (Clark County)

Clark County has designated Critical Areas in accordance with the Growth Management Act (GMA). A permit may be required if the project occurs in habitat conservation areas, wetlands protected by Clark County Code, or along unincorporated Clark County shorelines.

7.3.2.4 State Environmental Protection Act

The NEPA EIS will be submitted to state and local agencies which may adopt the NEPA EIS to fulfill SEPA requirements (see discussion above in the Washington state section).

7.3.2.5 Street Trees

Street Trees and Tree Conservation municipal codes require permits if the project alternative results in the cutting of trees on public or private property. There are two kinds of permits required for trees in the City: one for street trees and one for private trees. If the tree is in the public right-of-way, a street tree permit is required.

7.4 Regional and Local Resource Protection

Work on the Columbia River Crossing will be subject to Oregon and Washington regional planning zones and guidelines relevant to protecting fish, wildlife, and their habitat.

7.4.1 Oregon

7.4.1.1 City of Portland

The City of Portland applies two environmental overlay zones—protection and conservation—to various sites throughout the city to protect natural resources. The "conservation" overlay zone is intended to conserve important natural resources and their functions. This zone applies to areas where natural resources can be protected while allowing environmentally sensitive development. Environmental zoning is applied to all development and site disturbance activities. The Columbia River, North Portland Harbor, and Columbia Slough are zoned "conservation."

The environmental protection overlay zone offers the highest level of protection for the city's sensitive natural resources. This zone typically covers a stream, streamside area, wetland, or large forested area, and is essentially a "no-build" zone because development in these areas would degrade Portland's most important and sensitive natural resources. Some projects may be allowed if there is a clear public benefit (trails and interpretive facilities) or if there is no feasible project location outside of the protection zone (access). No lands in the project area are in designated protection zones.

7.4.1.2 Metro

In 2004, Metro updated its December 2002 inventory of riparian and upland habitat. Metro defines riparian habitats as land and vegetation located near rivers, streams, lakes and wetlands; upland habitats are natural areas providing wildlife with food and shelter and allowing movement from one habitat to another. Based on this inventory, Metro identified regionally significant habitat. These areas were then mapped with a ranking of "low, medium, and high" based on their capacity to protect fish and wildlife (Metro 2005).

7.4.1.3 City of Gresham

The City of Gresham inventoried wetland, riparian areas, and upland areas in the fall of 1987. The findings of this survey are summarized by the Inventory of Significant Natural Resources and Open Spaces that was adopted by the City of Gresham as an appendix to the Community Development Plan (City of Gresham 2005, 2006). This survey was oriented primarily toward wildlife habitat values of lowland and upland natural areas within the City of Gresham. The resource areas included in the inventory are significant wildlife habitats and noteworthy scenic features that perform a variety of useful natural functions, including retention of soils, pollution control, groundwater recharge, and flood control. Forty-five sites having potential significance as natural resource areas were identified within the City of Gresham and include wetlands, riparian corridors, upland areas, and greenways (City of Gresham 2005).

7.4.2 Washington

7.4.2.1 Priority Habitats

The Washington Department of Fish and Wildlife (WDFW) has established priority habitat areas within the state. Priority habitats are those habitats with "unique or significant value to a variety of different species" (WDFW 2008), and may consist of a unique vegetation type or dominant plant species, a described successional stage, or a specific structural element. Washington has identified 18 priority habitat types. Within the project area, established priority habitats include Riparian, Urban Natural Open Space, and Oak Woodland. These priority habitats were not field-verified during the September 2005 surveys.

7.4.2.2 Riparian

Riparian habitats are those areas adjacent to aquatic systems with flowing water that contain elements of both aquatic and terrestrial ecosystems that mutually influence each other. In riparian systems, perennial or intermittent water bodies influence the vegetation, water tables, soils, microclimate, and wildlife of terrestrial ecosystems. The biological and physical properties of the aquatic ecosystems are influenced by adjacent vegetation, nutrient and sediment loading, terrestrial wildlife, and organic and inorganic debris. Riparian habitats begin at the OHW and extend to the portion of the terrestrial landscape influenced by, or directly influencing, the aquatic ecosystem. Riparian habitat includes the entire extent of the floodplain and riparian areas of wetlands directly connected to stream courses (WDFW 2006).

The criteria used by WDFW for establishing priority riparian habitats include high fish and wildlife density, high fish and wildlife species diversity, important fish and wildlife breeding habitat, important wildlife seasonal ranges, important fish and wildlife movement corridors, high vulnerability to habitat alteration, and unique or dependent species (WDFW 2006).

7.4.2.3 Urban Natural Open Space

Urban Natural Open Spaces are isolated remnants of natural habitat larger than 4 hectares (ha) (10 acres) and surrounded by urban development, although local considerations may be given to smaller open space areas (WDFW 2006). Natural open spaces in urban areas are priority habitat due to the limited amount of such habitat. One or more priority species may reside within or adjacent to the open space and use it for breeding and/or feeding or the open space may function as a corridor connecting other priority habitats, especially those that would otherwise be isolated.

7.4.2.4 Oak Woodland

Oak Woodland priority habitats are those habitats with stands of pure oak or oak/conifer associations where canopy coverage of the oak component of the stand is at least 25 percent, or where total canopy coverage of the stand is less than 25 percent but where oak accounts for 50 percent or more of the canopy coverage present (oak savannah). In urban areas, single oaks or stands less than 0.4 ha (1 acre) are considered a priority when valuable to fish and wildlife. The criteria for this priority habitat are comparatively high fish and wildlife density, high fish and wildlife species diversity, limited and declining availability, high vulnerability to habitat alteration, and dependent species.

7.4.2.5 Critical Areas

The GMA requires cities and counties to designate and protect "critical areas," including fish and wildlife habitat, wetlands, flood hazard areas, geologic hazard areas, and critical aquifer recharge areas. Both Clark County and the City of Vancouver have passed ordinances designating critical areas. The City of Vancouver has jurisdiction only over critical areas within its boundary. Clark County has jurisdiction over critical areas in the unincorporated areas of the County.

7.4.2.6 City of Vancouver

The City of Vancouver protects priority habitat areas through its Critical Areas Protection Ordinance. Critical areas include fish and wildlife habitat conservation areas, wetlands, frequently flooded areas, critical aquifer recharge areas, and geologic hazard areas as defined by the GMA. Fish and wildlife habitat conservation areas include, but are not limited to, habitat for any life stage of state-designated or federally designated endangered, threatened, and sensitive fish or wildlife species, priority habitats and habitats of local importance, riparian management areas and riparian buffers, and water bodies. The City of Vancouver also applies the WDFW priority habitat designations.

7.4.2.7 Clark County

In Clark County, mapped critical areas include Riparian Priority Habitat, Other Priority Habitats and Species (PHS), and Locally Important Habitats and Species. Locally Important Habitats and Species areas are areas legislatively designated and mapped by the County because of unusual or unique habitat that warrants protection due to qualitative species diversity or habitat system health indicators. Such areas are designated as critical, sensitive, or both critical and sensitive.

8. References

Ager, L.M. 1976. A biotelemetry study of the movements of the walleye in Central Hills Reservoir, Tennessee. Proceedings, Annual Conference Southeastern Association of Game and Fish Commissioners 30:311-323.

Akkanen, J. and J.V.K. Kukkonen. 2001. Effects of water hardness and dissolved organic material on bioavailability of selected organic chemicals. Environmental Toxicology and Chemistry 20(10):2303-2308.

Ali, M.A. 1958. The ocular structure, retinomotor and photobehavioral responses of juvenile Pacific salmon. Ph.D. dissertation, University of British Columbia, Vancouver BC, Canada.

Ali, M.A. 1960. The effect of temperature on the juvenile sockeye salmon retina. Canadian Journal of Zoology 38:169-171.

Ali, M.A. 1962. Influence of light intensity on retinal adaptation in Atlantic salmon (Salmo salar) yearlings. Canadian Journal of Zoology 40:561-570.

Alpers, C.N., H. E. Taylor, and J.L. Domagalski (editors). 2000a. Metals Transport in the Sacramento River, California, 1996–1997 - Volume 1: Methods and Data. U.S. Geological Survey, Water-Resources Investigations Report 99-4286. Sacramento, California.

Alpers, C.N., R. C. Antweiler, H. E. Taylor, P. D. Dileanis, and J.L. Domagalski. 2000b. Metals Transport in the Sacramento River, California, 1996–1997 – Volume 2: Interpretation of Metal Loads. U.S. Geological Survey, Water-Resources Investigations Report 00-4002. Sacramento, California.

Anderson, C.W., F.A. Rinella and S.A. Rounds. 1996. Occurrence of Selected Trace Elements and Organic Compounds and Their Relation to Land Use in the Willamette River Basin, Oregon, 1992–94. U.S. Geological Survey, Water-Resources Investigations Report 96– 4234, Portland, Oregon.

Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz. 2003. Sublethal effects of copper on coho salmon: impacts on non-overlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry 22(10):2266-2274.

Bash, J., C. Berman, and S. Bolton. 2001. Effects of Turbidity and Suspended Solids on Salmonids. Washington State Transportation Center. Seattle, Washington. Prepared for the Washington State Transportation Commission. November 2001.

Baxter, L. II, E.E. Hays, G.R. Hampson, and R.H. Backus. 1982. Mortality of Fish Subjected to Explosive Shock as Applied to Oil Well Severance on Georges Bank. Woods Hole Oceanographic Institution Report WHO-82-54.

Beamesderfer, R.C. and B.E. Rieman. 1991. Abundance and Distribution of Northern Squawfish, Walleyes, and Smallmouth Bass in John Day Reservoir, Columbia River. Oregon Department of Fish and Wildlife. Clackamas, Oregon. Transactions of the American Fisheries Society 120:439-447.

Berg, L. 1982. The effect of exposure to short-term pulses of suspended sediment on the behavior of juvenile salmonids. pp. 177-196 in G.F. Hartman et al. [eds.] Proceedings of the Carnation Creek workshop: a 10-year review. Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, Canada.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behaviour in juvenile coho salmon (Oncohynchus kisutch) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Bjornn, T.C. and Reiser, D.W. 1991. Habitat requirements of salmonids in streams. In: Meehan, W.R. Influences of forest and rangeland management of salmonid fishes and their habitats. Bethesda, MD: American Fisheries Society: 83-138.

Blackwell, S.B., J.W. Lawson, and M.T. Williams. 2004. Tolerance by ringed seals (Phoca hispida) to impact pile-driving and construction sounds at an oil production island. Journal of the Acoustical Society of America 115:2346-2357.

Boehlert, G.W. and J.B. Morgan. 1985. Turbidity enhances feeding abilities of larval Pacific herring, Clupea harengus pallasi. Hydrobiologia 123: 161-170.

Bottom D.L., C.A. Simenstad, J Burke, A.M. Baptista, D.A. Jay, K.K. Jones, E. Casillas, and M.H. Schiewe. 2005. Salmon at River's End: The role of the Estuary in Decline and Recovery of Columbia River Salmon. NOAA Technical Memorandum NMFS-NWFSC-68, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington.

Brannon, E. and A. Sutter. 1992. Movements of White Sturgeon in Lake Roosevelt, Final Report 1988-1991. Project No. 89-44.

Brick, Jim. Biologist/ODOT Liaison, Oregon Department of Fish and Wildlife. Personal Communication. 20 February 2008.

Brown, R. and D. Geist. 2002. Determination of Swimming Speeds and Energetic Demands of Upriver Migrating Fall Chinook Salmon (Oncorhynchus tshawytscha) in the Klickitat River, Washington. Project No. 2001-02400, 76 electronic pages, (BPA Report DOE/BP-00000652-9). August 2002.

Brown, R.F., S. Jeffries, D. Hatch, B.E. Wright, S. Jonker, and J. Whiteaker. Field Report: 2009 Pinniped Management Activities At and Below Bonneville Dam. Field Report. October 28.

Brown, R.F., S. Jeffries, D. Hatch, B.E. Wright, and S. Jonker. Field Report: 2010 Pinniped Management Activities At and Below Bonneville Dam. Field Report. October 18.

Buchanan, D.V., R.M. Hooten, and J.R. Mooring. 1981. Northern squawfish (Ptychocheilus oregonensis) predation on juvenile salmonids in sections of the Willamette River basin, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 38:360-364.

BLM (Bureau of Land Management). 1998. Survey protocols for Survey and Manage Strategy 2 vascular plants: species information. Accessed August 8, 2007: <http://www.blm.gov/or/plans/surveyandmanage/SP/VascularPlants/cover.htm>.

CalTrans (Californian Department of Transportation). 2009. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish. Caltrans, Sacramento, California.

Carlson, T.J., G. Ploskey, R.L. Johnson, R.P. Mueller, and M.A. Weiland. 2001. Observations of the Behavior and Distribution of Fish in Relation to the Columbia River Navigation Channel and Channel Maintenance Activities. PNNL-13595, Pacific Northwest National Laboratory, Richland, Washington.

Carpenter, K. 2010. Personal communication. Email communication from Kurt Carpenter, Hydrologist, USGS, to William Hall, Biologist, Parametrix, on February 1, 2010.

Carrasquero, J. 2001. Over-Water Structures: Freshwater Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation.

Carter, J. A., G. A. McMichael, I. D. Welch, R. A. Harnish, and B. J. Bellgraph. 2009. Seasonal Juvenile Salmonid Presence and Migratory Behavior in the Lower Columbia River. PNNL-18246, Pacific Northwest National Laboratory, Richland, Washington.

Cary, G.A., J.A. McMahon, and W.J. Kuc. 1987. The effect of suspended solids and naturally occurring dissolved organics in reducing the acute toxicities of cationic polyelectrolytes to aquatic organisms. Environmental Toxicology and Chemistry 6:469-474.

Casey, A. 2011. Urban Peregrine Falcon Nests in the Portland Metro Area. Presentation given at the ODOT Environment Conference, April 6-8, 2011, Bend, OR.

Cederholm, C.J. and E.O. Salo. 1979. The effects of logging road landslide siltation on the salmon and trout spawning gravels of Stequaleho Creek and the Clearwater River basin, Jefferson County, Washington, 1972-1978. FRI-UW-7915. Fisheries Research Institute, University of Washington, Seattle, Washington. 99 p.

Celedonia, M.T., R.A. Tabor, S. Sanders, S. Damm, D.W. Lantz, T.M. Lee, Z. Li, J. Pratt, B.E. Price, and L. Seyda. 2008. Movement and Habitat Use of Chinook Salmon Smolts, Northern Pikeminnow, and Smallmouth Bass Near the SR 520 Bridge. 2007 Acoustic Tracking Study. Final Report to the Washington State Department of Transportation.

CH2M HILL. 2005. I-5: Delta Park (Victory Boulevard to Lombard Section) Multnomah County, Oregon, Biological Resources Technical Report. Final Technical Report. December 2005.

City of Gresham. 2005. Volume 1: Findings, Gresham Community Development Plan. Appendix 2: Inventory of Significant Natural Resources and Open Spaces. Gresham, Oregon Comprehensive Plan. December 2005.

City of Gresham 2009. Section 5.0100, Floodplain Overlay District. City of Gresham, Oregon Development Code. May 2009.

City of Portland. 2007. Chapter 33.430 Environmental Zones. Available at <http://www.portlandonline.com/>.

City of Portland. 2009. Current Characterization Documents for the Columbia Slough. Accessed online 27 April 2011: http://www.portlandonline.com/bes/index.cfm?c=36081&.

Clarke D., C. Dickerson, and K. Reine. 2002. Characterization of Underwater Sounds Produced by Dredges. Proceedings of 3rd Specialty Conference on Dredging and Dredged Material Disposal, Orlando, Florida, USA. Garbaciak, S. (Ed.) American Society of Civil Engineers, p 64.

Close, D.A., M.S. Fitzpatrick, and H.W. Li. 2002. The ecological and cultural importance of a species at risk of extinction, Pacific lamprey. Fisheries 27:19-25.

Coker, C.M. and E.H. Hollis. 1950. Fish Mortality Caused by a Series of Heavy Explosions in Chesapeake Bay. Journal of Wildlife Management 14:435-445.

Collis, K., R.E. Beaty, and B.R. Crain. 1995. Changes in catch rate and diet of northern squawfish associated with the release of hatchery-reared juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management 15:346-357.

Collis, K., D.D. Roby, D.P. Craig, S. Adamany, J. Adkins, and D.E. Lyons. 2002. Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of juvenile salmonids to avian predation. Transactions of the American Fisheries Society 131:537-550.

Columbia Basin Bulletin, 2010. Researches in January observe increased predation by Steller sea lions on white sturgeon. Accessed February 5, 2010, at: http://www.cbbulletin.com/375791.aspx.

Counihan, T. D., M. J. Parsley, D.G. Gallion, C.N. Frost, and M.N. Morgan. 1999. Report C in Effects of Mitigative Measures on Productivity of White Sturgeon Populations in the Columbia River Downstream from McNary Dam, and Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam, Annual Progress Report, April 1997-March 1998. Ward, D. L. (ed.), Portland, OR: Oregon State University, 94-129.

CRC (Columbia River Crossing). 2010. Biological Assessment for the Columbia River Crossing. Prepared by Parametrix, Portland, Oregon. June 2010.

CRITFC (Columbia River Inter-Tribal Fish Commission). 2008. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. Available at: www.critfc.org/text/lamprey/restor_plan.pdf.

Dawley, E.M., R.D. Ledgerwood, T.H. Blahm, C.W. Sims, J.T. Durkin, R.A. Kim, A.E. Rankin, G.E. Monan, and F.J. Ossiander. 1986. Migrational Characteristics, Biological Observations, and Relative Survival of Juvenile Salmonids Entering the Columbia River Estuary, 1966–1983. Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington.

DEA (David Evans and Associates). 2006. Columbia River Crossing Hydrographic and Geophysical Investigation: High Resolution Bathymetric Mapping, River Bed Imaging, and Subbottom Investigation. Prepared for the Oregon Department of Transportation and the Washington State Department of Transportation.

Davies-Colley, R.J. and D.G. Smith. 2001. Turbidity, Suspended Sediment, and Water Clarity: A Review. Journal of the American Water Resources Association. Vol. 37, No. 5. October 2001.

DEQ (Oregon Department of Environmental Quality). February 1991. Total Maximum Daily Load for 2,3,7,8-TCDD in the Columbia River Basin.

DEQ (Oregon Department of Environmental Quality). 2007. Oregon's 2004/2006 Integrated Report Online Database. Available at <http://www.deq.state.or.us/wq/assessment/rpt0406/search.asp>. Accessed October 8, 2009.

DEQ. 2009. Water Quality Assessment Database: 2004/2006 Integrated Report Database. Available at: http://www.deq.state.or.us/wq/assessment/rpt0406/search.asp#db. Accessed November 6, 2009.

DEQ (Oregon Department of Environmental Quality). 2010. Environmental Cleanup Site Information (ESCI) Database records for sites No.3759 (Diversified Marine) and No. 3526 (Pier 99). Accessed online 19 March 2010: http://www.deq.state.or.us/Webdocs/Forms/Output/FPController.ashx?SourceId=3526&SourceIdType=11 and http://www.deq.state.or.us/Webdocs/Forms/Output/FPController.ashx?SourceId=3759&SourceIdType=11.

Dickerson, C., K.J. Reine, and D.G. Clarke. 2001. Characterization of underwater sounds produced by bucket dredging operations. DOER Technical Notes Collection (ERCC TN-DOER-E14), US Army Engineer Research and Development Center, Vicksburg, MS. Accessed online at: www.wes.army.mil/el/dots/doer.

Ecology (Washington Department of Ecology). 2009a. Washington State's Water Quality Assessment [303(d)]. Accessed July 8, 2009: <http://www.ecy.wa.gov/programs/wq/303d/>

Ecology (Washington Department of Ecology). 2009b. Burnt Bridge Creek Water Quality Improvement Project. Accessed February 18, 2009: <http://www.ecy.wa.gov/programs/wq/tmdl/burntbridge/BurntBrtmdl.html>

Ecology (Washington Department of Ecology). 2009c. State of Washington Shoreline Management Information page. Accessed March 25, 2010: http://apps.leg.wa.gov/RCW/default.aspx?cite=90.58

Edwards, E., G. Gebhart, and O.E. Maughan. 1983. Habitat suitability information: smallmouth bass. U. S. Fish and Wildlife Service FWS/OBS-82/10.36.

Everhart, W.H., A.W. Eipper, and W.D. Youngs. 1953. Principles of Fishery Science. Cornell University Press, London.

FPC (Fish Passage Center). 2009. Spawning Surveys for Coho, Chum & Fall Chinook. Accessed online 21 December 2009: http://www.fpc.org/spawning/spawning_surveys.html

Fields, P.E. 1966. Final report on migrant salmon light guiding studies at Columbia River dams. Contract No. DA-45-108. CIVEN 6-23-29. Portland, Oregon.

Finneran, J. J., R. Dear, D.A. Carder, and S.H. Ridgway. 2003. Auditory and behavioral responses of California sea lions (Zalophus californianus) to single underwater impulses from an arc-gap transducer. Journal of the Acoustical Society of America, 114, 1667-1677.

Fresh, K. L., E. Casillas, L. L. Johnson, D. L. Bottom. 2005. Role of the estuary in the recovery of Columbia River Basin salmon and steelhead: An evaluation of the effects of selected factors on salmonid population viability. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-69, 105 p.

Friesen, T.A. 2005. Biology, Behavior, and Resources of Resident and Anadromous Fish in the Lower Willamette River. Final Report of Research, 2000-2004. Oregon Department of Fish and Wildlife, Clackamas, OR.

Frost, K.J., and L.F. Lowry, 1988: Effects of industrial activities on ringed seals in Alaska, as indicated by aerial surveys. In Port and ocean engineering under Arctic conditions. Vol. II. Symposium on noise and marine mammals. Edited by W.M. Sackinger, M.O. Jeffries, J.L. Imm, and S.D. Treacy. Geophysical Institute, University of Alaska Fairbanks, Fairbanks. pp. 15–25.

Gardner, M.B. 1981. Effects of turbidity on feeding rates and selectivity of bluegills. Transactions of the American Fisheries Society 110: 446-450.

Gaspin, J.B. 1975. Experimental Investigations of the Effects of Underwater Explosions on Swimbladder Fish, I: 1973 Chesapeake Bay tests. Naval Surface Weapons Center Report NSWC/WOL/TR 75-58.

Gentry, R.L., E.C. Gentry, and J.F. Gilman. 1990. Response of northern fur seals to quarrying operations. Marine Mammal Science 6:151-155.

Geosyntec Consultants. 2008. White Paper: BMP Effectiveness Assessment for Highway Runoff in Western Washington. Prepared for Washington State Department of Transportation, Olympia, Washington. March 25, 2008. Available at: http://www.wsdot.wa.gov/NR/rdonlyres/195AF37F-1AA3-43AE-B776-B4A616CC5C7B/0/BMP_EffectivHwyRunoffWestWA.pdf.

Goertner, J. F., M.L. Wiley, G.A. Young, and W.W. McDonald. 1994. Effects of Underwater Explosions on Fish without Swimbladders. Naval Surface Warfare Center Report NSWC TR88-114.

Gray, G.A. and D.W. Rondorf. 1986. Predation on juvenile salmonids in Columbia Basin reservoirs. Pages 178-185 in: G. E. Hall and M. J. Van Den Avyle, eds. Reservoir Fisheries Management: Strategies for the 80s. American Fisheries Society, Bethesda, MD. 327 p.

Gray, Steve. 2007. Fisheries biologist, Washington Department of Fish and Wildlife. Personal Communication with Jennifer Lord via email. September 7, 2007.

Green, J.E., and S.R. Johnson. 1983. The distribution and abundance of ringed seals in relation to gravel island construction in the Alaskan Beaufort Sea, pp. 1–28. In B.J. Gallaway [ed.], Biological Studies and Monitoring at Seal Island, Beaufort Sea, Alaska 1982. LGL Ecological Research Associates, Inc., Bryan, TX for Shell Oil Co., Houston, TX.

Gregory, R.S. 1992. The influence of ontogeny, perceived risk of predation, and visual ability on the foraging behavior of juvenile Chinook salmon. Theory and Application of Fish Feeding Ecology 18: 271-284.

Gregory, R.S. 1993. Effect of turbidity on the predator avoidance behavior of juvenile Chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 50:241–246.

Gregory, R.S. and T.G. Northcote. 1993. Surface, planktonic, and benthic foraging by juvenile Chinook salmon (Oncorhynchus tshawytscha) in turbid laboratory conditions. Canadian Journal of Fisheries and Aquatic Sciences 50: 233-240.

Gregory, R.S. and C.D. Levings. 1996. The effects of turbidity and vegetation on the risk of juvenile salmonids, Oncorhynchus spp., to predation by adult cutthroat trout, O. clarkii. Environmental Biology of Fishes 47: 279-288.

Gregory, R.S. and C.D. Levings. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. Transactions of the American Fisheries Society 127: 275-285.

Harris, R.E., G.W. Miller, and W.J. Richardson. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. Marine Mammal Science, 17, 795-812.

Hastings, M.C. and A.N. Popper. 2005. Effects of Sound on Fish. Unpublished report prepared for California Department of Transportation.

Havis, R.N. 1988. Sediment resuspension by selected dredges. EEDP-09-2. U.S. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

Hay, D.E. and McCarter, P.B. 2000. Status of the eulachon Thaleichthys pacificus in Canada. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145. Ottawa, Ontario.

Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity. Technical White Paper. NMFS, Office of Protected Resources, Lacey, WA. 45 pp.

Heiser, D.W. and E.L. Finn, Jr. 1970. Observations of juvenile chum and pink salmon in marina and bulkheaded areas. Supplemental progress report, Puget Sound stream studies. Washington Department of Fisheries, Management and Research Division.

Hennings, Lori. Senior Natural Resources Scientist, Metro. Personal Communication. Telephone call and emails between Lori Hennings, Senior Natural Resources Scientist, and Jennifer Lord, Parametrix Biologist. 20-21 September 2007.

Herrera Environmental Consultants. 2007. White Paper: Untreated Highway Runoff in Western Washington. Prepared for Washington State Department of Transportation, Olympia, Washington. May 16, 2007. Available at: http://www.wsdot.wa.gov/NR/rdonlyres/B947A199-6784-4BDF-99A7-DD2A113DAB74/0/BA_UntreatedHwyRunoffWestWA.pdf.

Hildebrand, J. A. 2005. Impacts of Anthropogenic Sound in J.E. Reynolds et al. (eds), Marine Mammal Research: Conservation beyond Crisis. The Johns Hopkins University Press, Baltimore, Maryland. Pages 101-124 (2005). Retrieved from: UC San Diego at: http://www.escholarship.org/uc/item/8997q8wj.

Hollis L., J.C. McGeer, D.G. McDonald, and C.M. Wood. 2000. Protective effects of calcium against chronic waterborne cadmium exposure to juvenile rainbow trout. Environmental Toxicology and Chemistry 19(11):2725-2734.

Hulse, D., S. Gregory, and J. Baker, Eds. 2002. Willamette River Basin Planning Atlas: Trajectories of Environmental and Ecological Change. Pacific Northwest Ecosystem Research Consortium, Oregon State University, Corvallis, OR.

Incardona, J. P., M.G. Carls, H. Teraoka, C.A. Sloan, T.K. Collier, and N.L. Scholz. 2005. Aryl hydrocarbon receptor-independent toxicity of weathered crude oil during fish development. Environmental Health Perspectives 113:1755-1762.

Incardona, J. P., T.K. Collier, and N.L. Scholz. 2004. Defects in cardiac function precede morphological abnormalities in fish embryos exposed to polycyclic aromatic hydrocarbons. Toxicology and Applied Pharmacology 196:191-205.

Incardona J.P., H.L. Day, T.K. Collier, and N.L. Scholz. 2006. Developmental toxicity of 4-ring polycyclic aromatic hydrocarbons in zebrafish is differentially dependent on AH receptor isoforms and hepatic cytochrome P450 1A metabolism. Toxicology and Applied Pharmacology 217:308-321.

Isaacs, F.B. and R.G. Anthony. 2004. Bald eagle nest locations and history of use in Oregon and the Washington portion of the Columbia River Recovery Zone, 1971 through 2004. Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, Corvallis, Oregon.

Isidori, M., M. Lavorgna, M. Palumbo, V. Piccoli, and V, Parrella. 2007. Influence of alklyl phenols and trace elements in toxic, genotoxic, and endocrine disruption activity of wastewater treatment plants. Environmental Toxicology and Chemistry 26(8):1686-1694.

Johnsen, R.C. and C.W. Sims. 1973. Purse seining for juvenile salmon and trout in the Columbia River estuary. Transactions of the American Fisheries Society 102:341–345.

Johnson, D.H. and T.A. O'Neil. 2001. Wildlife-Habitat Relationships in Oregon and Washington. Oregon State University Press, Corvallis, Oregon. 736 pp.

Johnson, F. H. 1969. Environmental and species associations of the walleye in Lake Winnibigoshish and connected waters, including observations on food habits and predator-prey relationships. Minnesota Fisheries Investigations 5:5-36.

Johnson, O.W. F.S. Goetz, and G.R. Ploskey. 1998. Unpublished report on salmon light study at Hiram M. Chittenden Locks, US Army Corps of Engineers, Stevenson, Washington.

Johnson, L.L., G.M. Ylitalo, M.R. Arkoosh, A.N. Kagley, C.L. Stafford, J.L. Bolton, J. Buzitis, B.F. Anulacion, and T.K. Collier. 2007. Contaminant exposure in outmigrant juvenile salmon from Pacific Northwest estuaries. Environmental Monitoring and Assessment. 124:167-194.

Johnson, L.L., G.M. Ylitalo, M.S. Myers, B.F. Anulacion, J. Buzitis, W.L. Reichert, and T.K. Collier. 2009. Polycyclic aromatic hydrocarbons and fish health indicators in the marine ecosystem in Kitimat, British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-98, 123 pp.

Kastak, D., and R.J. Schusterman, R. J. 1996. Temporary threshold shift in a harbor seal (Phoca vitulina). Journal of the Acoustical Society of America 100:1905-1908.

Kastak, D., R.J. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of the Acoustical Society of America 106:1142-1148.

Kastak, D., B.L. Southall, M.M. Holt, C.R. Kastak, and R.J. Schusterman. 2004. Noise-induced temporary threshold shift in pinnipeds: Effects of noise energy. Journal of the Acoustical Society of America 116 (4, pt. 2), 2531.

Kastak, D., B.L. Southall, R.J. Schusterman, and C. Reichmuth-Kastak. 2005. Underwater temporary threshold shift in pinnipeds: Effects of noise level and duration. Journal of the Acoustical Society of America 118:3154-3163.

Kastak, D., C. Reichmuth, M.M. Holt, J. Mulsow, B.L. Southall, and R.J. Schusterman. 2007. Onset, growth, and recovery of in-air temporary threshold shift in a California sea lion (Zalophus californianus). Journal of the Acoustical Society of America 122, 2916-2924.

Lambourn, Dyanna. Marine Mammal Research Biologist, Washington Department of Fish and Wildlife. Personal communication; telephone conversation with Jennifer Lord and Michelle Guay, Parametrix biologists. February 25, 2010.

Langness, Olaf. Fisheries Biologist. Washington Department of Fish and Wildlife. Personal communication. Emails and telephone calls with Jennifer Lord, Parametrix biologist, between November 2008 and December 2009.

LaSalle, M.W. 1988. Physical and chemical alterations associated with dredging: an overview. Pages 1-12 in C.A. Simenstad, ed. Effects of dredging on anadromous Pacific fishes. University of Washington, Seattle, Washington.

Laughlin, J. 2005. Underwater Sound Levels Associated With Restoration of the Friday Harbor Ferry Terminal. Friday Harbor Ferry Terminal Restoration Project, Washington State Department of Transportation, Seattle, WA.

LCREP (Lower Columbia River Estuary Partnership). 2007. Lower Columbia River and estuary ecosystem monitoring: Water quality and salmon sampling report. Lower Columbia River Estuary Partnership. Portland, Oregon.

Ledgerwood, R.D., F.P. Thrower, and E.M. Dawley. 1991. Diel sampling of migratory juvenile salmonids in the Columbia River estuary. Fishery Bulletin 88:69–78.

Lee, H. S.L. Laua, M. Kayhanianb, and M.K. Stenstrom. 2004. Seasonal first flush phenomenon of urban stormwater discharges. Water Research 38:19: 4153-4163.

LeGore, R.S. and D.M. DesVoigne. 1973. Absence of acute effects of threespine sticklebacks (Gasterosteus aculeatus) and coho salmon (Oncorhynchus kisutch) exposed to resuspended harbor sediment concentrations. Journal of the Fisheries Research Board of Canada 30(8):1240-1242.

Levings, C. D., C. D. McAllister, and B. D. Chang. 1986. Differential use of the Campbell River estuary, British Columbia, by wild and hatchery-reared juvenile Chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 43(7):1386–1397.

Levy, D.A and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Canadian Journal of Fisheries and Aquatic Sciences 39(2):270-276.

Li, H., B.J. Teppen, C.T. Johnston, and S.A Boyd. 2004. Thermodynamics of nitroaromatic compound adsorption from water by smectite clay. Environmental Science & Technology 38:5433-5442.

Lloyd, D.S. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North American Journal of Fisheries Management 7: 34-45.

Loge, F., M.R. Arkoosh, T.R. Ginn, L.L. Johnson, and T.K. Collier. 2006. Impact of Environmental Stressors on the Dynamics of Disease Transmission. Environmental Science & Technology 39(18):7329-7336.

Mason, Bruce, and Girard (MBG). 2005. Wildlife Hot Spots Along Highways in Northwestern Oregon. Prepared for the Oregon Department of Transportation. 55 pp.

McCabe, G.T. Jr., R.L. Emmett, W.D. Muir, and T.H. Blahm. 1986. Utilization of the Columbia River estuary by subyearling Chinook salmon. Northwest Science 60:113–124.

McDonald, J. 1960. The behavior of Pacific salmon fry during their downstream migration to freshwater and saltwater nursery areas. Journal of the Fisheries Research Board of Canada. 17:655-656. As cited in Tabor et al. 2004.

McIntyre, J.K., D.H. Baldwin, J.P. Meador, and N.L. Scholz. 2007. Chemosensory deprivation in juvenile coho salmon exposed to dissolved copper under varying water chemistry conditions. Environmental Science & Technology (in press) (since published in Environmental Science & Technology 42(17):6774-5).

McMahon, T.E., and S.H. Holanov. 1995. Foraging success of largemouth bass at different light intensities: implications for time and depth of feeding. Journal of Fish Biology 45: 759-767.

Metro (Metropolitan Regional Government). 2003. South Corridor Project Water Quality and Hydrology Results Report. Prepared by URS. Portland, Oregon.

Metro (Metropolitan Regional Government). 2005. Urban Growth Management Functional Plan, Title 13, "Nature in Neighborhoods." Appendix C to Ordinance No. 05-1077C. 1 pp. Available at <http://www.metro-region.org/library_docs/nature/092305-4_ord_05-1077c_ex_c_t13.pdf>. Accessed August 8, 2007.

Metro (Metropolitan Regional Government). 2007. Fish and wildlife habitat protection: Habitat Classes. Available at <http://www.metro-region.org/>. Accessed December 9, 2009.

Miles, P.R., C.I. Malme, G.W. Shepard, W.J. Richardson, and J.E. Bird. 1986. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales: Beaufort Sea (1985). BBN Report 6185, Outer Continental Shelf Study MMS 86-0046, Minerals Management Service, Anchorage, AK.

Miles, P.R., C.I. Malme, and W.J. Richardson. 1987. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. BBN Report 6509, Outer Continental Shelf Study MMS 87-0084, Minerals Management Service, Anchorage, AK.

Miller, G. W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray. 2005. Monitoring seismic effects on marine mammals – southeastern Beaufort Sea, 2001-2002. In S. L. Armsworthy, P. J. Cranford, and K. Lee (Eds.), Offshore oil and gas environmental effects monitoring: Approaches and technologies (pp. 511-542). Columbus, Ohio: Battelle Press.

Minor, Michael. 2009. Hydroacoustics Specialist, Michael Minor and Associates, Inc. Personal communication. E-mail correspondence on December 6, 2009.

Moyle, P. B. 2002. Inland Fishes of California: Revised and Expanded. Los Angeles: University of California Press.

Mulvihill, E.L., C.A. Francisco, J.B. Glad, K.B. Kaster, and R.E. Wilson. 1980. Biological impacts of minor shoreline structures on the coastal environment: State of the art review, Volume II, data printout. FWS/OBS-77/51. Prepared by Beak Consultants, Inc., Portland, Oregon, with O. Beeman, for National Coastal Ecosystems Team, Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior. As cited in Carrasquero 2001.

Myers, K.W., and H.F. Horton. 1982. Temporal use of an Oregon estuary by hatchery and wild juvenile salmon. In Estuarine Comparisons. Edited by V.S. Kennedy. Academic Press, New York, NY. pp. 377-392.

NAS (National Academy of Sciences). 1973. Water Quality Criteria, 1972. National Academy of Sciences, Washington, D.C.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Accessed May 2009 at http://www.natureserve.org/explorer.

Nedwell, J R. and B. Edwards. 2002. Measurements of underwater noise in the Arun River during piling at County Wharf, Littlehampton. Subacoustech Report Reference: 513R0108. August 2002.

Newman, M.C. and R.H. Jagoe. 1994. Ligands and the bioavailability of metals in aquatic environments. In: Hamelink JL et al. (eds) Bioavailability: Physical, Chemical, and Biological Interactions. CRC Press, Boca Raton, FL

NMFS (National Marine Fisheries Service). 2000. White Paper: Predation on salmonids relative to the Federal Columbia River Power System. Northwest Fisheries Science Center. National Marine Fisheries Service, Seattle, Washington.

NMFS (National Marine Fisheries Service). 2002. Endangered Species Act Section 7 Consultation and Magnuson-Stevens Act Essential Fish Habitat Consultation: Biological Opinion for the Columbia River Federal Navigation Channel Improvements Project.

NMFS (National Marine Fisheries Service). 2005a. Endangered Species Act Section 7 Consultation. Kensington Gold Project Operations. NMFS Protected Resources Division, Alaska Region. March 18, 2005.

NMFS (National Marine Fisheries Service). 2005b. Endangered Species Act - Section 7 Consultation Biological Opinion and Conference Opinion and Magnuson-Stevens Act Essential Fish Habitat Consultation Reinitiation of Columbia River Federal Navigation Channel Improvements Project. National Marine Fisheries Service, Northwest Region. Reference Number 2004/01612. February 16, 2005.

NMFS (National Marine Fisheries Service). 2006. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Tidewater Cove Marina, Columbia River. NMFS Reference Number: 2005/00228. July 6, 2006.

NMFS (National Marine Fisheries Service). 2007. Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. Prepared for NOAA Fisheries by the Lower Columbia River Estuary Partnership. Accessed online 9 December 2009: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Estuary-Module.cfm

NMFS (National Marine Fisheries Service). 2008a. Salmon Essential Fish Habitat. Accessed March 25, 2010: <http://www.nwr.noaa.gov/Salmon-Habitat/Salmon-EFH/Index.cfm>

NMFS (National Marine Fisheries Service). 2008b. Recovery Plan for the Steller Sea Lion Eastern and Western Distinct Population Segments (Eumetopias jubatus) Revision. Accessed online 8 October 2009: http://www.nmfs.noaa.gov/pr/pdfs/recovery/stellersealion.pdf

NMFS (National Marine Fisheries Service). 2008c. Revisions to Standard Local Operating Procedures for Endangered Species to Administer Maintenance or Improvement of Road, Culvert, Bridge and Utility Line Actions Authorized or Carried Out by the USACE in the Oregon (SLOPES IV Roads, Culverts, Bridges and Utility Lines). NMFS, Northwest Region. August 13, 2008.

NMFS (National Marine Fisheries Service). 2008d. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.

NMFS (National Marine Fisheries Service). 2008e. Proposed Designation of Critical Habitat for the Southern Distinct Population Segment of North American Green Sturgeon: Draft Biological Report. Available at: http://swr.nmfs.noaa.gov/gs/Final_Draft_GS_BioRpt.pdf. Accessed April 2, 2009.

NMFS (National Marine Fisheries Service). 2009. Guidance Document: Data Collection Methods to Characterize Background and Ambient Sound within Inland Waters of Washington State. NMFS Northwest Fisheries Science Center - Conservation Biology Division and Northwest Regional Office - Protected Resources Division. November 30, 2009.

NOAA (National Oceanic and Atmospheric Administration). 2007. Seal & Sea Lion Facts of the Columbia River & Adjacent Nearshore Marine Areas. Available at <http://www.nwr.noaa.gov/Marine-Mammals/Seals-and-Sea-Lions/upload/CR-Pinniped-FS.pdf>. Accessed December 9, 2009.

NOAA (National Oceanic and Atmospheric Administration). 2009. 2009 Hayden and Sauvie Island Habitat Usage Progress Report, Agreement No. 09-2009. Prepared for the City of Portland by Sean Sol, O. Paul Olson, and Lyndal Johnson. Northwest Fisheries Science Center. September 29, 2009

Noggle, C.C. 1978. Behavioral, physiological and lethal effects of suspended sediment on juvenile salmonids. Master's thesis. University of Washington, Seattle, Washington.

NPCC (Northwest Power and Conservation Council). 2004. Lower Columbia Salmon and Steelhead Recovery and Subbasin Plan. Technical Foundation Volume III: Other Species. Pacific Lamprey. Prepared by the Lower Columbia Recovery Board. May 28, 2004 DRAFT.

Ocker, P. A., L. C. Stuehrenberg, M. L. Moser, A. L. Matter, J. J. Vella, B. P. Sandford, T. C. Bjornn, K. R. Tolotti. 2001. Monitoring adult Pacific lamprey (Lampetra tridentata) migration behavior in the lower Columbia River using radiotelemetry, 1998-99. Report to the U.S. Army Corps of Engineers, Portland District, Contract E96950021, 72 p.

ODOT (Oregon Department of Transportation). 2003. Peregrine Falcon Management Plan - 2002-2007. Available at <http://egov.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/docs/researchperegrine_falcon_plan.pdf>.

ODOT (Oregon Department of Transportation). 2008. Stormwater Treatment Program - BMP Selection Tool. Accessed online March 29, 2010: ftp://ftp.odot.state.or.us/techserv/Geo-Environmental/Stormwater%20Team/BMP_Selection_Tool/BMP_Selection_Tool/ODOT_BMP_Selection_Tool_Memo_Final.pdf.

ODFW (Oregon Department of Fish and Wildlife). 2010. Wildlife Division: Wildlife Management Plans. Available online: http://www.dfw.state.or.us/wildlife/management_plans/

Omernik, J.M. 1987. Ecoregions of the Coterminous United States: Map Supplement. Association of American Geographers 77(1):118-125.

ONHAC (Oregon Natural Heritage Advisory Council). 2010. Oregon Natural Areas Plan. Oregon Biodiversity Information Center, Institute for Natural Resources – Portland, Portland State University, Portland, OR. 198pp. Accessed online May 3, 2011: http://orbic.pdx.edu/documents/2010NAP.pdf

ORNHIC (Oregon Natural Heritage Information Center). 2003. Rare, Threatened and Endangered Plants and Animals of Multnomah County. Oregon Natural Heritage Program. Portland, Oregon.

ORNHIC (Oregon Natural Heritage Information Center). 2005. Oregon Threatened or Endangered Plant Field Guide.

ORNHIC (Oregon Natural Heritage Information Center). 2007. Rare, Threatened and Endangered Plants and Animals of Multnomah County. Oregon Natural Heritage Program. Portland, Oregon.

OSPAR. 2009. Assessment of the environmental impact of underwater noise. Convention for the Protection of the Marine Environment of the North-East Atlantic. OSPAR Commission, 2009. Publication Number 436/2009.

Pacific EcoRisk. 2007. White paper: Potential Effects of Highway Runoff on Priority Fish Species in Western Washington. Prepared for Washington State Department of Transportation. December 2007. Available at: http://www.wsdot.wa.gov/Environment/Biology/BA/BAguidance.htm#Stormwater.

Palermo, M.R., J.H. Homziak, and A.M. Teeter. 1990. Evaluation of clamshell dredging and barge overflow, Military Ocean Terminal, Sunny Point, North Carolina. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg Mississippi. March 1990.

Paragamian, V.L. 1989. Seasonal habitat use by walleye in a warmwater river system, as determined by radio telemetry. North American Journal of Fisheries Management 9:392-401.

Parametrix. 2005 and 2006. Botany field surveys. Parametrix, Inc., Portland, Oregon.

Parcel Insight. 2009. Columbia River Crossing, Oregon and Washington Corridor Report. 200.40. March 3, 2009.

Parsley, M. J., L. G. Beckman, and G. T. McCabe. 1993. Spawning and Rearing Habitat Use by White Sturgeons in the Columbia River Downstream From McNary Dam. Transactions of the American Fisheries Society 122:217-227.

PBS (PBS Engineering and Environmental). 2003. Biological Evaluation: Burnt Bridge Creek Regional Wetland Bank and Greenway Trails Project. PBS Engineering and Environmental, Vancouver, Washington.

Pentec (Pentec Environmental). 1997. Movement of Juvenile Salmon through an Industrialized Everett Harbor. Report to the Port of Everett, Everett, Washington.

Petersen, J.H. and T.P. Poe. 1993. System wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report 1992. Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon. December 1993.

Pflug, D.E. and G.B. Pauley. 1984. Biology of smallmouth bass (Micropterus dolomieui) in Lake Sammamish, Washington. Northwest Science 58:118-130.

Poe, T.P., R.S. Shively, and R.A. Tabor. 1994. Ecological consequences of introduced piscivorous fishes in the lower Columbia and Snake Rivers. Pages 347-360, in D. J. Stouder, K. Fresh, and R. J. Feller (eds.), Theory and Application in Fish Feeding Ecology. Bell W. Baruch Library and Marine Sciences, No. 18, University of South Carolina Press, Columbia, South Carolina.

Popper, A.N., T.J. Carlson, A.D. Hawkins, B.L. Southall, and R.L. Gentry. 2006. Interim criteria for injury of fish exposed to pile driving operations: a white paper. Available at <http://www.dot.ca.gov/hq/env/bio/fisheries_bioacoustics.htm>. Accessed December 5, 2009.

Pribyl, A.L., J.S. Vile, and T.A. Friesen. 2004. Population structure, movement, habitat use, and diet of resident piscivorous fishes in the Lower Willamette River. ODFW Columbia River Investigations, Clackamas, Oregon.

Prinslow, T.E., E.O. Salo, and B.P. Snyder. 1979. Studies of behavioral effects on a lighted and an unlighted wharf on outmigration salmonids: March-April 1978. Fisheries Research Institute, University of Washington, Seattle, Washington.

Probst, W. E., C. F. Rabeni, W.G. Covington, and R.E. Marteney. 1984. Resource use by stream-dwelling rock bass and smallmouth bass. Transactions of the American Fisheries Society 113:283-294.

PSMFC (Pacific States Marine Fisheries Commission). 2003. Presence/Absence Study for Salmonids in Burnt Bridge Creek. Funded by the City of Vancouver. Vancouver, Washington.

Quigley, T.M., R.W. Haynes, and R.T. Graham, editors. 1996. Integrated scientific assessment for ecosystem management in the Interior Columbia Basin. USDA Forest Service. Pacific Northwest Research Station. General Technical Report. PNW-GTR-382.

Ratte, L.D. and E.O. Salo. 1985. Under-pier ecology of juvenile Pacific salmon in Commencement Bay, Washington. Final report to the City of Tacoma. FRI-UW-8508. University of Washington, Fisheries Research Institute, Seattle, Washington.

Redding, J.M., C.B. Schreck, and F.H. Everest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Transactions of the American Fisheries Society 116: 737-744.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego. 576 pp.

Riddell, D.J., J.M.Culp, and D.J. Baird. 2005. Sublethal effects of cadmium on prey choice and capture efficiency in juvenile brook trout (Salvelinus fontinalis). Environmental Toxicology and Chemistry 24(7):1751-1758.

Roberts M.G., C.L. Ruch, H. Li, B.J. Teppen, and S.A. Boyd. 2007. Reducing bioavailability and phytotoxicity of 2,4-dinitrotoluene by sorption on k-smectite clay. Environmental Toxicology and Chemistry 26(2):358-360.

Roby, D.D., D.E. Lyons, D.P. Craig, K. Collis, and G.H. Visser. 2003. Quantifying the effects of predators on endangered species using a bioenergetics approach: Caspian terns and juvenile salmonids in the Columbia River estuary. Canadian Journal of Zoology 81:250-265.

Roni, P. and L.A. Weitkamp. 1996. Environmental monitoring of the Manchester Naval Fuel Pier replacement, Puget Sound, Washington, 1991-1994. Report to the U.S. Department of Navy, Naval Facilities Engineering Command, Western Division, Contract N62474-91-MP-00758, 40 pp. plus appendices.

Ruggerone, G.T. 1986. Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River dam. Transactions of the American Fisheries Society 115:736-742.

Salo, E.O., T.E. Prinslow, R.A. Campbell, D.W. Smith, and B.P. Snyder. 1979. Trident Dredging Study: the effects of dredging at the U.S. Naval submarine base at Bangor on outmigrating juvenile chum salmon, Oncorhynchus keta, in Hood Canal, Washington. FRI-UW-7918. University of Washington College of Fisheries, Fisheries Research Institute, September 1979.

Salo, E.O., N.J. Bax, T.E. Prinslow, C.J. Whitmus, B.P. Snyder, and C.A. Simenstad. 1980. The Effects of Construction of Naval Facilities on the Out-migration of Juvenile Salmonids from Hood Canal, Washington. Final Report to the US Navy. University of Washington Fisheries Research Institute (FRI-UW-8006), Seattle, Washington.

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science & Technology 41(8):2998-3004.

Scordino, J. 2010. West Coast Pinniped Program Investigations on California Sea Lion and Pacific Harbor Seal Impacts on Salmonids and Other Fishery Resources. Pacific States Marine Fisheries Commission. Portland, Oregon. 102 pp.

Servizi, J.A. and D.W. Martens. 1987. Some effects of suspended Fraser River sediments on sockeye salmon (Oncorhynchus nerka). pp. 254-264. In H.D. Smith, L. Margolis, and C.C. Wood [ed.]. Sockeye salmon (Oncorhynchus nerka) population biology and future management. Canadian Journal of Fishery Aquatic Science 96: 254-264.

Servizi, J.A. and D.W. Martens. 1992. Sublethal responses of coho salmon (Oncorhynchus kisutch) to suspended sediments. Canadian Journal of Fishery Aquatic Science 49: 1389-1395.

Sheng G., C.T. Johnston, B.J. Teppen, and S.A. Boyd. 2002. Adsorption of dinitrphenol herbicides from water by montmorillonites. Clays and Clay Minerals 50:25-34.

Shreffler, D.K., and R.A. Moursund. 1999. Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines. Phase II: Field studies at Port Townsend ferry terminal. WA-RD 480.1, GCA-1723. Prepared for Washington State Transportation Center (TRAC), Seattle, Washington.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American Fisheries Society 113: 142-150.

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. Pages 343-363 in Kennedy, V.S. (ed.), Estuarine comparisons, Academic Press, New York, New York.

Simenstad, C.A., C.D. Tanner, R.M. Thom, and L.L. Conquest. 1999. Estuarine Habitat Assessment Protocol. U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

Simenstad, C.A. and B. Nightingale. 1999. Impacts of Ferry Terminals on Juvenile Salmon Migrating along Puget Sound Shorelines Phase I: Synthesis of State of Knowledge. Prepared by Washington State Transportation Center (TRAC). Prepared for Washington State Transportation Commission. June 1999.

Simenstad, C.A. and B. Nightingale. 2001. White Paper: Overwater Structures: Marine Issues. Prepared by Washington State Transportation Center (TRAC). Prepared for Washington State Transportation Commission. June 2001.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals 33(4): 411-509.

Southard, S.L., R.M. Thom, G.D. Williams, J.D. Toft, C.W. May, G.A. McMichael, J.A. Vucelick, J.T. Newell, J.A. Southard. 2006. Impacts of Ferry Terminals on Juvenile Salmon Movement along Puget Sound Shorelines. Prepared by Batelle Memorial Institute. Prepared for the Washington Department of Transportation.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonids conservation. 21TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, Oregon (Available from NMFS, Portland, Oregon).

Sprague, J.B. 1964. Avoidance of copper-zinc solutions by young salmon in the laboratory. Journal Water Pollution Control Federation 36:990-1004.

Sprague, J.B. 1968. Avoidance reactions of rainbow trout to zinc sulphate solutions. Water Research Pergamon Press 2:367-372.

Spromberg, J. A., J. P. Meador. 2006. Relating chronic toxicity responses to population-level effects: A comparison of population-level parameters for three salmon species as a function of low-level toxicity. Ecological Modeling 199:240-252.

Stadler, John. Fisheries biologist, National Marine Fisheries Service. Personal communication: email to Jennifer Lord, Parametrix. July 20, 2010.

Stansell, R., B. van der Leeuw, and K. Gibbons. 2011. Status Report - Pinniped Predation and Deterrent Activities at Bonneville Dam, May 20, 2011. U.S. Army Corps of Engineers Portland District, Fisheries Field Unit, Cascade Locks, Oregon.

Stansell, R.S., K.M. Gibbons, and W.T. Nagy. 2010. Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace, 2008-2010. U.S. Army Corps of Engineers Portland District, Fisheries Field Unit, Cascade Locks, Oregon.

Stansell, R., and K. Gibbons. 2010. Pinneped predation and deterrent activities at Bonneville Dam, May 28, 2010 Weekly Status Report. U.S. Army Corps of Engineers Fisheries Field Unit, Cascade Locks, OR. Available at: http://www.nwd-wc.usace.army.mil/tmt/documents/fish/2010/update20100528.pdf.

Stansell, R.,S. Tackley, W. Nagy, and K. Gibbons. 2009. Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace. 2009 Field Report. U.S. Army Corps of Engineers Fisheries Field Unit, Cascade Locks, OR. Available at: http://www.nwd-wc.usace.army.mil/tmt/documents/fish/2009/2009_Pinniped_Report.pdf.

Stober, Q.J., B.D. Ross, C.L. Melby, P.A. Dinnel, T.H. Jagielo, E.O. Salo. 1981. Effects of suspended volcanic sediment on coho and Chinook salmon in the Toutle and Cowlitz Rivers. University of Washington, Fisheries Research Institute, Technical Completion Report FRI-UW-8124.

Tabor, R.A., G. Brown, and V. Luiting. 1998. The effect of light intensity on predation of sockeye salmon fry by prickly sculpin and torrent sculpin. U.S. Fish and Wildlife Service, Western Washington Office, Lacey, Washington. May 1998.

Tabor, R.A. and R.M. Piaskowski. 2001. Nearshore habitat use by juvenile Chinook salmon in lentic systems of the Lake Washington basin, Annual Report, U.S. Fish and Wildlife Service, Western Washington Office, Lacey, Washington.

Tabor, R.A., G.S. Brown, and V.T. Luiting. 2004. The effect of light intensity on sockeye salmon fry migratory behavior and predation by cottids in the Cedar River, Washington. North American Journal of Fisheries Management. 24:128-145.

Tackley, S., R. Stansell, and K. Gibbons. 2008. Pinniped predation on adult salmonids and other fish in the Bonneville Dam tailrace, 2005-2007. U.S. Army Corps of Engineers, CENWP-OP-SRF, Bonneville Lock and Dam, Cascade Locks, OR.

Taylor, W.S., and W.S. Willey. 1997. Port of Seattle fish migration study; Piers 64 & 65 short-stay moorage facility: Qualitative fish and avian predator observations. Prepared for Beak Consultants, Seattle, Washington.

Teel, D.J., C. Baker, D.R. Kuligowski, T.A. Friesen, and B. Shields. 2009. Genetic stock composition of subyearling Chinook salmon in seasonal floodplain wetlands of the lower Willamette River, Oregon. Transactions of the American Fisheries Society 138(1): 211-217.

Tennis, M. J. 2009 and 2010. Field project leader, Columbia River Sea lions - Pacific States Marine Fisheries Commission (PSMFC). Personal communication. Emails with Jennifer Lord, Parametrix biologist May 14-15, 2009, November 24, 2009, and March 18, 2010.

Thompson, R.B. 1959. Food of the squawfish (Ptychocheilus oregonensis) of the lower Columbia River. U.S. Fish and Wildlife Service, Fishery Bulletin 158:43-58.

Thompson, R. Environmental Specialist, Bureau of Environmental Services—Watershed Services, City of Portland, Oregon. Personal communication email. 26 September 2007.

Thomsen, F. S. McCully, D. Wood, F. Pace, and P. White. 2009. A generic investigation into noise profiles of marine dredging in relation to the acoustic sensitivity of the marine fauna in UK waters with particular emphasis on aggregate dredging: PHASE 1 Scoping and review of key issues MEPF Ref No. MEPF/08/P21. Centre for Environment, Fisheries & Aquaculture Science (CEFAS), Suffolk and Institute of Sound and Vibration Research, University of Southampton. 20th February 2009. Accessed online 25 March 2010: http://www.alsf-mepf.org.uk/media/13478/mepf-08-p21%20final%20report%20published.pdf

Toft, J.D., J. Cordell, C. Simenstad, and L. Stamatiou. 2004. Fish distribution, abundance, and behavior at nearshore habitats along City of Seattle marine shorelines, with an emphasis on juvenile salmonids. Technical Report SAFS-UW-0401, School of Aquatic and Fishery Sciences, University of Washington. Prepared for Seattle Public Utilities, City of Seattle, Seattle, Washington.

USACE (United States Army Corps of Engineers). 1989. Columbia River and Tributaries Review Study: Project Data and Operating Limits, North Pacific Division, CRT 69. Available at <http://www.nwd-wc.usace.army.mil/TMT/basin.html>. Accessed October 8, 2008.

USACE (United States Army Corps of Engineers). 2001. Columbia River Channel Improvements Project Biological Assessment. Portland District, Portland, Oregon.

USACE. 2008. Dredge Material Evaluation and Disposal Procedures. Prepared by the Dredge Material Management Office, U.S. Army Corps of Engineers. July 2008.

USACE. 2009 (Accessed). River Sediment Quality Evaluation for the Columbia River Channel Deepening Feasibility Report. Available at: https://www.nwp.usace.army.mil/ec/docs/Planning/crcd/main.pdf.

USFWS (United States Fish and Wildlife Service). 2002. Bull Trout (Salvelinus confluentus) Draft Recovery Plan for the Klamath River and Columbia River Distinct Population Segments of Bull Trout. Portland, Oregon. Available online: <http://www.fws.gov/pacific/bulltrout/Recovery.html>. Accessed March 11, 2009.

USFWS (U.S. Fish and Wildlife Service). 1998. Bull Trout Interim Conservation Guidance. 47 pp.

USFWS (United States Fish and Wildlife Service). 2003 and 2006. Threatened and Endangered Species System (TESS). Available online: <http://ecos.fws.gov/tess_public/servlet/gov.doi.tess_public.servlets.UsaLists?state=all>. Accessed December 9, 2009.

USFWS. 2004. Biological Opinion: Edmonds Crossing Ferry Terminal, USFWS Log # 1-3-03-F-1499. Prepared for the Federal Highway Administration, August 30, 2004.

USFWS. 2009. Bull trout proposed critical habitat justification: Rationale for why habitat is essential, and documentation of occupancy. Idaho Fish and Wildlife Office, Boise, Idaho. Available at http://www.fws.gov/pacific/bulltrout/pdf/Justificationdocfinal.pdf. Accessed November 10, 2009.

USFWS. 2010. Pacific Lamprey (Lampetra tridenta) Species Fact Sheet. Available online: http://www.fws.gov/oregonfwo/Species/Data/PacificLamprey/default.asp Accessed July 15, 2010.

USGS (United States Geological Survey). 2007. Oregon Water Science Center Data Grapher. Available online: <http://or.water.usgs.gov/cgi-bin/grapher/graph_setup.pl?basin_id=tdg&site_id=453439122223900>. Accessed December 9, 2009.

Van Dyke, E.S., A.J. Storch, and M.J. Reesman. 2009. Seasonal Composition and Distribution of Fish Species in the Lower Columbia Slough: Completion Report 2009. Oregon Department of Fish and Wildlife. Prepared for the City of Portland Bureau of Environmental Services. Portland, Oregon. September 2009.

Vogel, J.L. and D.A. Beauchamp. 1999. Effects of light, prey size, and turbidity on reaction distances of lake trout (Salvelinus namaycush) to salmonid prey. Canadian Journal of Fisheries and Aquatic Sciences 56: 1293-1297.

Wahl, D.H. 1995. Effect of habitat selection and behavior on vulnerability to predation of introduced fish. Canadian Journal of Fisheries and Aquatic Science 52:2312-2319.

WDFW (Washington Department of Fish and Wildlife) and ODFW (Oregon Department of Fish and Wildlife). 2001. Washington and Oregon Eulachon Management Plan.

WDFW (Washington Department of Fish and Wildlife). 2007. Burnt Bridge Creek Fish Passage Inventory and Habitat Assessment. Presented by Susan Cierebiej, Fisheries Biologist. 22 October 2007.

WDFW (Washington Department of Fish and Wildlife). 2008. Priority Habitat and Species List. Olympia, Washington. 175 pp.

WDFW/HMCC (Washington Department of Fish and Wildlife/Mount Hood Community College). 1999. Burnt Bridge Creek: A Model for Urban Stream Recovery in Clark County. Compiled by the Washington Department of Fish and Wildlife and Mount Hood Community College.

WDNR-NHP (Washington Department of Natural Resources, Natural Heritage Program). 2005. Field Guide to Selected Rare Vascular Plants of Washington. Available at <http://www1.dnr.wa.gov/nhp/refdesk/fguide/htm/fgmain.htm>. Accessed April 21, 2009.

Wedermeyer, G.A. and D.J. McLeay. 1981. Methods for Determining the Tolerance of Fishes to Environmental Stressors. Pp. 247-268. In A.D. Pickering [ed.] Stress and fish. Academic Press, Toronto, Ontario.

Weinheimer, J.M. 2007. E-mail correspondence with John Weinheimer, District 9 Fish Biologist, Washington Department of Fish and Wildlife. September 7, 2007.

Weitkamp, D.E. 1982. Juvenile chum and Chinook salmon behavior at Terminal 91, Seattle, Washington. Prepared for Port of Seattle by Parametrix, Seattle, Washington.

Wheeler, A.P. and M.S. Allen. 2003. Habitat and diet partitioning between shoal bass and largemouth bass in the Chipola River, Florida. Transactions of the American Fisheries Society 132:438-449.

White, Steven T. 1975. The influence of piers and bulkheads on the aquatic organisms in Lake Washington. Master's thesis. University of Washington, College of Fisheries, Seattle. As cited in Carrasquero 2001.

Wicks, B. J., R. Joensen, Q. Tang, and D. J. Randall. 2002. Swimming and ammonia toxicity in salmonids: the effect of sub lethal ammonia exposure on the swimming performance of coho salmon and the acute toxicity of ammonia in swimming and resting rainbow trout. Aquatic Toxicology 59:55–69.

Williams, G.D., and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. Aquatic Habitat Guidelines: An integrated approach to marine, freshwater, and riparian habitat protection and restoration. PNWD-3087. Prepared for Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation by Battelle Marine Sciences Laboratory, Sequim, Washington.

Williams G.D., R.M. Thom, D.K. Shreffler, J.A. Southard, L.K. O'Rourke, S.L. Sargeant, V.I. Cullinan, R.A. Moursund, and M. Stamey. 2003. Assessing Overwater Structure-Related Predation Risk on Juvenile Salmon: Field Observations and Recommended Protocols. PNNL-14435. Prepared for the Washington State Department of Transportation by the Pacific Northwest National Laboratory's Marine Sciences Laboratory, Sequim, Washington, in collaboration with Shreffler Environmental, Sequim, Washington, and the University of Washington, Seattle, Washington.

Wilson, M.F., R.H. Armstrong, M.C. Hermanns, and K. Koski. 2006. Eulachon: A Review of Biology and an Annotated Bibliography. Alaska Fisheries Science Center. National Marine Fisheries Service. Juneau, Alaska. August 2006.

Wright, B.E., M.J. Tennis and R.F. Brown. 2010a. Movements of California sea lions captured in the Columbia River. Northwest Science 84(1): 60-72.

Wright, B.E. 2010b. Personal communication. E-mail communication from Bryan Wright, Biometrician, ODFW. August 24, 2010.

WSDOT (Washington Department of Transportation). 2008. Highway Runoff Manual. Publication M 31-16.01. Washington State Department of Transportation, Environmental and Engineering Programs.

WSDOT (Washington Department of Transportation). 2009a. Marine Mammal, Fish, and Marbled Murrelet Injury and Disturbance Thresholds for Marine Construction Activities. Available online at: http://www.wsdot.wa.gov/NR/rdonlyres/216F21DA-A91B-43F2-8423-CD42885EE0EC/0/BA_MarineNoiseThrshlds.pdf.

WSF (Washington State Ferries) 2009. Reference Biological assessment: Washington State Ferries Capital, Repair, and Maintenance Projects. Washington State Ferries, Seattle, Washington.

Wydoski, R. S. and R. R. Whitney. 2003. Inland fishes of Washington, 2nd ed. University of Washington Press, Seattle, WA. 322 pp.

Yelverton, J.T., D.R. Richmond, E.R. Fletcher, and R.K. Jones. 1973. Safe distance from underwater explosions for mammals and birds. Defense Nuclear Agency, Dept. of Defense, Wash. D.C., Tech. Rept. DNA 3114 T. 67 pp.

Yonge, D., A. Hossain, M. Barber, S. Chen, and D. Griffin. 2002. Wet Detention Pond Design for Highway Runoff Pollutant Control. National Cooperative Highway Research Program.

Zawlocki, K.R. 1981. A Survey of Trace Organics in Highway Runoff in Seattle, Washington. Master's thesis. University of Washington, Seattle, Washington.

Zimmerman, M.P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:1036-1054.

This page intentionally left blank.

APPENDIX A

Pacific Lamprey and the Columbia River Crossing Project: a White Paper

INTERSTATE 5 COLUMBIA RIVER CROSSING

Pacific Lamprey and the Columbia River Crossing Project: a White Paper

Columbia River CROSSING

April 2011

Title VI

The Columbia River Crossing project team ensures full compliance with Title VI of the Civil Rights Act of 1964 by prohibiting discrimination against any person on the basis of race, color, national origin or sex in the provision of benefits and services resulting from its federally assisted programs and activities. For questions regarding WSDOT's Title VI Program, you may contact the Department's Title VI Coordinator at (360)705-7098. For questions regarding ODOT's Title VI Program, you may contact the Department's Civil Rights Office at (503)986-4350.

Americans with Disabilities Act (ADA) Information

If you would like copies of this document in an alternative format, please call the Columbia River Crossing (CRC) project office at (360)737-2726 or (503)256-2726. Persons who are deaf or hard of hearing may contact the CRC project through the Telecommunications Relay Service by dialing 7-1-1.

¿Habla usted español? La informacion en esta publicación se puede traducir para usted. Para solicitar los servicios de traducción favor de llamar al (503)731-4128.

Cover Sheet

Interstate 5 Columbia River Crossing

Pacific Lamprey and the Columbia River Crossing Project: a White Paper

Submitted By:

Jennifer Lord

Parametrix

This page intentionally left blank.

TABLE OF CONTENTS

List of Figures

List of Appendices

This page intentionally left blank.

ACRONYMS

CRITFC	Columbia River Inter-Tribal Fish Commission
CTGR	Confederated Tribes of the Grand Ronde Community of Oregon
MAX	Metropolitan Area Express
MHRR	Mount Hood Railroad
ODFW	Oregon Department of Fish and Wildlife
PAH	polycyclic aromatic hydrocarbon
PDX	Portland International Airport
PGIS	pollution-generating impervious surface
PSMFC	Pacific States Marine Fisheries Commission
RM	river mile
RKm	river kilometer
SPCC	spill prevention, control, and countermeasures
USFWS	United States Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife

This page intentionally left blank.

1. Introduction

Lampreys have significant cultural, spiritual, ceremonial, medicinal, subsistence, and ecological value for many Native American tribes in the Pacific Northwest (Archuleta 2005, CRITFC 2008). Lampreys play a key role in the aquatic and terrestrial food web, and are an indicator species for anthropogenic impacts to ecological systems (Close et al. 2002). Pacific lamprey (*Entosphenus tridentatus*, formerly *Lampetra tridentata*) are one of three lamprey species in the Columbia River Basin, and are the most important lamprey species to the tribes (Close et al. 2002). This species has declined in abundance due primarily to human factors, including dams for hydropower and flood control facilities, irrigation and municipal water diversions, lost and degraded habitat, poor water quality, excessive mammal, avian and fish predation, exposure to chemicals used in fish eradication programs (CRITFC 2008).

Pacific lampreys occur in the Columbia River basin and are likely to be present in the Columbia River Crossing Project area. Very little is known about this species' occurrence and use of habitat within the project area. CRC developed this white paper to summarize what is currently known and what potential project impacts may occur, and to identify research efforts that will provide additional information on this species in the lower Columbia River.

1.1 Status

Pacific lamprey and three other lamprey species were petitioned for listing under the federal Endangered Species Act in 2003 (Nawa et. al. 2003). The U.S. Fish and Wildlife Service (USFWS) determined that the petition did not adequately define the portion of the species' range that should be listed; therefore no status review was initiated. However, the USFWS's review of the petition indicated a likely decline in abundance and distribution of Pacific lamprey throughout California, Oregon, Washington, and Idaho, and acknowledged the existence of both short- and long-term threats to the species (USFWS 2008).

The Pacific lamprey is currently designated as a federal Species of Concern by USFWS. In Oregon, they are designated as Sensitive-Vulnerable, and in Washington they are proposed for the Washington Department of Fish and Wildlife (WDFW) Priority Habitat and Species List.

1.2 Life History

Pacific lampreys spend 1 to 3 years maturing in the ocean environment before migrating as adults to freshwater systems. Adults enter the mainstem Columbia River between approximately February and June (Kostow 2002). Pacific lampreys do not feed after entering freshwater, and subsist through the winter on lipid (fat) reserves (Kostow 2002). Adults are thought to overwinter in freshwater habitat for approximately one year before spawning (USFWS 2008). However, ongoing research by the Confederated Tribes of the Grand Ronde Community of Oregon (CTGR) may indicate that some adult lampreys live in freshwater habitats for up to two years before spawning (Karnosh pers. comm. 2011).

Spawning occurs between March and July in gravel-bottomed streams, at the upstream end of riffle habitat, and often near habitat suitable for ammocoetes (e.g., silty pools and banks) (Kostow 2002, Moyle 2002). After the eggs are deposited and fertilized, the adults usually die within 3 to 36 days (Kostow 2002).

Ammocoetes (larvae) drift downstream to areas of low velocity and silt or sand substrate, where they burrow and remain for 3 to 7 years. Ammocoetes are typically found in depositional areas with soft substrate near stream margins associated with pools, alcoves and glides (Graham and Brun 2007). They are relatively immobile in stream substrates and usually concentrate in areas that include many age classes (USFWS 2008). Ammocoetes are filter-feeders and feed on algae and other detritus (Kostow 2002; Moyle 2002). After reaching approximately 6 inches (15 cm) in length, ammocoetes metamorphose into macropthalmia (Moyle 2002). Downstream migrating macropthalmia have weak swimming ability (USFWS 2008) and tend to move at night (USFWS 2010). Metamorphism is reported to occur between July and November, followed by outmigration to the ocean November through June (peaking in the spring) (Kostow 2002).

Pacific lampreys migrate primarily at night, possibly in response to temperature cues or an aversion to light (Kostow 2002, USFWS 2008, USFWS 2010). Unlike most fishes, lampreys do not have swim bladders and are therefore not able to maintain neutral buoyancy; they must swim constantly or attach to objects to maintain their position in the water column (Liao 2002; Mesa et al. 2003 as cited in USFWS 2008). Lampreys may travel deeper in the water column compared to salmonids (USFWS 2008) (however, some dam passage studies have found juvenile lamprey much higher in the water column [CRITFC 2008]). Pacific lamprey adults are parasitic and feed on a variety of marine and anadromous fish. They are preyed upon by sharks, sea lions, and other marine animals (USFWS 2008).

No population estimates are available for Pacific lamprey in the Columbia River basin. Dam counts are unreliable for absolute abundance for several reasons, including lampreys migrate at night and pass counting windows when no counts are being taken; lampreys also pass via routes that bypass the counting stations; and there are large gaps in the years counts have been taken (Moser and Close 2003). However, dam passage counts can be a useful metric to describe changes in relative abundance over time, and are a clear indication of the decline of this species from historical conditions (Moser and Close 2003). For example, lamprey counts at Bonneville Dam prior to 1970 were regularly at least 50,000 adults; only about 25,000 adults have passed Bonneville Dam in recent annual counts (Kostow 2002). Passage counts show an even sharper decline at the furthest upstream dams: two hundred lampreys have been observed annually at the upper Snake River dams (Kostow 2002). Tribal and commercial harvest data at Willamette Falls also show a sharp decline in abundance of this species since the early 1900's (Close et al. 1995).

1.3 Threats

Causes of decline and threats to Pacific lamprey include the following (USFWS 2008):

- Artificial barriers to juvenile downstream migration, including culverts and water diversions. Outmigrating macropthalmia can be entrained in water diversions or turbine intakes, and impinged on vertical bar screens and trash racks.
- Artificial barriers to adult upstream migration. Many fish ladders and culverts designed to pass salmonids do not effectively pass lampreys due to sharp angles and high water velocities that are difficult for lampreys to navigate.
- Poor water quality—water temperatures above 72°F (22°C) may cause significant death or deformation of eggs or ammocoetes.
- Chemical poisoning (accidental spills as well as intentional chemical treatments such as rotenone).
- Predation by nonnative species (e.g., bass, sunfish, walleye).

- Stream and floodplain degradation, and consequent loss of side channel habitat, reduces areas for spawning and ammocoetes rearing.
- Poor ocean conditions affect prey species such as salmon, hake, and other host species.
- Dredging for channel maintenance and mining has significant impacts on ammocoetes in the substrate.
- Harvest may alter distribution and population structure.
- Dewatering and flow management in reservoirs and water diversions can strand ammocoetes present in the substrate.

The reduction in distribution and abundance of Pacific lampreys is a result of a combination of these threats. Many of these factors (e.g., dewatering and flow management, dredging and other channel alterations, chemical poisoning) may affect several age classes of ammocoetes in one event. Because ammocoetes are filter feeders and remain in the substrate of river systems for 3-7 years, they accumulate PCBs, mercury, and other heavy metals (USFWS 2008). Juvenile life stages of Pacific lamprey are vulnerable to exposure to 'legacy contaminants' that were released before regulation of toxic chemicals took effect, but that are still present in surface water and sediments.

1.4 Distribution and Abundance

Historically, Pacific lampreys are thought to have been distributed wherever salmon and steelhead once occurred (USFWS 2008). Their range extends around the Pacific Rim from Japan, through Alaska and the West Coast of the U.S., down to Mexico. Pacific lampreys are the most widely distributed lamprey species on the west coast, and occur in major river systems including the Fraser, Columbia-Snake, Klamath-Trinity, Eel, and Sacramento-San Joaquin Rivers (USFWS 2008).

Pacific lamprey populations are known to have declined or been extirpated in significant portions of their previous distribution from Alaska to California (USFWS 2008). Their decline has been noted in coastal streams as well as in large rivers, including the Columbia River basin. They have been extirpated above dams and other impassable barriers in several waterways, including the upper Snake and Columbia Rivers (USFWS 2008).

The mainstem Columbia River is used as a migration corridor for returning adult lamprey and outmigrating juveniles (macropthalmia), but the mainstem river contains relatively little spawning habitat (Silver et al. 2008). Knowledge of larval lamprey presence in mainstem habitats has been largely based on anecdotal observations at hydropower facilities or in downstream bypass reaches (CRITFC 2008). In general, lamprey in the ammocoete and macrophthalmia life stages are known to be present in the lower mainstem Columbia River, but their distribution and abundance have not been extensively studied, and are not well documented. Likewise, their timing, duration, and habitat use of the lower Columbia River basin are poorly understood (Jolley et al. 2010). Despite the apparent abundance of presumably suitable rearing habitat in the mainstem Columbia River (Silver et al. 2008), the extent to which ammocoetes rear in the mainstem is also unknown (Jolley et al. 2010).

However, recent USFWS research in the mainstem Columbia River has begun to address these data gaps. Studies conducted in 2010 in the Bonneville reservoir and tailwater, and in the lower Columbia River estuary near the river's mouth (up to RM 38), have focused on documenting presence/absence, age distribution, and species composition of larval lamprey (Jolley et al. 2011a, 2011b). Low abundance was documented in 2010 above Bonneville, and no larval lamprey were documented below Bonneville or in the estuary; however, this research is ongoing and will include additional portions of the mainstem Columbia River both above and below Bonneville Dam in 2011.

These Columbia River mainstem studies build on surveys conducted in the Willamette River in 2009 (Jolley et al. 2010), which documented the first quantitative information on larval Pacific lamprey and *Lampetra* spp. occupancy in mainstem river habitats. These studies applied a statistically robust and rigorous sampling methodology to describe patterns of larval lamprey distribution, occupancy, and detection, and have created a foundation for comparisons of lamprey occupancy and detection in other mainstem areas (Jolley et al. 2011a). The Willamette River surveys documented rearing ammocoetes in the Portland Harbor area of the Lower Willamette River, which drains into the Lower Columbia River approximately five river miles downstream of the project site. Differences in substrate types between the Willamette and Lower Columbia Rivers preclude direct extrapolation of survey results; however, the Willamette River study highlights the importance of mainstem areas as rearing habitat and not just as migration corridors (Jolley et al. 2011a). Research in the Columbia River is expected to continue through at least 2011, and may provide valuable new insights into lamprey use of habitat in this system.

Studies done on European lamprey (which have similar substrate requirements to Pacific lamprey) indicate that juvenile lamprey populations may have disparate distributions with a wide range of presence and population size, and that dispersal is commonly unrelated to presence of suitable habitat (King et al. 2008). Jolley et al. (2010) bears this out, having sampled for ammocoetes in the Multnomah Channel but finding none, despite the presence of apparently suitable habitat. Because relatively little sampling has been done in the mainstem Columbia River and its side channels, data are not available at a fine resolution to indicate what depths and substrates are preferred by larval and juvenile lamprey in mainstem habitats (Jolley pers. comm. 2010).

1.4.1 Distribution and Abundance in the Project Area

Although there have been no studies specifically of lamprey of any age class within the project area, ammocoetes have been documented in the mainstem Columbia River and in the North Portland Harbor[1]. These observations confirm the presence of ammocoetes in the project area, but because the data are limited and in some cases the observations were incidental to other projects, no inferences can be made regarding ammocoete abundance or distribution in the project area.

In March 2011, lamprey ammocoetes were incidentally observed in the project area during the course of a sediment sampling and characterization project for CRC. Sediment grab samples were taken at a total of 15 sites, 11 in the Columbia River and 4 in North Portland Harbor. Lamprey ammocoetes were found at four of these sites. Three detections occurred in North Portland Harbor and one in the Columbia River mainstem (see map in Appendix A). One lamprey was found at each site, at depths ranging from 7.0 to 29.5 feet, ranging in length from 2.5 to 6.0 inches. Each of the lamprey ammocoetes occurred where water velocities were slow in loose, silty sediments, as opposed to the coarse sands of the Columbia River mainstem navigational channel (Parametrix 2011). These ammocoetes were not identified to the species level. Sampling equipment used was not optimal for capturing larval lamprey (i.e., a power grab sampler vs. an electrofisher), and this project was not designed to study lamprey; therefore, few inferences can be made beyond confirming ammocoete presence in the project area at the time of sampling.

[1] The I-5 bridge that crosses the Oregon Slough, a side channel of the Columbia River, is known by title as the North Portland Harbor Bridge. In this paper, the term "Portland Harbor" is interchangeable with Oregon Slough.

In July 2010, biologists from USFWS testing lamprey sampling gear (e.g., deepwater electrofishers) in the mainstem Columbia River near Portland International Airport (PDX) documented larval lamprey in sediment in approximately 12 feet of water (Jolley pers. comm. 2010). This site is approximately four miles upstream of the I-5 bridge.

A 2007 USFWS study of Pacific lamprey and western brook lamprey use of mainstem habitat in the Columbia River documented Pacific lamprey and western brook lamprey in nearshore (less than 1 meter (m) deep) areas. Of 21 sites sampled in the mainstem Columbia River, ammocoetes were detected at only three sites: the Cowlitz River delta, the Government Island area, and the Cottonwood Island area. Of these sites, Government Island is the nearest to the CRC project area and is approximately 8 miles upriver of the I-5 bridge. Sites where ammocoetes were found were typically a mix of sand, small gravel and silt, and organic matter (Silver et al. 2008).The study detected lamprey ammocoetes along underwater ledges near drop-offs to deeper water (referred to in this study as water over 1 m deep), but did not find ammocoetes in many shallow, sandy areas that appeared to provide suitable habitat. The authors of the study posited that ammocoetes may be more likely present in deeper areas because such habitat is not subject to drying during summer months (Silver et al. 2008). Sampling of ammocoetes in deeper water has not been done on a large scale due to specialized gear requirements (i.e., the difficulty associated with using deepwater electrofishers).

North Portland Harbor has not been sampled for adult or larval lamprey (Jolley pers. comm. 2010).Timing of adult lamprey upstream migration through the project area may be expected from approximately February through June (Kostow 2002). After entering fresh water, Pacific lamprey may overwinter in some habitats before spawning the following season. It is possible that adult lamprey may overwinter in the project area, although this habitat use has not been well documented in this area and the extent to which adults overwinter in the mainstem Columbia River is unknown.

Lampreys are known to occur in Burnt Bridge Creek (PSMFC 2003) and the Columbia Slough (BES 2005); however, no data are available on distribution, abundance, timing, or habitat use for these waterways.

The primary method used to sample the mainstem Columbia River for ammocoetes has been backpack electrofishing (Silver et al. 2008). This method has also been used to sample mainstem Columbia River tributaries (e.g., the John Day, Umatilla, and Walla Walla Rivers) (Moser and Close 2003). Deepwater electroshocking gear has been used to sample the Willamette River (Jolley et al. 2010), and will be necessary to sample any deep water areas of the Columbia River. Radio telemetry and trapping at dam fishways has also been used to assess lamprey presence and passage success higher in the Columbia River basin (e.g., at Bonneville, the Dalles, and John Day dams) (Kostow 2002, Moser and Close 2003). Researchers have noted the need for standardized larval lamprey monitoring that provides both abundance and size distributions (Moser and Close 2003).

2. Columbia River Crossing Project Overview

The following discussion is a brief overview of the proposed Columbia River Crossing project. The discussion below focuses on project components that may directly or indirectly affect Pacific lamprey in the project area.

The I-5 CRC project is a multimodal transportation project focused on improving safety, reducing congestion, and increasing mobility of motorists, freight, bicyclists, and pedestrians along a 5-mile section of the I-5 corridor connecting Vancouver, Washington and Portland, Oregon, and extending the Yellow Line Metropolitan Area Express (MAX) from Delta Park in Portland to Clark College in Vancouver. The project area stretches from SR 500 in northern Vancouver, south through downtown Vancouver and over the I-5 bridges across the Columbia River to just north of Columbia Boulevard in north Portland (Figure 1).

The project proposes to:

- Replace the existing Columbia River bridges with two new structures.
- Widen the existing North Portland Harbor bridge and construct three additional structures across the harbor.
- Improve seven interchanges along I-5 in Portland and Vancouver.
- Improve highway safety and mobility along I-5 in Portland and Vancouver.
- Extend light rail transit from north Portland to downtown Vancouver.
- Add improved bike/pedestrian access on the new bridges and surrounding areas.
- Construct three new park and ride facilities in Vancouver.
- Expand the Ruby Junction Maintenance Facility to accommodate additional light rail transit vehicles.
- Demolish existing Columbia River bridges.

The ODFW- and WDFW-specified in-water work window for this portion of the Columbia River and North Portland Harbor is November 1 through February 28. Because of the large amount of in-water work involved, this project would not be able to complete the in-water work during this time period. Therefore, the project would request a variance to the published in water work window. Some in-water construction activities are proposed to occur year-round (e.g., installation and extraction of piles ≤48"; installation of drilled shaft casings ≥72"; installation and removal of cofferdams; superstructure construction). Activities taking place outside of the normal in-water work would occur in coordination with ODFW, WDFW, NMFS, and USFWS and in compliance with the terms and conditions of all regulatory permits obtained for this project.

Figure 1. Project Location

Columbia River CROSSING

2.1 Project Area

The aquatic portion of the project area encompasses the Columbia River from approximately RM 101 to 118 (RKm 163 to 190), and North Portland Harbor 3.5 miles downstream and 1.9 miles upstream of the existing bridge. In Burnt Bridge Creek and the Columbia Slough, the extent of the project area is based on the distance to where stormwater pollutants are expected to dilute to background levels. In Burnt Bridge Creek, based on proposed treatment and infiltration methods, pollutant levels in stormwater runoff would outflow only in infrequent storm events, and pollutants entering the creek are expected to dilute to background levels in close proximity to the stormwater outfall. In the Columbia Slough watershed, stormwater runoff from the project travels through open ditches before being pumped to the Columbia Slough. Based on stormwater treatment, pollutant levels are expected to dilute to background levels at or close to the Columbia Slough outfall, prior to reaching the salmon-bearing portion of the slough.

3. Project Activities Potentially Affecting Lamprey

Given that the current state of knowledge of larval, juvenile, and adult lamprey use of the mainstem Columbia River, North Portland Harbor, Burnt Bridge Creek, and the Columbia Slough in the project area is essentially lacking, we cannot analyze or quantify project impacts to Pacific lamprey with any level of certainty. However, because the following project activities have potential impacts to salmonids and other native fish, and in the interest of erring on the side of being over-protective rather than under-protective in the face of uncertainty, these activities merit discussion in the context of potential impacts to Pacific lamprey.

3.1 Bridge Construction

The project would construct two new bridges across the mainstem Columbia River downstream (to the west) of the existing interstate bridges. The existing North Portland Harbor bridges would be widened, and three new bridges would be constructed across North Portland Harbor. General sequencing of the bridge construction appears below.

- Install temporary cofferdam.
- Install temporary piles to moor barges and to support temporary work platforms and work bridges.
- Install drilled shafts for each pier complex.
- Remove work platform or work bridge and associated piles.
- Install shaft caps at the water level.
- Remove cofferdam.
- Erect tower crane.
- Construct columns on the shaft caps.
- Build bridge superstructure spanning the columns.
- Remove tower crane.

- Connect superstructure spans with mid-span closures.
- Remove barge moorings.

The existing Columbia River bridges would then be demolished.

3.2 Roadway Improvements

The proposed project 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. The proposed project would increase the total impervious area by approximately 42 acres, which would result in increased stormwater runoff rates and volumes. Stormwater from roadways is known to convey pollutant loads of suspended sediments, nutrients, polycyclic aromatic hydrocarbons (PAHs), oils and grease, antifreeze from leaks, cadmium and zinc from tire wear, and copper from wear and tear from brake pads, bearings, metal plating, and engine parts. However, with the construction of new conveyance systems and water quality facilities, untreated PGIS would be reduced from the current 219 acres to approximately 8 acres. Improvements to stormwater treatment on new and resurfaced impervious surfaces, including the I-5 and North Portland Harbor bridges, would result in a net improvement for water quality in the Columbia River, North Portland Harbor, Burnt Bridge Creek, and the Columbia Slough.

4. Analysis of Potential Project Effects to Pacific Lamprey

The following discussion addresses known or potential project impacts in the context of their effects to Pacific lamprey.

4.1 Hydroacoustics

The following discussion is an overview of what is currently known about hydroacoustic impacts to fish, based on laboratory studies as well as field observations.

Hydroacoustic impacts from impact pile driving are the farthest reaching extent of project aquatic impacts in the Columbia River and North Portland Harbor. Due to the curvature of the river and islands present, underwater noise from impact pile driving is expected to encounter land before it reaches ambient levels. Noise from impact pile driving is not expected to extend beyond Sauvie Island, approximately 5.5 miles downstream, and Lady Island, 12.5 miles upstream. This distance encompasses the Columbia River from approximately RM 101 to 118 (RKm 163 to 190). Within North Portland Harbor, underwater noise is expected to extend 3.5 miles downstream and 1.9 miles upstream.

Direct injury, mortality, or behavioral disturbance to fish species may result from sound levels associated with impact pile driving and other in-water construction techniques associated with the installation of temporary steel piles necessary for the construction of the bridges over the Columbia River and North Portland Harbor. Impacts associated with pile driving may include physical injury (particularly to air-filled spaces such as swim bladders), auditory tissue damage, temporary or permanent hearing loss, behavioral effects, and immediate and delayed mortality.

The amount of energy and the resulting sound pressure from pile driving depend on the size and type of pile, type of hammer, energy of the hammer, depth of the water column, and substrate. Impacts to individual fish depend on sound pressure levels, fish species, fish size, fish condition, and depth of the water column (Popper et al. 2006). Use of bubble curtains or other noise attenuation devices during impact pile driving may reduce the level of noise impacts to fish (Caltrans 2009).

It is well documented that hydroacoustic impacts can be significant, causing injury or mortality, for fish with swimbladders. Lampreys do not have swimbladders and it is therefore difficult to determine the extent of this impact. Fish species without swimbladders are thought to be at lower risk from underwater sound than fishes with swimbladders (Stadler pers. comm. 2010, Hastings and Popper 2005, Coker and Hollis 1952, Gaspin 1975, Baxter et al. 1982, Goertner 1994). No thresholds for disturbance or injury have been established for such fish (Stadler pers. comm. 2010). Therefore, hydroacoustic impacts to lamprey should not be discounted, but they cannot be quantified or analyzed with any level of certainty.

Data on hydroacoustic effects to fish eggs and larvae, particularly hydroacoustics of pile driving, are lacking (Hastings and Popper 2005); in addition, there is next to no information on distribution, abundance, and timing of ammocoetes in the project area. Therefore, we cannot speculate on the potential hydroacoustic project impacts to lamprey ammocoetes in the project area.

Despite the uncertainties surrounding hydroacoustic impacts to lamprey, it should be noted that a test pile project conducted by CRC in February, 2011, to evaluate the geotechnical and sound propagation characteristics of the project area found that hydroacoustic impacts from pile driving were less than anticipated (i.e., transmission loss was slightly greater than what had been expected due to lower source values). Hydroacoustic data collected during the test pile project were still being analyzed in April 2011; however, preliminary results indicate that effects to fish will be less than what was modeled for the ESA Section 7 consultation.

4.2 Temporary Effects to Water Quality

The project will implement BMPs during in-water and upland construction activities to avoid and minimize impacts to water quality. Although there are several potential sources of chemical contaminants, there is a low risk that chemicals would actually enter the Columbia River and North Portland Harbor. A Spill Prevention, Control, and Countermeasures (SPCC) plan would be implemented to completely contain sources of chemical contamination such as equipment leaks, uncured concrete, and other pollutants. All project activities that release water would meet state water quality standards.

The project is likely to generate temporary, localized turbidity during the in-water work in the Columbia River and North Portland Harbor. Turbidity would pose fairly limited impacts to habitat, as the project would restrict the extent of turbidity to distances specified by regulatory permits (anticipated to be no more than 300 feet). In actuality, many of the activities would restrict the turbidity plume to far shorter distances than the anticipated 300 foot mixing zone. Permits would also restrict the duration of each turbidity plume to approximately 4 to 6 hours.

Minimization measures would limit effects to water quality. Some level of turbidity may actually contribute to juvenile lamprey survival by concealing macropthalmia from predation (CRITFC 2008). Temporary effects to water quality are not likely to measurably affect any life stages of lamprey.

4.3 Contaminated Sediments

State and federal databases have identified upland sites in the project area or immediate vicinity that are known or suspected to contain contaminated media (Parcel Insight 2009). These include two former marine repair facilities, a former landfill, and a former lumber mill. The CRC project completed sediment evaluation testing in the immediate project area for North Portland Harbor and Columbia River in March, 2011. As of mid-April, 2011, the lab results from the sediment evaluation are pending.

The project would implement several measures to prevent the mobilization of contaminated sediments in the project area, including Phase I and II environmental site assessments (as necessary) for each property. The project would implement BMPs to ensure that the project either: 1) avoids areas of contaminated sediment or 2) enables responsible parties to initiate cleanup activities for contaminated sediments occurring within the project construction areas. This aspect of the project is not likely to measurably affect any life stages of lamprey.

4.4 Stormwater

Improvements to stormwater treatment on new and resurfaced impervious surfaces, including the I-5 and North Portland Harbor bridges, would result in a net improvement for water quality in the Columbia River, North Portland Harbor, Burnt Bridge Creek, and the Columbia Slough. Most of the runoff generated by the existing highway corridor is not treated before being discharged. All new and rebuilt impervious surfaces, as well as some resurfaced and existing pavement, would be treated in accordance with current stormwater treatment standards before being discharged to project area receiving streams. On the Washington side of the alignment, the project would exceed state stormwater treatment standards.

In Burnt Bridge Creek, based on proposed treatment and infiltration methods, pollutant levels in stormwater runoff would outflow only in infrequent storm events. Therefore, any pollutants entering the creek are expected to dilute to background levels in close proximity to the outfall, and most definitely by the confluence with Vancouver Lake.

In the Columbia Slough watershed, stormwater runoff from the project travels through open ditches before being pumped to the Columbia Slough. Based on the enhanced treatment proposed and some infiltration that would occur prior to the outfall to the Columbia Slough, pollutant levels are expected to dilute to background levels at or close to the Columbia Slough outfall, prior to reaching the salmon-bearing portion of the slough.

In the Columbia River and North Portland Harbor, lampreys may potentially be exposed to degraded water quality within a short distance of the outfalls during periods when lampreys are present, and when there is an event that exceeds the design storm design. Exposure would be minimal due to the high dilution capacity of these large water bodies. During events that do not exceed the design storm, the project is expected to discharge runoff that has less pollutant content than the pre-project condition due to the high level of stormwater treatment relative to the net new PGIS. While it is inconclusive whether this constitutes a benefit to lamprey, the high level of treatment makes it improbable that the runoff would degrade the baseline or cause higher levels of exposure during these events.

In the Columbia Slough, there is a minimal chance that lampreys would be exposed to degraded water quality. Stormwater outfalls discharge directly into water bodies that do not contain listed fish, and by association, are unlikely to contain lampreys. Stormwater discharging into these water bodies would travel through several thousand linear feet of a vegetated open conveyance system before entering the Columbia Slough. Given the distance between stormwater outfalls and the nearest locations where listed fish and lamprey are present, and given the high levels of dilution likely to occur, pollutants would likely dissipate to ambient levels before discharging to fish bearing waters.

In Burnt Bridge Creek, lampreys may be exposed to degraded water quality and flow regime during periods when lamprey are present and when there is an event that exceeds the design storm. The abundance and distribution of lampreys in Burnt Bridge Creek are unknown, and the level of exposure cannot be quantified at this time.

4.5 Effects to Shallow Water Habitat

The project would have both temporary and permanent effects to shallow-water habitat (water less than 20 feet deep) in the Columbia River and North Portland Harbor. Project elements responsible for temporary physical loss include the footprint of the numerous temporary piles associated with in-water work platforms, work bridges, tower cranes, oscillator support piles, cofferdams, and barge moorings in the Columbia River and North Portland Harbor. Permanent impacts include the addition of in-water and overwater bridge elements and the removal of existing in water and overwater structures.

The project would lead to temporary physical loss of approximately 20,700 sq. ft. of shallow-water habitat. Pier 7 is located in shallow water on the Vancouver side of the Columbia River (Figure 2); in-water portions of the new structures at this pier would result in the permanent physical loss of approximately 250 sq. ft. of shallow-water habitat. Demolition of the existing Columbia River structures would permanently restore about 6,000 sq. ft. of shallow-water habitat, and removal of a large overwater structure at the Quay, also on the Vancouver side of the Columbia River, would permanently restore about 600 sq. ft. of shallow water habitat. Overall, there would be a net permanent gain of about 5,345 sq. ft. of shallow-water habitat in the Columbia River. At North Portland Harbor, there would be a permanent net loss of about 2,435 sq. ft. of shallow water habitat at all of the new in water bridge bents. Exact pier locations in North Portland Harbor have not yet been determined; however, because the harbor is shallow in general, all North Portland Harbor impacts are expected to be in shallow water (Figure 3).

In-water portions of the structures would not pose a complete blockage to migration anywhere in the action area. Although these structures would cover potential nearshore migration areas for lamprey, the habitat is not rare and is not of particularly high quality. Adult and juvenile lamprey would still be able to use the abundant shallow water habitat available for miles in either direction. Information on ammocoete use of shallow water habitat in or near the project area may be extrapolated from Silver et al. (2008)—in this study, ammocoetes were found in shallow water on the north bank of Government Island. As discussed above, ammocoetes have also been documented in the mainstem Columbia River near PDX (Jolley pers. comm. 2010). These results indicate potential ammocoete presence in shallow water habitat within the project area. The work discussed above would remove or disturb substrate that may contain ammocoetes. Therefore, ammocoetes may be injured or killed by the temporary work done at the sites discussed above. Potential project impacts to this life stage should not be discounted, but because abundance and distribution data are so limited, impacts cannot be quantified at this time.

PRELIMINARY

Pier # / Location	Min. Depth	Max. Depth	Average Depth
P-2	15	30	23
P-3	24	29	27
P-4	24	27	25
P-5	28	31	30
P-6	28	30	29
P-7	6	31	20
N. Portland Harbor	6	20	13

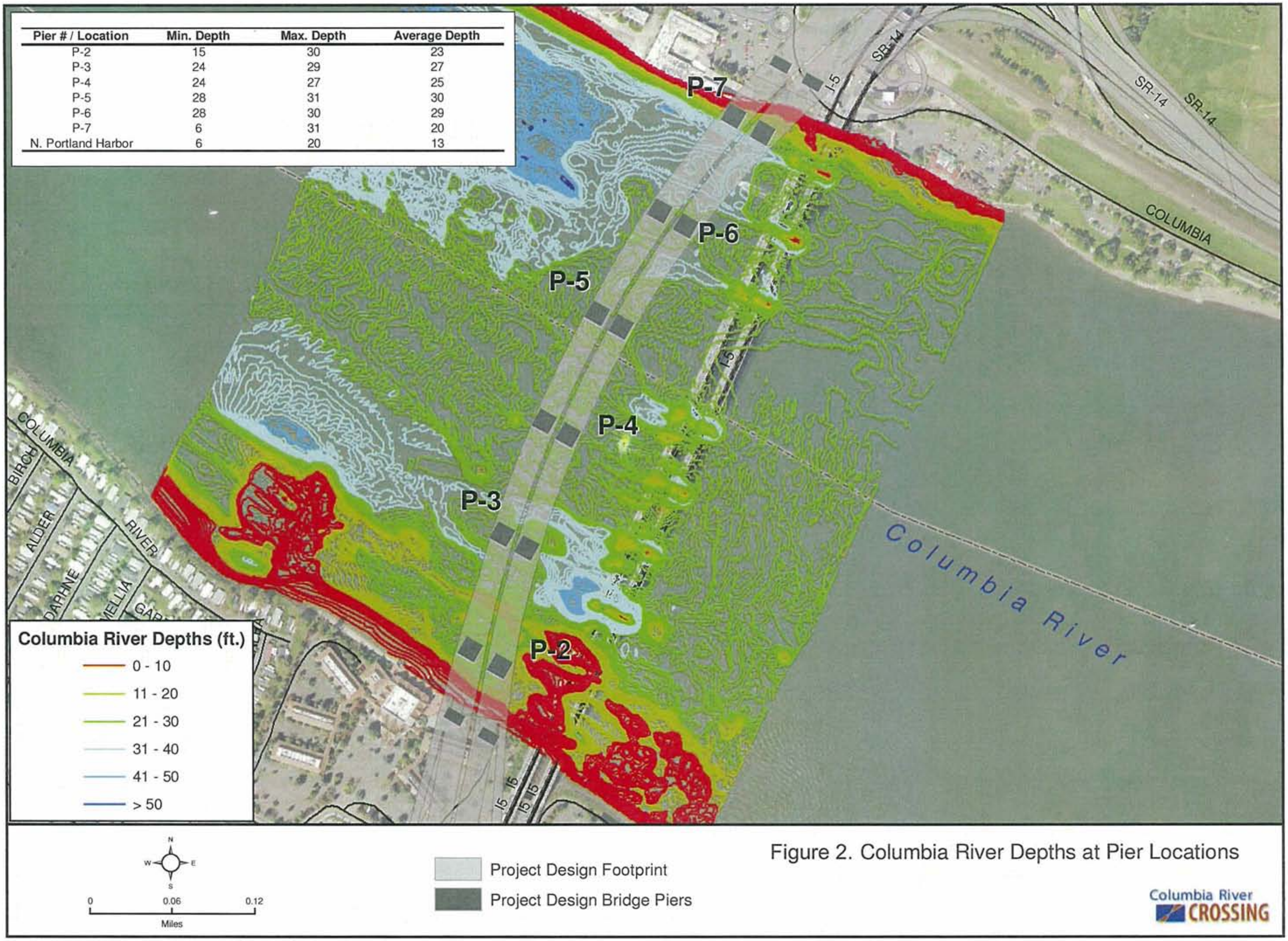


Figure 2. Columbia River Depths at Pier Locations

Columbia River CROSSING

6399

6400

Pier # / Location	Min. Depth	Max. Depth	Average Depth
P-2	15	30	23
P-3	24	29	27
P-4	24	27	25
P-5	28	31	30
P-6	28	30	29
P-7	6	31	20
N. Portland Harbor	6	20	13

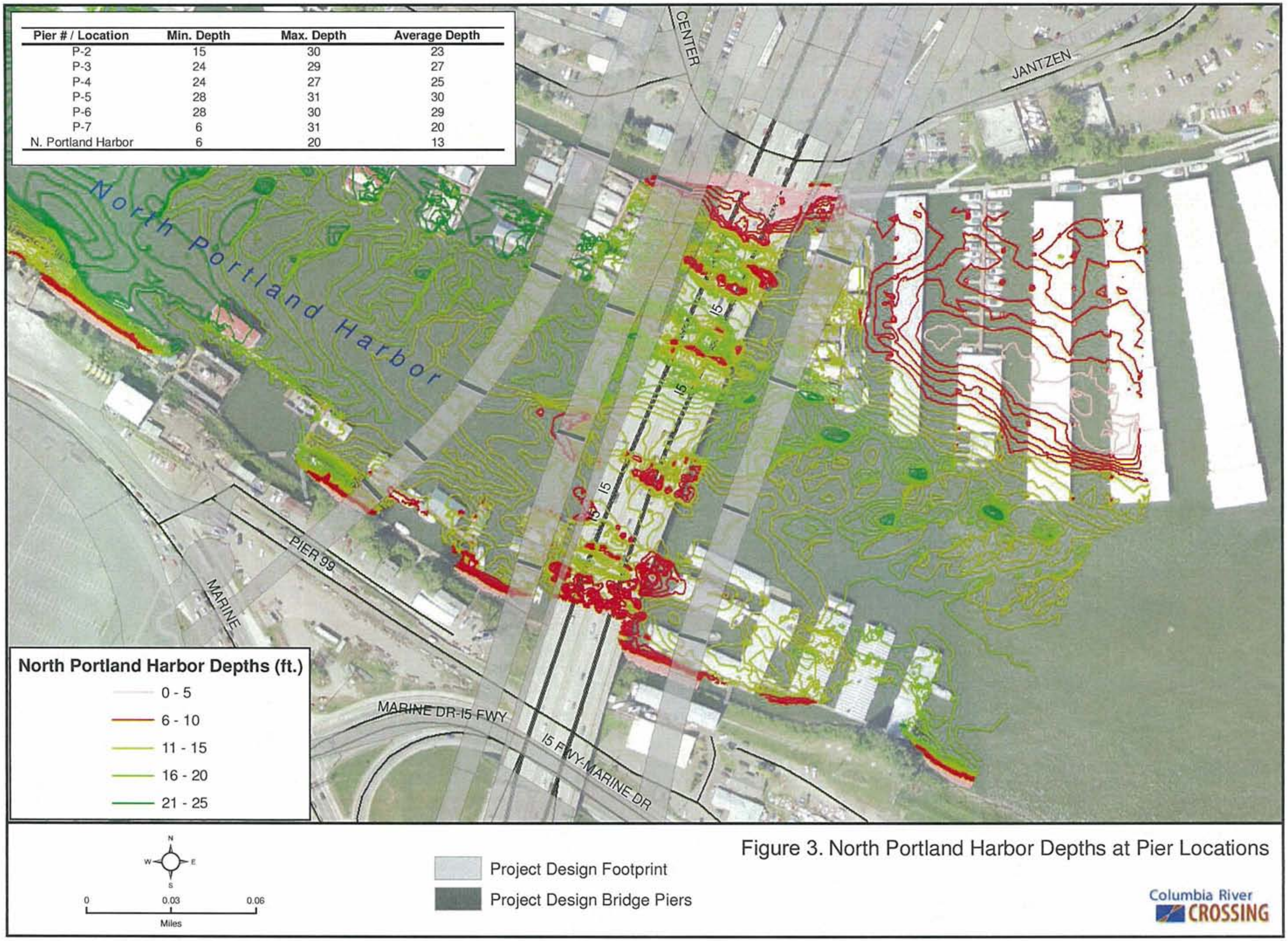


Figure 3. North Portland Harbor Depths at Pier Locations

4.6 Effects to Deep Water Habitat

Deep-water habitat (defined generally as water greater than 20 feet deep) occurs only in the Columbia River and not in the other waterways in the project area. Project elements responsible for temporary physical loss include the cofferdams and numerous temporary piles associated with in-water work platforms and moorings. Project elements responsible for permanent physical loss include the presence of new bridge piers in the river.

The project would lead to temporary physical loss of approximately 16,635 sq. ft. of deep-water habitat, consisting chiefly of coarse sand with a small proportion of gravel. Project elements responsible for temporary physical loss include the cofferdams and numerous temporary piles associated with in-water work platforms and moorings. The in-water portions of the new structures would result in the permanent physical loss of approximately 6,300 sq. ft. of deep-water habitat at pier complex 2 (on the Oregon side of the river) through pier complex 7 in the Columbia River. Demolition of the existing Columbia River piers would permanently restore about 21,000 sq. ft. of deep-water habitat. Overall there would be a net permanent gain of about 15,000 sq. ft. of deep water habitat in the Columbia River.

The lost habitat is not rare or of particularly high quality, and there is abundant similar habitat in immediately adjacent areas of the Columbia River and for many miles both upstream and downstream. The lost habitat would represent a very small fraction of the remaining habitat available. The structures would not pose a physical barrier to adult and juvenile lamprey migration.

Other than serving as migration habitat, no data are available on larval, juvenile, or adult lamprey use of deep water in the mainstem Columbia River. Larval Pacific lampreys and western brook lampreys have been documented in the lower Willamette River at depths up to 16 m (Jolley et al. 2010). A rough assumption could be made that lamprey may also occur in the Columbia River at such depths; however, extrapolating these results to the Columbia River may be problematic due to differences in substrate between the two rivers (Jolley pers. comm. 2010). In the Willamette study, distribution of ammocoetes was not associated with a particular depth. Other studies indicate that various species of lamprey can occur in deep water habitats: larval sea lamprey (*Petromyzon marinus*) and American brook lamprey (*Lethenteron appendix*) have been found in lentic areas of the Great Lakes (Hansen and Hayne 1962) and in deepwater tributaries (Bergstedt and Genovese 1994; Fodale et al. 2003, as cited in Jolley et al. 2010).

The work discussed above would remove or disturb substrate that may contain ammocoetes. Therefore, ammocoetes may be injured or killed by the temporary work done at the sites discussed above. Potential project impacts to larval, juvenile, or adult lamprey in deep water portions of the project area should not be discounted, but because data are lacking, impacts cannot be quantified at this time.

4.7 Effects to Prey Species

Adult lampreys prey on many species of fish, including salmon and steelhead, when in a marine environment. Adult and juvenile Pacific lampreys do not feed during freshwater migration, and subsist on lipid reserves during this life stage (Kostow 2002). The project would have no impact on the marine life stages of lamprey prey species. Project activities are anticipated to impact a very small portion of the salmon and steelhead runs in the Columbia River (depending on the ESU/DPS, this impact is expected to be less than 1% of the mean cumulative run; for many ESUs/DPSs, this would be less than 0.4%) (refer to section 6 and Appendix K of the Biological Assessment for a full analysis [CRC 2010]). The project is therefore expected to have insignificant effects to salmon and steelhead as the lamprey prey base. Ammocoetes are filter-feeders and feed on algae and other detritus (Kostow 2002; Moyle 2002). Project activities are not expected to impact the food base for ammocoetes.

5. Minimization and Mitigation Measures

5.1 Minimization

The CRC project's efforts at minimization and design refinements have reduced the acreage of the project footprint in the river by approximately one-half from initial designs. Specific design modifications to minimize the project footprint include:

- The original bridge crossing design was for 3 bridge spans (2 bridges for roadway and a separate bridge crossing for transit and bike/ped crossing). Using a Stacked Transit Highway Bridge (STHB) has reduced the design to 2 bridge spans and minimized the permanent in-water impact by over 40% (from 3.04 acres to 1.58 acres).
- The North Portland Harbor bridge will not be replaced, thereby reducing in-water impacts in North Portland Harbor.
- The number of piers in the Columbia River has been reduced from 21 to 12. Further design refinements on the bridge piers reduced the permanent footprint of the bridge an additional 10 percent, and reduced hydraulic effects in the river.
- Removal of the existing I-5 Bridge will restore 0.43 acre of aquatic habitat in the river bed.
- Providing a high level of stormwater treatment will minimize impacts to water quality and may provide a net improvement in water quality associated with the bridges.

All project work would be performed according to the requirements and conditions of the regulatory permits issued by federal, state, and local governments. Additional minimization measures that would be employed to limit project impacts to aquatic species and habitat include:

- Seasonal restrictions, such as in-water work windows.
- A Water Quality Sampling Plan would be developed and implemented for conducting water quality monitoring.
- A Spill Pollution and Prevention Control Plan would be developed and implemented in accordance with ODOT and WSDOT standard specifications.
- A Site Erosion and Sediment Control Plan would be developed and implemented in accordance with ODOT and WSDOT standard specifications.

- If work occurs at night, temporary lighting should be used in the night work zones. Directional lighting with shielded luminaries would be used to control glare and direct light onto work area; not surface waters.
- Hydroacoustic impacts would be minimized by the following measures:
  - Permanent foundations would be installed by means of drilled shafts, which would significantly reduce the amount of impact pile driving, the size of piles, and amount of in-water noise.
  - Installation of piles using impact driving may only occur between September 15 and April 15 of the following year.
  - In waters with depths more than 0.67 meters (2 feet), a bubble curtain or other sound attenuation measure would be implemented for impact driving of pilings.
  - Hydroacoustic levels would be monitored to limit exposure to migrating fish and to test the effectiveness of noise attenuation devices.
  - One 12-hour rest period would occur each work day in which no impact pile driving would occur.
  - A qualified biologist would be present during all impact pile driving operations to observe and report any indications of dead, injured, or distressed fishes, including direct observations of these fishes or increases in bird foraging activity.
  - Temporary piles shall be removed with a vibratory hammer and shall never be intentionally broken by twisting or bending. Except when piles are hollow and were placed in clean, sand-dominated substrate, the holes left by the removed pile shall be filled with clean native sediments immediately following removal. No filling of holes shall be required when hollow piles are removed from clean, sand-dominated substrates. At locations where hazardous materials are present or adjacent to utilities, temporary piles may be cut off at the mud line with underwater torches.

5.2 Mitigation

To offset project impacts to aquatic habitat in the Columbia River and North Portland Harbor, CRC will provide compensatory mitigation at two sites (one in Oregon and one in Washington) in compliance with the statutory requirements of each state. The mitigation designs have not yet been developed, but the mitigation sites will comply fully with all regulatory permit terms and conditions.

CRC coordinated with NMFS, USFWS, ODFW, and WDFW to develop mitigation goals used to select the two mitigation sites. The goals are:

- To restore habitat types or aspects that have been lost or greatly reduced over the last approximately 75 years.
- To restore access to historical habitats for anadromous and resident aquatic species.
- To provide connectivity and not be physically isolated from other habitat areas.
- To address impaired watershed processes that affect the aquatic system, water quality, and related ecosystem services.
- To preserve, enhance, and protect natural processes in order to maintain the habitat restored.
- To help implement adopted recovery plans or develop information to help advance the science.

In Oregon, CRC selected the Hood River Off-Channel Reconnection because it will provide high-value off-channel rearing habitat for juvenile salmonids and some spawning habitat for adult salmonids. Lampreys are known to occur in the Hood River and its tributaries. No ammocoetes were observed at the mitigation site during an ODFW/Confederated Tribes of the Warm Springs survey in September 2010 (Seals pers. comm. 2010); however, ammocoetes were documented in the mainstem river near the mitigation areas in October 2009 (Graham pers. comm. 2010).

The restoration site is part of a 400-acre parcel owned by Columbia Land Trust. CRC is providing funding for design and implementation of restoring a historic side channel of the Hood River. Columbia Land Trust and Hood River Watershed Council would be responsible for establishing the restoration site. CRC is proposing off-site compensatory mitigation on the lower Hood River located between RM 1.0 and 2.0 where the Mount Hood Railroad (MHRR) has cut off and isolated a historic side channel and associated wetland. The purpose of the mitigation project is to restore connectivity of the side channel and associated 21 acre wetland to the mainstem Hood River, greatly improving aquatic habitat complexity for migrating and rearing salmonids. The final design and construction sequence of the reconnected side channel and wetland will be based upon construction and staging methods, site topography, groundwater levels, and stream flow.

In Washington, CRC selected the Lewis River Confluence Side Channel Restoration project because the restored shallow water off channel habitats will provide high-value tidal rearing habitat for juvenile salmonids. Pacific lampreys are known to occur in the Lewis River and its tributaries, although specific data regarding abundance and habitat use in the mainstem portion of the river are lacking (Hallock pers. comm. 2010). USFWS has conducted a multi-year study of Pacific lamprey in Cedar Creek, a tributary to the mainstem Lewis River, and anecdotal records exist of adults spawning in the lower mainstem portion of the river (Silver pers. comm. 2010).

Mitigation will occur on the east bank of the Lewis River at its confluence with the Columbia River. This site is located downriver and approximately 10 miles northwest of the CRC project in the Lewis River watershed in Clark County. The restoration site is a 640-acre privately owned site managed by Wildlands of Washington, Inc. The CRC project is providing funding to buy a conservation easement on approximately 80 acres of the property, of which 18.1 acres is proposed restoration of historic side channels to mitigate for the CRC project's waterway impacts. The remaining 60+ acres of the easement would be re-creation and restoration of a riparian corridor along the restored side channels, enhancement of the existing riparian corridor along the Lewis River and shoreline enhancement and floodplain re-connection by removal of remnant levee along the east bank of the Lewis River. Historically, the east bank of the Lewis River at the confluence of the Columbia River had multiple side channels with an open hydraulic connection to the Columbia River. Those side channels were filled in and blocked by deposition of dredge spoils by USACE between the years 1965 to 1973. Restoration of the side channels will consist of removal of the dredge spoils to restore the channels and reconnect to the Lewis and Columbia Rivers. The mitigation project would restore over 21,100 linear feet of historic side channels of the Lewis River totaling 18.1 acres.

5.3 Best Management Practices Specific to Pacific Lamprey

CRC acknowledges that instream activities associated with aquatic habitat restoration for salmonids can impact habitat for Pacific lamprey (USFWS 2010), however the goals for the mitigation projects for salmonids are consistent with those for lamprey habitat restoration—i.e., to restore access to, and ecological function of, degraded historical habitat. USFWS (2010) has identified the following specific characteristics of desirable lamprey habitat:

- Stream and river reaches that have relatively stable flow conditions and that are not extreme or flashy.
- Large substrates (i.e. very large cobble and boulders) submerged in low or no flow areas of rivers and streams that provide high quality adult overwintering habitat.
- Areas of small to medium cobbles, free of fine sediment, that serve as spawning habitats.
- Depositional areas, including alcoves, side channels, backwater areas, pools, and low velocity stream and river margins that recruit fine sands and silts, downstream of spawning areas, that provide ammocoete rearing habitat.
- A combination of habitat components to serve all life stages, including deep pools, low velocity rearing areas with fine sand or silt, silt-free cobble areas upstream of rearing areas, and summer temperatures at or below 20° C (68° F).

USFWS (2010) has also identified the following "BMPs for Instream Activities to Avoid Adverse Effects to Pacific Lampreys":

- Consult with local federal, state and tribal biologists to obtain information on known lamprey populations in the drainage. Perform a site reconnaissance with nest surveys or other appropriate methods to identify locations of lamprey spawning and rearing habitat, and if possible, lamprey presence.
- Avoid working in stream or river channels from March 1 to July 1 in low to mid elevation reaches (<5,000 ft). In high elevation reaches (>5,000 feet), avoid working in stream or river channels from March 1 to August 1.
- Avoid dewatering stream reaches where lampreys are known to exist; survey to determine ammocoete presence, preferably at the project planning stage and when the project is implemented. Ramping flows, particularly during hours of darkness, can be effective in encouraging ammocoetes to move out of areas of impact.
- If dewatering is necessary in reaches with known lamprey presence, attempt salvage and move ammocoetes to a safe area. Dewater slowly over several days or at a minimum overnight. Identify areas adjacent to ammocoete habitat outside of the disturbance area but within the channel, and dig holes (e.g., few scoops with a backhoe) where ammocoetes may take refuge as dewatering occurs; cover these 'refuge' holes to protect them from predators. Anecdotal information suggests ammocoetes will move into areas that retain water—placing straw bales in habitats where ammocoetes are present may encourage them to move into the straw as dewatering occurs. Bales and ammocoetes can be safely removed the next day. If successful, document and provide this information to the USFWS.
- Avoid instream channel reconstruction, re-routing, dredging, and other activities that disturb or remove substrate materials where ammocoetes are known to exist. Where avoidance is not possible, salvage efforts should be attempted prior to activity. Sift through the removed substrate—salvaging any ammocoetes—and return them to the stream away from the construction activity.

The project will consider the specific habitat requirements of lamprey, the life history traits of lamprey, and the BMPs in the implementation of the mitigation projects discussed above. The dredge spoils to be removed at the mouth of the Lewis River are dry and are not suitable habitat for any life stage of lamprey.

CRC feels that the restoration projects in the Hood River and Lewis River will provide significant benefit to all native fish, especially lamprey. Both restoration projects will provide side channels, backwater areas, pools, and lower velocity stream flow and lower stream temperatures that will provide ideal ammocoete rearing areas (USFWS 2010). Studies in Ireland (King et al.) show that lamprey can rapidly colonize new habitat. In these studies, new habitat areas on the River Nore in Kilkenny, Ireland were terrestrial dry-land habitats prior to excavation for channel widening. Following restoration work, new lamprey populations colonized the sites via downstream drift, facilitated by displacement of upstream lamprey by flooding or torrential flow events. Both the Hood River and Lewis River projects will restore upland areas to their historic status as side channels of the river.

6. On-going Research and Data Needs

Pilot studies have been conducted in the mainstem Columbia River (Silver et al. 2008) and in the lower Willamette River (Jolley et al. 2010) that provide a starting point for assessing larval, juvenile, and adult lamprey presence and distribution in and near the project area. More research is needed to fully understand lamprey population dynamics in the project area and to allow project impact analysis with any level of certainty. As of August 2010, the following studies are currently underway or will be soon, and are anticipated to provide valuable information:

- USFWS will be continuing research in the mainstem Columbia River to examine occupancy and habitat use above and below Bonneville Dam, as well as in the tidally influenced portion of the river near and below Skamokawa (Jolley pers. comm. 2010). These studies are not being conducted within the CRC project area, but may have results useful for identifying lamprey use of mainstem habitats.
- The Columbia River Basin Lamprey Technical Workgroup has a subgroup that is developing a project to sample dredge spoils at various sites in the mainstem Columbia River for ammocoetes. The intent of this project is to help describe ammocoete distribution and impacts from dredging (Luzier pers. comm. 2010). Depending on the sampling locations, results from this project could help identify where ammocoetes are likely to occur in the mainstem Columbia River. Data on preferred depths, substrate characteristics, distribution patterns, and other parameters may help fill in existing data gaps for lamprey in the mainstem river.
- The U.S. Fish and Wildlife Service Pacific Lamprey Conservation Plan is in the process of being revised to include other existing restoration plans (e.g., the CRITFC restoration plan [2008]) nested within one document. Incorporating all existing plans into one document will minimize the duplicative nature and volume of existing management, conservation, and restoration plans. The revised document went out for internal review in mid-August 2010. This document, once finalized, will be a useful source of the most up-to-date lamprey conservation guidance.
- The Portland Harbor Natural Resources Trustee Council is conducting a study which began in 2009 to evaluate impacts of contaminated sediment on lamprey ammocoetes.
- CTGR is conducting an adult lamprey tracking study which began in 2006 to evaluate movements of adult lampreys in the Willamette River and its tributaries. While this study does not include the Lower Columbia River, it may provide valuable insights into the behavior of adult lamprey, which is largely unknown at this point.

Additional research needs include developing standardized methodologies designed to accurately sample all lamprey life stages to assess the status of this species (Moser and Close 2003), and studies of larval lamprey mainstem habitat to provide quantitative assessments of larval abundance, distribution and habitat parameter (Silver et al. 2008). Quantifying physical and chemical parameters may also aid development of tools for predicting larval distribution in large river systems (Silver et al. 2008).

7. Conclusions

Significantly more information is needed on lamprey distribution, abundance, and habitat use in the project area in order for CRC to complete a full project impacts analysis. It is well known that Pacific lamprey larvae, juveniles, and adults are present in the Columbia River, and impacts to all life stages cannot be wholly discounted. However, given the current paucity of existing data, as well as the lack of research on hydroacoustic impacts to lamprey, the extent of impacts is unknown, and an impact analysis is largely speculative. Lamprey ammocoetes may be impacted by in-water construction at each bridge pier site; however, ammocoete distribution and use of mainstem substrate is unknown and impacts cannot be quantified.

Project impacts to lamprey may be minimized by the following points:

- Adult lampreys are nocturnal and migrate at night. Lamprey movement through the project area would be expected to be at night, when impact pile driving would not occur and reduced construction activity is likely. It is unknown whether lampreys attach to manmade or natural in-water structures in the project area, such as bridge piers, dock pilings, rip rap, or boats, and therefore could be present in the project area during daytime.
- Major threats to lamprey in the mainstem Columbia River include barriers to migration, poor water quality, loss of floodplain and side channel habitat, dredging, and dewatering. The CRC project would not pose any of these threats to lamprey. Some habitat parameters are expected to improve over existing conditions due to enhanced stormwater treatment and improved side channel habitat at the two mitigation sites described above.

8. References

Archuleta, G. 2005. Skakwal (Lamprey Eel) at Willamette Falls. Prepared for the Confederated Tribes of Grand Ronde Cultural Resources Department.

BES (City of Portland, Bureau of Environmental Services). 2005. Columbia Slough: Current Characterization Documents, "Chapter 7, Physical Habitat and Biological Communities Characterization." Portland, Oregon: City of Portland. Available at: http://www.portlandonline.com/BES/index.cfm?c=36081&a=63589

Baxter, L. II, E.E. Hays, G.R. Hampson, and R.H. Backus. 1982. Mortality of Fish Subjected to Explosive Shock as Applied to Oil Well Severance on Georges Bank. Woods Hole Oceanographic Institution Report WHO-82-54.

Bergstedt, R.A., and J.H. Genovese. 1994. New technique for sampling sea lamprey larvae in deepwater habitats. North American Journal of Fisheries Management 14:449-452.

CRC (Columbia River Crossing). 2010. Biological Assessment for the Columbia River Crossing. Prepared by Parametrix, Portland, Oregon. June 2010.

CRITFC (Columbia River Inter-Tribal Fish Commission). 2008. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. Available at: www.critfc.org/text/lamprey/restor_plan.pdf. (February 2010).

Caltrans (Californian Department of Transportation). 2009. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish. Caltrans, Sacramento, California.

Close, D.A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of the Pacific lamprey (Lampetra tridentata) in the Columbia River Basin. Technical Report to Bonneville Power Administration DOE/BP-39067-1.

Close, D.A., M.S. Fitzpatrick, and H.W. Li. 2002. The ecological and cultural importance of a species at risk of extinction, Pacific lamprey. Fisheries 27:19-25.

Coker, C.M. and E.H. Hollis. 1950. Fish Mortality Caused by a Series of Heavy Explosions in Chesapeake Bay. Journal of Wildlife Management 14:435-445.

Fodale, M.F., C.R. Bronte, R.A. Bergstedt, D.W. Cuddy, and J.V. Adams. 2003. Classification of lentic habitat for sea lamprey (Petromyzon marinus) larvae using a remote seabed classification device. Journal of Great Lakes Research 29 (Supplement 1):190–203.

Gaspin, J.B. 1975. Experimental Investigations of the Effects of Underwater Explosions on Swimbladder Fish, I: 1973 Chesapeake Bay tests. Navel Surface Weapons Center Report NSWC/WOL/TR 75-58.

Goertner, J. F., M.L. Wiley, G.A. Young, and W.W. McDonald. 1994. Effects of Underwater Explosions on Fish without Swimbladders. Naval Surface Warfare Center Report NSWC TR88-114.

Graham, J. and C. Brun. 2007. Determining Lamprey Species Composition, Larval Distribution, and Adult Abundance in the Deschutes River, Oregon, Subbasin. 2006-2007 Annual Report, Project No. 200201600, 39 electronic pages, (BPA Report DOE/BP-00026436-1). Available at: http://www.fishlib.org/library/Documents/BPA_Fish_and_Wildlife/00009553-1.pdf

Graham, Jennifer. Fisheries Biologist. Confederated Tribes of the Warm Springs. Personal communication. Email correspondence with Steve Morrow, CRC Biologist. September 2, 2010.

Hallock, Molly. Fisheries Biologist, Washington Department of Fish and Wildlife. Personal communication. Telephone call to Jennifer Lord, Parametrix Biologist, September 20, 2010.

Hansen, M.J., and D.W. Hayne. 1962. Sea lamprey larvae in Ogontz Bay and Ogontz River, Michigan. Journal of Wildlife Management 26:237-247.

Hastings, M.C. and A.N. Popper. 2005. Effects of Sound on Fish. Unpublished report prepared for California Department of Transportation.

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2010. Occurrence, Detection, and Habitat Use of Larval Lamprey in Mainstem Environments: the Lower Willamette River. U.S. Fish and Wildlife Service 2009 Annual Report. Available at: http://www.fws.gov/columbiariver/publications/2009_Mainstem_lamprey_AR.pdf.

Jolley, Jeffrey. Fish Biologist. U.S. Fish and Wildlife Service. Personal communication. Email correspondence with Jennifer Lord, Parametrix Biologist, between July 27 and August 13, 2010.

Jolley, J.C. G.S. Silver, and T.A. Whitesel. 2011a. Occurrence, Detection, and Habitat Use of Larval Lamprey in Columbia River Mainstem Environments: The Lower Columbia River. 2010 Annual Report. U.S. Fish and Wildlife Service, Vancouver, Washington.

Jolley, J.C. G.S. Silver, and T.A. Whitesel. 2011b. Occurrence, Detection, and Habitat Use of Larval Lamprey in Columbia River Mainstem Environments: Bonneville Reservoir and Tailwater. 2010 Annual Report. U.S. Fish and Wildlife Service, Vancouver, Washington.

King, J.J., G. Hanna, and G.D. Wightman. 2008. Ecological Impact Assessment (EcIA) of the Effects of Statutory Arterial Drainage Maintenance Activities on Three Lamprey Species (Lampetra planeri Bloch, Lampetra fluviatilis L., and Petromyzon marinus L.). Series of Ecological Assessments on Arterial Drainage Maintenance No 9 Environment Section, Office of Public Works, Headford, Co. Galway. Available at: http://www.opw.ie/en/media/Issue%20No.%209%20EcIA%203%20Lamprey%20Species.pdf.

Karnosh, Michael. Ceded Lands Program Manager, Confederated Tribes of Grand Ronde. Personal communication. Email correspondence with Steve Morrow, Columbia River Crossing Environmental Coordinator. January 20, 2011.

Kostow, K. 2002. Oregon Lampreys: Natural History, Status, and Analysis of Management Issues. Oregon Department of Fish and Wildlife Information Report No. 2002-01.

Liao, J.C. 2002. Swimming in needlefish (Belonidae): anguilliform locomotion with fins. Journal of Experimental Biology 205:2875-2884.

Luzier, Christina W. U.S. Fish and Wildlife Service. Personal communication. Email correspondence with Jennifer Lord, Parametrix Biologist. August 12, 2010.

Mesa, M. G., J. M. Bayer, and J. G. Seelye, 2003. Swimming performance and physiological responses to exhaustive exercise in radio-tagged and untagged Pacific lamprey. Transaction of the American Fisheries Society 132:483-492.

Moser, M. and D. Close. 2003. Assessing Pacific Lamprey Status in the Columbia River Basin. Project No. 1994-02600 (BPA Report DOE/BP-00005455-5). 10 pp.

Moyle, P. B. 2002. Inland fishes of California. Revised and expanded. University of California Press, Berkeley, CA. xv + 502 pp.

Nawa, R.K., J.E. Vaile, P. Lind, Nadananda, T. McKay, C. Elkins, B. Bakke, J. Miller, W. Wood, K. Beardslee, and D. Wales. A petition for rules to list: Pacific lamprey (*Lampetra tridentata*); River lamprey (*Lampetra ayresi*); Western brook lamprey (*Lampetra* *richardsoni)*; and Kern brook lamprey (*Lampetra hubbsi*) as threatened or endangered under the Endangered Species Act. January 23, 2003.

PSMFC (Pacific States Marine Fisheries Commission). 2003. Presence/Absence Study for Salmonids in Burnt Bridge Creek. Funded by the City of Vancouver. Vancouver, Washington.

Parametrix. 2011. Technical Memorandum from Elisabeth Bowers, Parametrix, to Steve Morrow, CRC. Sediment Sampling - Lamprey Observation Summary. April 7, 2011.

Parcel Insight. 2009. Columbia River Crossing, Oregon and Washington Corridor Report. 200.40. March 3, 2009.

Popper, A.N., T.J. Carlson, A.D. Hawkins, B.L. Southall, and R.L. Gentry. 2006. Interim criteria for injury of fish exposed to pile driving operations: a white paper.

Seals, Jason. Assistant District Fish Biologist. Oregon Department of Fish and Wildlife. Personal communication. Email correspondence with Steve Morrow, CRC Biologist. September 14, 2010.

Silver, G.S., C.W. Luzier, and T.A. Whitesel. 2008. Investigation of larval Pacific lamprey occupancy of the mainstem Columbia River and Willamette River. U.S. Fish and Wildlife Service 2007 Annual Report.

Silver, Greg. Fisheries Biologist. U.S. Fish and Wildlife Service. Personal communication. Email correspondence with Jennifer Lord, Parametrix Biologist, September 21, 2010.

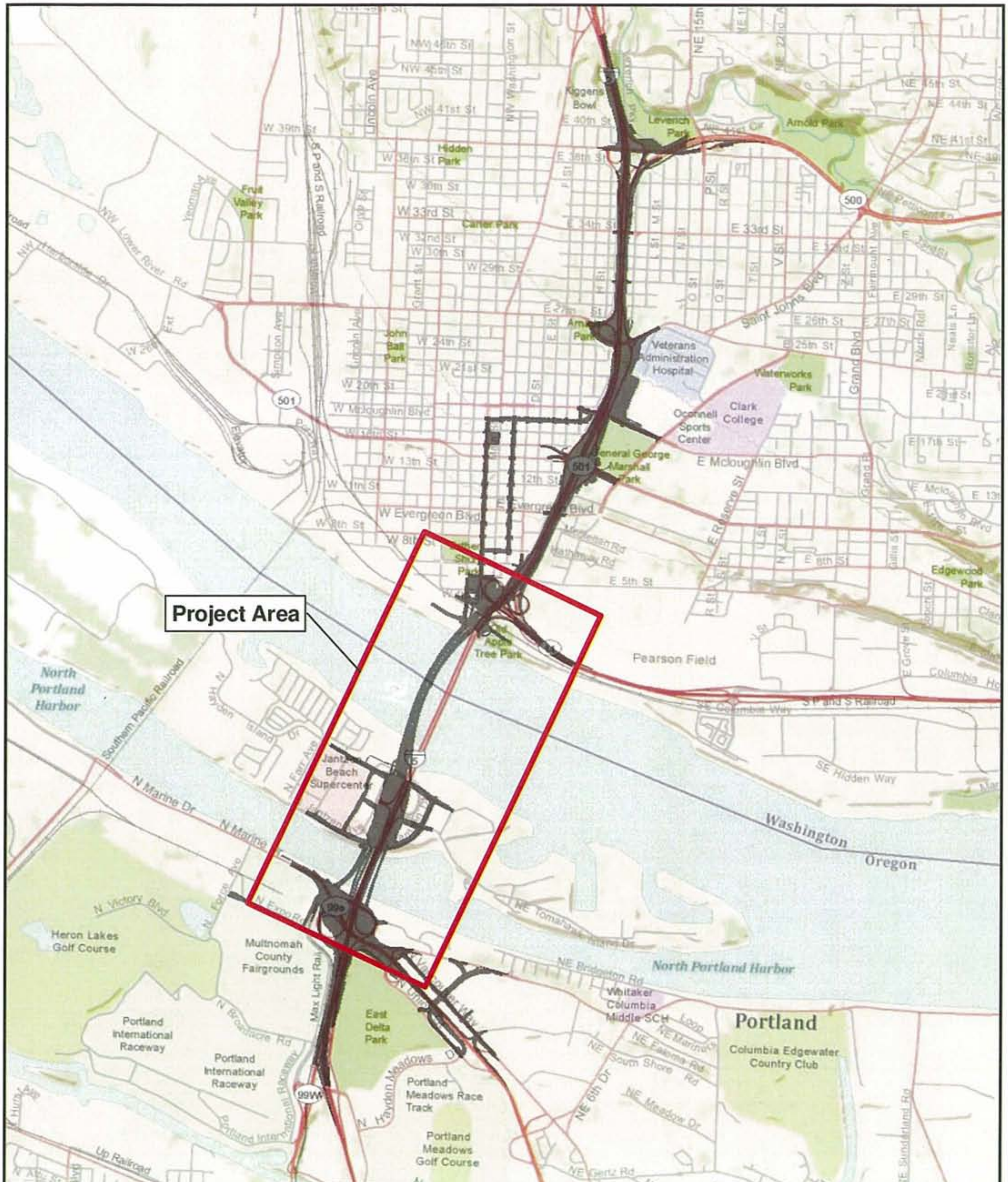
Stadler, John. Fisheries biologist, National Marine Fisheries Service. Personal communication: email to Jennifer Lord, Parametrix. July 20, 2010.

USFWS (U.S. Fish and Wildlife Service). 2008. Draft Outline of the Pacific Lamprey Conservation Plan. Available at: http://www.fws.gov/pacific/fisheries/sp_habcon/lamprey/pdf/Pacific%20Lamprey%20Conservation%20Initiative%20ver%20060809.pdf.

USFWS (U.S. Fish and Wildlife Service). 2010. Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (*Entosphenus tridentatus*). Available at: http://www.fws.gov/pacific/fisheries/sp_habcon/lamprey/pdf/Best%20Management%20Practices%20for%20Pacific%20Lamprey%20April%202010%20Version.pdf.

APPENDIX A

Sediment Sampling Map



Project Footprint

0 2,000 4,000
Feet

Figure A-1. Project Location Map

Columbia River CROSSING

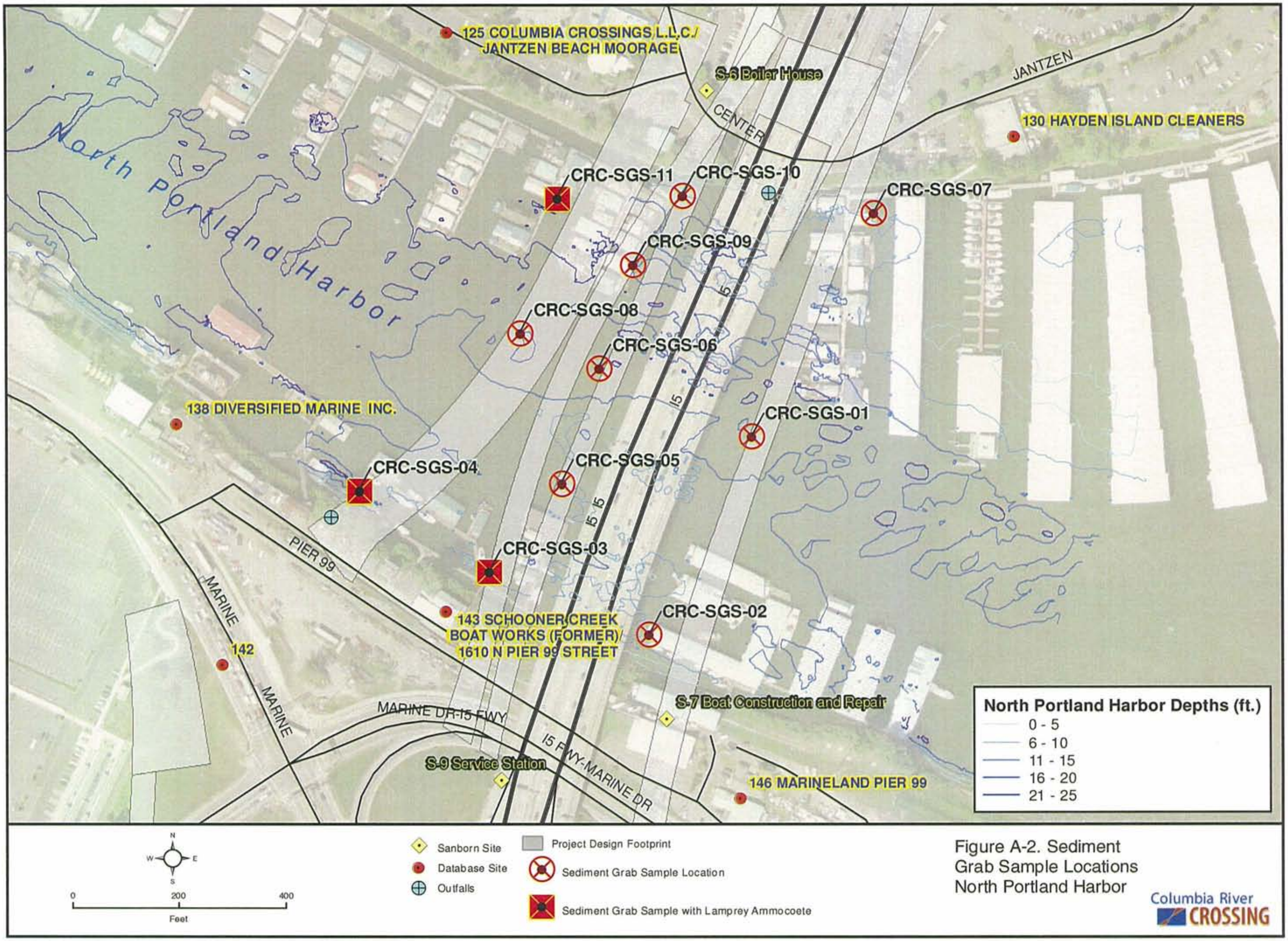


Figure A-2. Sediment
Grab Sample Locations
North Portland Harbor

PRELIMINARY

PRELIMINARY

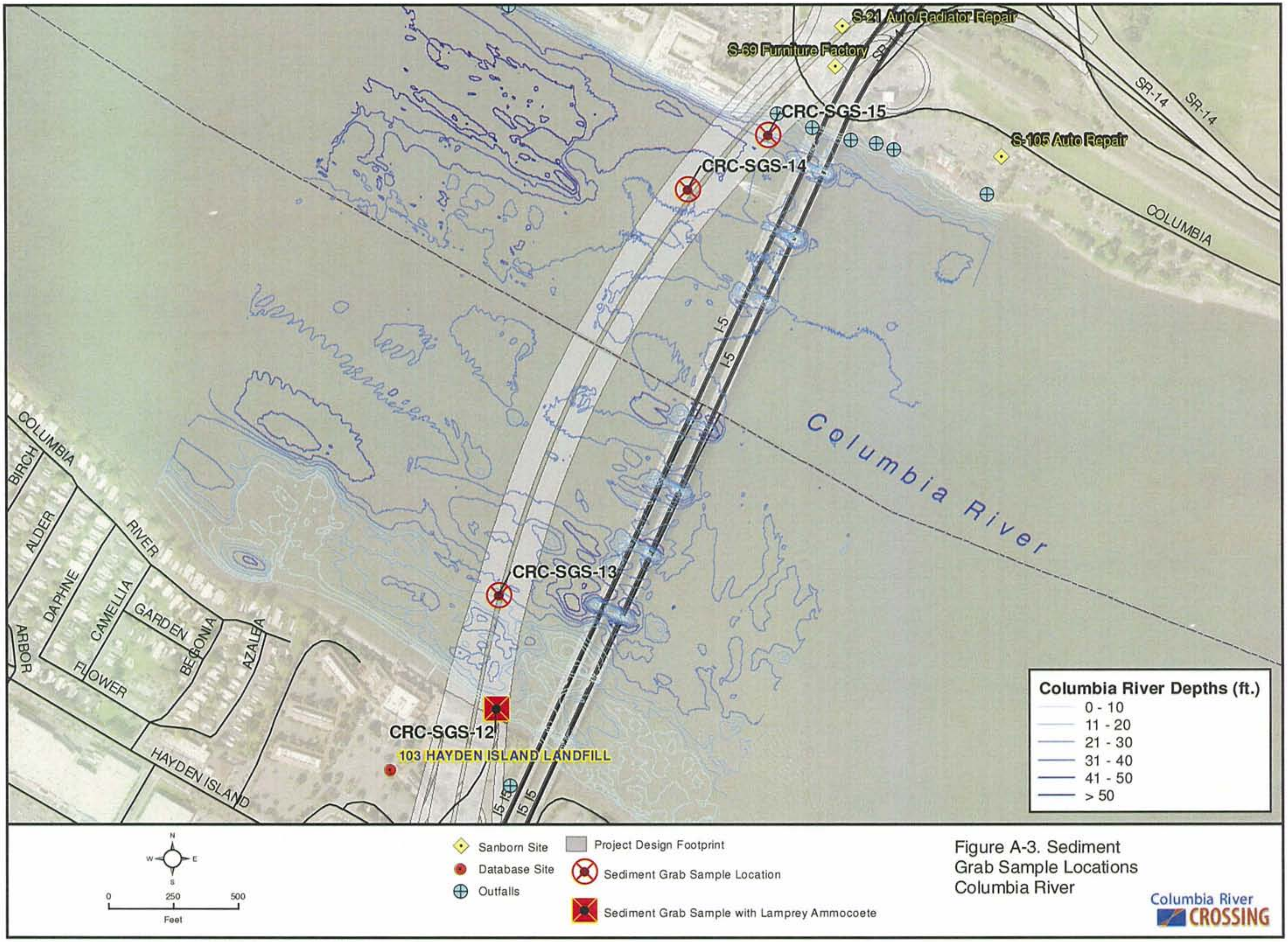


Figure A-3. Sediment Grab Sample Locations Columbia River

U.S. DEPARTMENT OF TRANSPORTATION

Federal Highway Administration
Oregon Division Office
530 Center Street, Suite 100
Salem, Oregon 97301
503-399-5749

Federal Transit Administration
Region 10
915 Second Avenue, Room 3142
Seattle, Washington 98174-1002
206-220-7954

April 19 2011

RECEIVED

APR 25 2011

Columbia River Crossing

Nancy Boyd
Project Director
Columbia River Crossing
700 Washington Street, Suite 300
Vancouver, WA 98660

RE: CRC's NEPA Re-evaluation for Composite Truss Bridge Type

Dear Ms. Boyd:

The Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) have received the Environmental Re-Evaluation Worksheet, including supporting documentation, dated March 29, 2011, and supplemental information, submitted on April 11, 2011 regarding the Columbia River Crossing project's recommendation to change the design for the main river crossing bridge type from an open web box (OWB) girder to a composite truss. The design changes considered are between Oregon Interstate 5 milepost 308.38 and Washington Interstate 5 milepost 0.52. You have offered this information seeking FHWA's and FTA's position on whether this change in bridge design will require a Supplemental Draft Environmental Impact Statement (SDEIS) under the National Environmental Policy Act (NEPA).

While the Draft Environmental Impact Statement (DEIS) for the project, dated May, 2008, did not evaluate a specific bridge type, it did however dismiss "high level" and "low level" bridges due the impacts on navigation and air traffic. What remained for bridge types that would fit within the DEIS project description are considered "mid-level" bridges. Both the OWB girder and the composite truss can be designed to fit within the "mid-level" range for overall height and river clearance. The composite truss is very similar to the open web box (OWB) girder regarding footprint and environmental impacts and is considered a "mid-level" bridge, thus avoiding the environmental constraints related to navigation and air traffic identified in the DEIS. The submitted Re-evaluation is based on the assumption that the composite truss bridge will remain on the same over-water, curved alignment and will touch down on land in the same locations that was presented in the DEIS. The primary differences between the composite truss and the OWB girder are that vertical concrete elements will be replaced with steel diagonal members, and that the structure will be lighter, resulting in a smaller in-water footprint due to smaller foundations. Other than (the potential lessening of) impacts related to the smaller water

6420

footprint, and minor changes to pedestrian connections on the Washington shore, the submitted Re-evaluation indicated no changes in environmental impacts due specifically (and only) to this change in bridge design.

The purpose of the March 29, 2011 Re-evaluation is to evaluate the narrow question of whether the change from an open web box girder to a composite truss bridge will require a Supplemental DEIS. In that evaluation, we must consider whether the new bridge design presents significant environmental impacts which were not reviewed in the DEIS. (23 CFR Section 771.129). Based on the specific information you have provided, FHWA and FTA concur that the change from an OWB girder bridge type to a composite truss bridge type does not create new significant environmental impacts that would require a Supplemental DEIS.

Please note that we offer this position solely on the limited question of whether NEPA would require a Supplemental DEIS only focusing on the bridge type change due to potential significant impacts that a change in bridge design could create. However, we also understand that the project is considering other project changes that may also bring into question the need for supplemental environmental reviews -- including a Supplemental DEIS. We ask that any future request for environmental review re-evaluation include, as much as possible, all project changes and refinements that have been implemented since the May, 2008 DEIS so that we can make one final determination as to whether or not a Supplemental DEIS will be required for the project.

Sincerely,

R.F. Krochalis
Regional Administrator
Federal Transit Administration

for Phillip Ditzler
Division Administrator - Oregon
Federal Highway Administration

Daniel Mathis

Daniel Mathis
Division Administrator – Washington
Federal Highway Administration

Columbia River CROSSING

700 WASHINGTON STREET
SUITE 300
VANCOUVER, WA 98660
360-737-2726 | 503-256-2726

March 29, 2011

R.F. Krochalis
Federal Transit Administration, Region 10
915 2nd Avenue, Suite 3142
Seattle, WA 98174-1002

John McAvoy
Federal Highway Administration-Oregon Division
610 E 5th Avenue
Vancouver, WA 98661

Subject: CRC Composite Truss NEPA Re-evaluation

To Mr. McAvoy and Mr. Krochalis,

Attached is a NEPA Re-evaluation to cover a change in bridge type from the current open web box girder (OWBG) to a composite truss. The bridge would still be on the same downstream curved alignment that was analyzed in the Draft Environmental Impact Statement. The DEIS did not actually specify a particular bridge type. Rather, the DEIS described the basic location, size, height and clearance assumptions for the bridge, noting that the specific design would be determined later. A key limitation on the DEIS analysis was that the bridge would not include tall towers. The OWBG, composite truss, and other similar bridge types all fit within the bridge parameters and impacts described and analyzed in the DEIS.

The OWBG and composite truss are almost identical in terms of environmental impacts, size and look. The primary difference is that the composite truss has a lighter weight superstructure, which results in a slightly smaller footprint in the water because the pier foundations can be smaller. The OWBG is a concrete box structure with portions of the webs (vertical walls) removed and replaced with diagonal steel members. By contrast, a composite truss is comprised of primarily steel framing (similar to a traditional truss structure) with concrete slabs on upper and lower levels.

Based on the information contained in the attached re-evaluation, we conclude that there are no new significant environmental impacts from changing bridge types to a composite truss and a Supplemental Environmental Impact Statement is not warranted.

We request, in writing, FHWA and FTA concurrence on the conclusion that a Supplemental DEIS is not necessary for a composite truss bridge type on the downstream curved alignment.

Thank You,

Heather Wills, CRC Environmental Manager
cc: Steve Saxton, FTA
Project Controls

6426

ENVIRONMENTAL RE-EVALUATION CONSULTATION

Note: The purpose of this worksheet is to assist sponsoring agencies in gathering and organizing materials for re-evaluations required under the National Environmental Policy Act (NEPA). Submission of the worksheet by itself does not meet NEPA requirements. FTA & FHWA must concur in writing with its determination and/or the sponsoring agency's NEPA recommendation. Contact the FTA Region 10 office at (206) 220-7954 or FHWA CRC Project Manager at (360) 619-7591 if you have any questions regarding this worksheet. We strongly encourage you to contact us to discuss your project changes before you fill out this worksheet.

For Agency Use *Date Received:*	
Recommendation by FTA Planner or Engineer: ☐ *Accept* ☐ *Return for Revisions* ☐ *Not Eligible* *Recommendation by FHWA Planner or Engineer:* ☐ *Accept* ☐ *Return for Revisions* ☐ *Not Eligible*	*Reviewed By:* *Date:* *Reviewed By:* *Date:*
Comments:	
Concurrence by FTA Counsel: ☐ *Accept Recommendation* ☐ *Return with Comments* *Concurrence by FHWA Counsel:* ☐ *Accept Recommendation* ☐ *Return with Comments*	*Reviewed By:* *Date:* *Reviewed By:* *Date:*
Comments:	
Concurrence by Approving Officials: FTA: FHWA:	*Date:* *Date:*

Please answer the following questions, fill out the impact chart and attach project area and site maps. Using a site map from the previously approved NEPA document, show project changes using a different color. Include additional site maps to help reviewer understand project changes.

PROJECT TITLE Columbia River Crossing-BRP Alternative-Composite Truss-Existing Alignment – This is only for the truss bridge type on the existing alignment; any other changes would require an additional re-evaluation.

LIST CURRENT, APPROVED ENVIRONMENTAL DOCUMENTS (e.g. EIS/ROD, EA/FONSI, BA, RE-EVALUATION, etc.) If Re-evaluation, briefly describe.
Title: DEIS Date: May 2008 Type and Date of Last Federal Action
Title: Biological Assessment Date: June 2010 Type and Date of Last Federal Action: Received Biological Opinion in January 2011
Title: Biological Opinion Date: January 2011 Type and Date of Last Federal Action

HAS THE MOST CURRENT AND OTHER PERTINENT APPROVED ENVIRONMENTAL DOCUMENTS BEEN *RE-READ* TO COMPARE PROPOSED PROJECT CHANGES?

☐ **NO (STOP! The most current approved environmental document MUST be re-read prior to completing a re-evaluation.)**

☒ **YES NAME: Seth English-Young DATE: March 24, 2011**

IS THE PROJECT CURRENTLY UNDER ☒ DESIGN OR ☐ CONSTRUCTION?

REASON FOR RE-EVALUATION The CRC project was analyzing an innovative truss bridge type called an "open web box girder" for the Final Environmental Impact Statement. An independent review panel suggested that the project convene a bridge type review panel to analyze potential risk associated with the open web design. The bridge panel made several recommendations. First, they recommended that further design work on the open web box design be halted. They also recommended three alternative bridge types for the CRC project to analyze and move forward with on the project (see Bridge Review Panel report at http://www.columbiarivercrossing.com/FileLibrary/GeneralProjectDocs/BRP_Report.pdf). One of the recommended bridge types is the composite truss. This document re-evaluates the impacts of the composite truss bridge on the existing alignment analyzed in the DEIS.

DESCRIPTION OF PROJECT CHANGES OR NEW INFORMATION

This re-evaluation worksheet will analyze the composite truss bridge type on the current downstream curved alignment as depicted in the DEIS. The changes with the bridge type only occur on the Columbia River over water structure. All touchdown points, highway lane configurations, interchange improvements, and transit alignments, remain the same as the open web. The bicycles and pedestrians would still be located under the highway lanes as well as the transit inside the box.

The open web box girder (OWBG) is a concrete box structure with portions of the webs (vertical walls) removed and replaced with diagonal steel members. By contrast, a composite truss is comprised of primarily steel framing (similar to a traditional truss structure) with concrete slabs on upper and lower levels.

The DEIS remains silent on the type of bridge that would ultimately be selected (see DEIS pages 2-16 to 2-17). Specifically, it says, "If a replacement crossing is chosen, this will not yet determine the bridge type (for example, three parallel bridges or a stacked transit/highway bridge…) or bridge material (for example, concrete, steel, or composite)." However, high level bridge types were specifically discarded

(See page 2-46 to 2-47 of DEIS for alternatives discarded). It is still important to complete this re-evaluation of impacts of the composite truss in case this bridge type has additional environmental impacts.

HAVE ANY NEW OR REVISED LAWS OR REGULATIONS BEEN ISSUED SINCE APPROVAL OF THE LAST ENVIRONMENTAL DOCUMENT THAT AFFECTS THIS PROJECT? If yes, please explain.

☐ **NO**
☒ **YES**

The FHWA published a final rule updating 23 CFR 772 on "PROCEDURES FOR ABATEMENT OF HIGHWAY TRAFFIC NOISE AND CONSTRUCTION NOISE" on July 13, 2010. This final rule does not affect the bridge type discussion, but will impact the noise analysis in the FEIS.

IS THE LIST OF THREATENED AND ENDANGERED SPECIES (NMFS AND USFWS) MORE THAN 6 MONTHS OLD?

☒ **NO**
☐ **YES (STOP! Endangered Species lists and analysis MUST be updated.)**

WILL THE NEW INFORMATION HAVE THE POTENTIAL TO CAUSE A CHANGE IN THE DETERMINATION OF IMPACTS FROM WHAT WAS DESCRIBED IN THE ORIGINAL ENVIRONMENTAL DOCUMENT FOR ANY OF THE AREAS LISTED BELOW? For each impact category, please indicate whether there will be a change in impacts. For all categories with a change, continue to the table at the end of this worksheet and provide detailed descriptions of the impacts as initially disclosed, new impacts and a discussion of the changes. The change in impact may be beneficial or adverse.

Transportation	☐ **Yes**	☒ **No**
Land Use and Economics	☐ **Yes**	☒ **No**
Acquisitions, Displacements, & Relocations	☐ **Yes**	☒ **No**
Neighborhoods & Populations (Social)	☐ **Yes**	☒ **No**
Visual Resources & Aesthetics	☒ **Yes**	☐ **No**
Air Quality	☐ **Yes**	☒ **No**
Noise & Vibration	☐ **Yes**	☒ **No**
Ecosystems (Vegetation & Wildlife)	☒ **Yes**	☐ **No**
Water Resources	☐ **Yes**	☒ **No**
Energy & Natural Resources	☐ **Yes**	☒ **No**
Geology & Soils	☐ **Yes**	☒ **No**
Hazardous Materials	☐ **Yes**	☒ **No**

Public Services	☐ Yes	☒ No
Utilities	☐ Yes	☒ No
Historic, Cultural & Archaeological Resources	☐ Yes	☒ No
Parklands & Recreation	☐ Yes	☒ No
Construction	☐ Yes	☒ No
Secondary and Cumulative	☐ Yes	☒ No

Will the changed conditions or new information result in revised documentation or determination under the following federal regulations?

Endangered Species Act	☐ Yes	☒ No
Magnuson-Stevens Act	☐ Yes	☒ No
Farmland Preservation Act	☐ Yes	☒ No
Section 404-Clean Water Act	☐ Yes	☒ No
Floodplain Management Act	☐ Yes	☒ No
CERCLA (Hazardous Materials)	☐ Yes	☒ No
Section 106 National Historic Preservation Act	☐ Yes	☒ No
Uniform Relocation Act	☐ Yes	☒ No
Section 4(f) Lands	☐ Yes	☒ No
Section 6(f) Lands	☐ Yes	☒ No
Wild & Scenic Rivers	☐ Yes	☒ No
Coastal Barriers	☐ Yes	☒ No
Coastal Zone	☐ Yes	☒ No
Sole Source Aquifer	☐ Yes	☒ No
National Scenic Byways	☐ Yes	☒ No
Other Marine Mammal Protection Act	☐ Yes	☒ No

If you checked yes to any of these, describe how the changes impact compliance and any actions needed to ensure compliance of the new project:
Will these changes or new information likely result in substantial public controversy?

☒ **Yes** ☐ **No**

Comments: The bridge type has been a topic of discussion and disagreement since the NOI was issued in September 2005. There is a portion of the public that wants a bridge with above deck features even though they were dismissed from consideration in 2006 due to aviation safety issues (See Page 2-46 to 2-47 of the DEIS). There is also a portion of the public that wants the streamlined bridge without above deck features to move forward. Either way, there is public controversy around the aesthetics conversation. There will continue to be public discourse about aesthetics if we move forward with the composite truss design or if a high bridge is chosen.

ADDITIONAL COMMENTS: Attached is the DEIS comment letter from FAA concurring with dismissal of high level bridges in the DEIS.

CONCLUSIONS AND RECOMMENDATIONS: The composite truss bridge type on the downstream, curved alignment is similar in appearance and form to the OWBG. Also, the quantity, configuration, and impact of permanent piles necessary to support the composite truss are similar to that of the open web box girder design. Finally, the impacts related to construction methods, in-water work and permanent structure are less with the composite truss bridge type than what was analyzed in the Biological Assessment for Endanger Species Act Section 7 consultation. The DEIS was written broad enough around bridge type to include differing types that carry similar impacts. The new information regarding the composite truss bridge type does not require a Supplemental DEIS because there are no new significant environmental impacts that were not already disclosed to the public in the DEIS.

LIST OF ATTACHMENTS:

1. DEIS Pages 2-16, 2-17, 2-46, 2-47
2. Bridge review panel report - contains preliminary information about the difference between the open web box girder design and the truss design.
   http://www.columbiarivercrossing.com/FileLibrary/GeneralProjectDocs/BRP_Report.pdf
3. Deck truss preliminary foundation study - validating the information in the bridge report that the piers would be smaller is size than the open web box girder
4. Plan view drawings of the pier size and layout for the open web and composite truss bridge types
5. Plan view of truss touchdown points on the north and south sides of the river
6. FAA DEIS comment letter

SUBMITTED BY:
By signing this, I certify that to the best of my knowledge this document is complete and accurate.

Name Heath Wells Title Environmental Manager	Date 3/29/11

Submit two paper copies of this form, attachments, and a transmittal letter recommending a NEPA finding to the address below. Submit an electronic version to your area FTA Community Planner and FHWA Project Manager. Contact FTA or FHWA at the number below if you are unsure who this is or if you need the email address. Modifications are typically necessary. When the document is approved, FTA and FHWA may request additional copies.

Federal Transit Administration, Region 10
915 2nd Avenue, Suite 3142
Seattle, WA 98174-1002
phone: (206) 220-7954
fax: (206) 220-7959

Federal Highway Administration Oregon Division
530 Center Street NE., Suite 100
Salem, OR 97301
phone: (503) 399-5749
fax: (503) 399-5838

Federal Highway Administration Washington Division
711 S. Capitol Way, Suite 501
Olympia, WA 98501
phone: (360) 753-9480
fax: (360) 753-9889

Impact Category	Impacts as Initially Disclosed	New Impacts	Change in Impacts
Water Resources/Impervious Surface/	Up to six lanes of traffic in each direction. A four lane and six lane configuration was analyzed for the DEIS.	The LPA now assumes five lanes in each direction, which has less impervious surface than the six lane configuration.	The composite truss bridge type is within the range of impacts reported in the DEIS.
Transportation	The stacked transit highway bridge was analyzed as an option in the DEIS with bikes/peds and transit inside the box.	The composite truss bridge type still accommodates the stacked transit highway bridge configuration	No change from the DEIS. There would be no difference in traffic or transit alignment or performance between the OWBG and the composite truss.
Land Use and Economics			None
Acquisitions, Displacements, & Relocations			There is no additional ROW required for the composite truss. The touchdown points and interchanges analyzed in the DEIS will still apply (see plan view of truss touchdown points on the north and south sides of the river).
Neighborhoods & Populations (Social)			None

Visual Resources & Aesthetics	The DEIS did not specify bridge type beyond the three bridge or stacked transit highway bridge options. The substructure of the stacked transit highway configuration can accommodate v-shaped columns.	The substructure of the composite truss can still accommodate the v-shaped columns and the stacked transit highway configuration	Since the DEIS did not specify bridge type either the composite truss or the OWBG could accommodate the v-shaped columns and stacked transit highway configuration and have very similar visual impacts. When viewed from a distance, the OWBG and composite truss superstructures will be similar. When viewed from up close, steel framing and associated connections will be more evident for the composite truss. The pier shape for the composite truss bridge is yet to be determined, but will be similar in nature to the OWBG (columns).
Air Quality			No change in traffic impacts, therefore no change in emissions and air quality.
Noise & Vibration			None
Ecosystems (Vegetation & Wildlife)	A three bridge option and stacked transit highway bridge were discussed in the DEIS. The stacked transit highway bridge had less permanent in-water structure than the three bridge option--six piers on each structure for a total of 12 in water piers.	A stacked transit highway bridge would still be used for the composite truss bridge type. However, because the new bridge type is mostly steel with less concrete, the permanent in-water structures would be lighter than the OWBG (See plan drawings and calculations attached).	The change from OWBG to composite truss would result in fewer impacts to fish. The composite truss would result in a decrease in permanent in-water structure and temporary works, and a reduction in in-water construction duration compared to the OWBG.

	The DEIS disclosed there would be impacts from pile driving to fish, but the detailed analysis did not come until the Biological Assessment development.	Additionally, since the composite truss is lighter than the OWBG, it would result in approximately 15% fewer permanent in-water drilled shafts and a 10% footprint reduction in-water shaft caps. Due to the reduced size of the drilled shafts, the composite truss would have less temporary work structures and a shorter construction duration.	
Water Resources			Only the ecosystems impacts described above would be different.
Energy			None
Geology & Soils			None
Hazardous Materials			None

Public Services			None
Utilities			None
Historic, Cultural & Archaeological Resources	The near shore construction has a high probability of finding archeological resources on the north side of the river.	The near shore construction has a high probability of finding archeological resources on the north side of the river.	No change
Parklands & Recreation	The touchdown points and the SR-14 interchange impact the VNHR.	The touchdown points and the SR-14 interchange can be configured the same way as the OWBG.	No change
Construction	In water pile driving would have an impact on fish.	In-water pile driving will have an impact on fish, but slightly less than what was disclosed in the BA.	Less impact from the composite truss than the OWBG, as described in ecosystems (above).
Secondary and Cumulative			None
Other			

ENVIRONMENTAL RE-EVALUATION CONSULTATION

SUPPLEMENTAL INFORMATION TO COMPOSITE TRUSS RE-EVALUATION

Note: The purpose of this worksheet is to assist sponsoring agencies in gathering and organizing materials for re-evaluations required under the National Environmental Policy Act (NEPA). Submission of the worksheet by itself does not meet NEPA requirements. <u>FTA & FHWA must concur in writing</u> with its determination and/or the sponsoring agency's NEPA recommendation. Contact the FTA Region 10 office at (206) 220-7954 or FHWA CRC Project Manager at (360) 619-7591 if you have any questions regarding this worksheet. We strongly encourage you to contact us to discuss your project changes before you fill out this worksheet.

For Agency Use *Date Received:*	
Recommendation by FTA Planner or Engineer: ☐ *Accept* ☐ *Return for Revisions* ☐ *Not Eligible* *Recommendation by FHWA Planner or Engineer:* ☐ *Accept* ☐ *Return for Revisions* ☐ *Not Eligible*	*Reviewed By:* *Date:* *Reviewed By:* *Date:*
Comments:	
Concurrence by FTA Counsel: ☐ *Accept Recommendation* ☐ *Return with Comments* *Concurrence by FHWA Counsel:* ☐ *Accept Recommendation* ☐ *Return with Comments*	*Reviewed By:* *Date:* *Reviewed By:* *Date:*
Comments:	
Concurrence by Approving Officials: FTA: FHWA:	*Date:* *Date:*

<u>Please answer the following questions, fill out the impact chart and attach project area and site maps.</u> Using a site map from the previously approved NEPA document, show project changes using a different color. Include additional site maps to help reviewer understand project changes.

PROJECT TITLE
Columbia River Crossing-BRP Alternative-Composite Truss-Existing Alignment – *This document is a supplement to the Composite Truss Re-evaluation submitted to FTA & FHWA on April 4, 2011. This document provides information in response to an email request from FTA.*

LIST CURRENT, APPROVED ENVIRONMENTAL DOCUMENTS (e.g. EIS/ROD, EA/FONSI, BA, RE-EVALUATION, etc.) If Re-evaluation, briefly describe.
Title: Date: Type and Date of Last Federal Action
Title: Date: Type and Date of Last Federal Action:
Title: Date: Type and Date of Last Federal Action

HAS THE MOST CURRENT AND OTHER PERTINENT APPROVED ENVIRONMENTAL DOCUMENTS BEEN *RE-READ* TO COMPARE PROPOSED PROJECT CHANGES?

☐ **NO (STOP! The most current approved environmental document MUST be re-read prior to completing a re-evaluation.)**

☐ **YES NAME: DATE:**

IS THE PROJECT CURRENTLY UNDER ☐ DESIGN OR ☐ CONSTRUCTION?

REASON FOR RE-EVALUATION

DESCRIPTION OF PROJECT CHANGES OR NEW INFORMATION

HAVE ANY NEW OR REVISED LAWS OR REGULATIONS BEEN ISSUED SINCE APPROVAL OF THE LAST ENVIRONMENTAL DOCUMENT THAT AFFECTS THIS PROJECT? If yes, please explain.

☐ **NO**
☐ **YES**

IS THE LIST OF THREATENED AND ENDANGERED SPECIES (NMFS AND USFWS) MORE THAN 6 MONTHS OLD?
☐ **NO**
☐ **YES (STOP! Endangered Species lists and analysis MUST be updated.)**

WILL THE NEW INFORMATION HAVE THE POTENTIAL TO CAUSE A CHANGE IN THE DETERMINATION OF IMPACTS FROM WHAT WAS DESCRIBED IN THE ORIGINAL ENVIRONMENTAL DOCUMENT FOR ANY OF THE AREAS LISTED BELOW? For each impact category, please indicate whether there will be a change in impacts. For all categories with a change, continue to the table at the end of this worksheet and provide detailed descriptions of the impacts as initially disclosed, new impacts and a discussion of the changes. The change in impact may be beneficial or adverse.

Transportation	☐ Yes	☐ No
Land Use and Economics	☐ Yes	☐ No
Acquisitions, Displacements, & Relocations	☐ Yes	☐ No
Neighborhoods & Populations (Social)	☐ Yes	☐ No
Visual Resources & Aesthetics	☐ Yes	☐ No
Air Quality	☐ Yes	☐ No
Noise & Vibration	☐ Yes	☐ No
Ecosystems (Vegetation & Wildlife)	☐ Yes	☐ No
Water Resources	☐ Yes	☐ No
Energy & Natural Resources	☐ Yes	☐ No
Geology & Soils	☐ Yes	☐ No
Hazardous Materials	☐ Yes	☐ No
Public Services	☐ Yes	☐ No
Utilities	☐ Yes	☐ No
Historic, Cultural & Archaeological Resources	☐ Yes	☐ No
Parklands & Recreation	☐ Yes	☐ No
Construction	☐ Yes	☐ No
Secondary and Cumulative	☐ Yes	☐ No

Will the changed conditions or new information result in revised documentation or determination under the following federal regulations?

Endangered Species Act	☐ Yes	☐ No
Magnuson-Stevens Act	☐ Yes	☐ No
Farmland Preservation Act	☐ Yes	☐ No
Section 404-Clean Water Act	☐ Yes	☐ No
Floodplain Management Act	☐ Yes	☐ No
CERCLA (Hazardous Materials)	☐ Yes	☐ No
Section 106 National Historic Preservation Act	☐ Yes	☐ No
Uniform Relocation Act	☐ Yes	☐ No

Section 4(f) Lands	☐ Yes	☐ No
Section 6(f) Lands	☐ Yes	☐ No
Wild & Scenic Rivers	☐ Yes	☐ No
Coastal Barriers	☐ Yes	☐ No
Coastal Zone	☐ Yes	☐ No
Sole Source Aquifer	☐ Yes	☐ No
National Scenic Byways	☐ Yes	☐ No
Other Marine Mammal Protection Act	☐ Yes	☐ No

If you checked yes to any of these, describe how the changes impact compliance and any actions needed to ensure compliance of the new project:
Will these changes or new information likely result in substantial public controversy?

☐ **Yes** ☐ **No**

Comments:

ADDITIONAL COMMENTS:

CONCLUSIONS AND RECOMMENDATIONS:

LIST OF ATTACHMENTS:

SUBMITTED BY:
By signing this, I certify that to the best of my knowledge this document is complete and accurate.

Name Title	Date

Submit two paper copies of this form, attachments, and a transmittal letter recommending a NEPA finding to the address below. Submit an electronic version to your area FTA Community Planner and FHWA Project Manager. Contact FTA or FHWA at the number below if you are unsure who this is or if you need the email address. Modifications are typically necessary. When the document is approved, FTA and FHWA may request additional copies.

Federal Transit Administration, Region 10
915 2nd Avenue, Suite 3142
Seattle, WA 98174-1002
phone: (206) 220-7954
fax: (206) 220-7959

Federal Highway Administration Oregon Division
530 Center Street NE., Suite 100
Salem, OR 97301
phone: (503) 399-5749
fax: (503) 399-5838

Federal Highway Administration Washington Division
711 S. Capitol Way, Suite 501
Olympia, WA 98501
phone: (360) 753-9480
fax: (360) 753-9889

Impact Category	Impacts as Initially Disclosed	New Impacts	Change in Impacts
Water Resources/ Impervious Surface/			
Transportation			**Bridge Crossing Mileposts:** Oregon: MP 307.96 to MP 308.38 Washington MP 0.00 to MP 0.52 **Multi-Use Path:** The change in bridge type between the OWBG and the composite truss will not have an effect on the multi-use path design or profile. . The change from the MUP concept in the DEIS to the current design is a result of refinements developed in coordination with the two cities and the pedestrian bicycle advisory committee (PBAC). (Please see exhibits submitted with original re-evaluation illustrating DEIS 2-bridge and 3-bridge designs and the current LPA) Below is a description of the changes in pedestrian connection between the DEIS and the current design. These changes will be covered in the "overall" NEPA Re-evaluation which is being produced separate from this document. In the DEIS the path was conceived to connect near 5th Street on the Washington

			side. The length needed to connect varied based on whether it was 3-bridge or 2-bridge. The 2-bridge path concept was lower crossing the river so it needed less length to touch down in Vancouver. The switchback at the touch down on the 3-bridge concept provided the additional length needed as a result of the higher profile across the river (the path was on the top deck with the 3-bridge option and was under the top deck with the 2-bridge option). Through coordination with stakeholders, the current path has been designed to be under the north bound highway deck. The connection to Vancouver is by way of a loop down to the waterfront connecting at Columbia Street which is the existing designated north-south bike route in downtown Vancouver. It connects near the Waterfront Trail. In Oregon a similar process has occurred and is still on-going. The multi-use path was originally conceived in the DEIS to be west of the LRT alignment with options to connect down to Hayden Island with ramps, loops and stairs. With the path now located under the north bound highway bridge, the alignment is located to the east of the LRT alignment. Currently a loop down to Hayden Island Drive is conceived with ramps and stairs connecting at the LRT station. However, the location of the path as it crosses Hayden Island and the location

			of the Oregon connections continue to be refined through coordination with the City of Portland, PBAC and the public. **Roundabouts:** The roundabouts have evolved through input from and coordination with the City of Vancouver. They are independent from and not a function of bridge type. A discussion of the roundabouts and other design changes will be captured in the "overall" NEPA Re-evaluation which is being produced separate from this document.
Land Use and Economics			
Acquisitions, Displacements, & Relocations			
Neighborhoods & Populations (Social)			
Visual Resources & Aesthetics			
Air Quality			

6452

Noise & Vibration			
Ecosystems (Vegetation & Wildlife)			
Water Resources			
Energy			
Geology & Soils			
Hazardous Materials			
Public Services			
Utilities			
Historic, Cultural & Archaeological Resources			
Parklands & Recreation			
Construction			
Secondary and Cumulative			
Other			

Aviation and Navigation	The DEIS reported a range of impacts for aviation and navigation. The highest impact reported to aviation was that with the Supplemental and No Build alternatives the lift spans on the existing bridge would be retained and would remain a hazard to aviation at Pearson Field. The highest impact reported to river navigation was an adverse impact due to the addition of the supplemental bridge making the S-curve maneuver more difficult. There would be more piers in the water and narrower channels.	The top of deck elevation of the composite truss bridge would be approximately five feet higher than the OWBG, but would still be below the Pearson Field Part 77 surfaces. The Part 77 surface is the standard by which obstructions in navigable airspace are determined. No bridge type option would penetrate Pearson Airfield Part 77 surfaces with the bridge deck or above deck features. Above deck features, such as light poles and signs, have not been designed yet and the actual heights will be determined through design refinements and coordination with the FAA. However, above deck features would not intrude into Pearson Field Part 77 surfaces. Penetrations into the Obstacle Clearance Surfaces (OCS) are considered when developing departure procedures and calculating climb gradients. Since the new bridge types considered would significantly reduce the penetration into the OCS compared to the lift towers of the existing bridge, new climb gradients would be calculated with any replacement bridge type. The composite truss would impact the OCS by approximately five feet more than the OWBG, but it would still be significant improvement compared to No-Build.	The aviation impacts from the composite truss would be much less than the highest impacts reported in the DEIS for the supplemental bridge, and comparable to the impacts from the replacement bridge. The above deck features (lighting and sign structures) will have similar heights relative to the highway surface (top of deck) for both the composite truss and OWBG. However, due to the increased structure depth associated with the composite truss, the highway surface is anticipated to be approximately five feet higher than that of the OWBG. Despite the higher elevation, the structure and above deck features of the composite truss will not penetrate the Pearson Field Part 77 surfaces. Above deck features have not been designed yet and the actual heights will be determined through design refinements and coordination with the FAA. Penetration into the OCS will be significantly improved compared to No-Build. The composite truss will be approximately five feet higher than the OWBG. New climb gradients for western departure at Pearson Airfield will have to be calculated with any new bridge type and the height of the bridge will be taken into consideration when calculating climb gradients.

		The composite truss would have slightly less impact to river navigation than the OWBG due to the smaller in-water footprint. The piers would be in the same location with either bridge type, eliminating the S-curve maneuver (see plan view drawings of the pier size and layout for the open web and composite truss bridge types provided with the original re-evaluation).	The navigation impacts from the composite truss would be less than the highest impacts reported in the DEIS from the supplemental bridge and the same or slightly less than the impacts from the replacement bridge.
4(f) Resources			Both composite truss and OWBG would cause the same impacts to 4(f) resources. Any difference in impacts to 4(f) resources between the FEIS and the DEIS is not a function of bridge type and will be described in the "overall" Re-evaluation being produced separate from this document. Overall, impacts to the Vancouver Historic Reserve would be lower with the current design than they were in the DEIS.

2.3 Components

Components are the building blocks of the alternatives. When combined, the components create the multimodal CRC alternatives intended to address the project's purpose and need. The components of the alternatives include:

- Multimodal river crossing and highway improvements
  - Bridges over the Columbia River carrying transit, highway, and bicycle and pedestrian traffic
  - Bicycle and pedestrian improvements between north Portland and downtown Vancouver
  - Highway and interchange improvements between Marine Drive in north Portland and SR 500 in Vancouver
- High-capacity transit modes
- Transit terminus and alignment options
  - Transit terminus options
  - Transit alignment options
- Transit operations (frequency of train or bus rapid transit service, as well as local buses)
- Bridge tolls
- Transportation System and Demand Management measures

2.3.1 Multimodal River Crossing and Highway Improvements

There are two primary multimodal river crossing options under consideration:

- A replacement multimodal river crossing (included with Alternatives 2 and 3), and
- A supplemental multimodal river crossing (included with Alternatives 4 and 5).

Both river crossings provide improved facilities for highway users, transit users, and bicyclists and pedestrians to enhance the multimodal crossing of the Columbia River and to improve safety, capacity, and mobility on I-5. The replacement and supplemental river crossings differ in the three key elements that comprise this component:

- The bridges over the Columbia River (with dedicated lanes for transit vehicles, cars and trucks, and bicycles and pedestrians),
- Bicycle and pedestrian facilities through Hayden Island, over the Columbia River, and at the Vancouver waterfront, and
- Highway and interchange improvements on I-5 throughout the project area.

Upcoming decisions to define a locally preferred alternative (LPA) will select between a supplemental or replacement crossing (or No Build), but will not decide the specific bridge type or material selection. To narrow the decision further, more analysis is required, and such decisions will be

made after the Draft Environmental Impact Statement (DEIS) and after adoption of an LPA. The decision for this phase of the project regarding the river crossing is only to choose a replacement or a supplemental crossing, or the No-Build Alternative. This process will ensure that the appropriate structural and material selection is evaluated fully before any decision becomes final.

If a replacement crossing is chosen, this will not yet determine the bridge type (for example, three parallel bridges or a stacked transit/highway bridge—see below for information on these design concepts) or bridge material (for example, concrete, steel, or composite). Decisions on bridge type and design would have to be approved by the Federal Highway Administration (FHWA) before a final selection is made. The Federal Transit Administration (FTA) will also take an approval action on the final structure type.

Likewise, if a supplemental crossing is chosen, bridge type or material of the new bridge would be determined during further design and evaluation after adoption of an LPA. Should the supplemental crossing move forward in the National Environmental Policy Act (NEPA) process and become part of the LPA, a bridge type study will be done to determine the bridge type and material, and that information will be submitted to FHWA for approval. FTA will also take approval action on the final structure type.

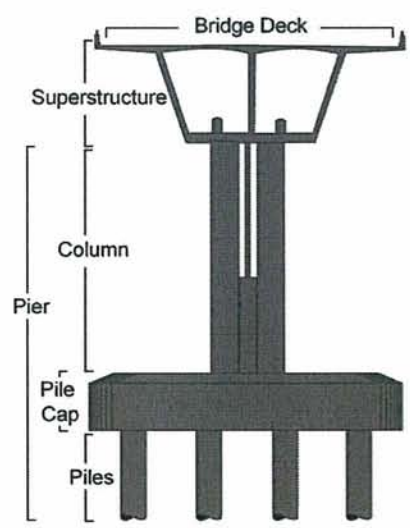
Replacement River Crossing Bridges (Alternatives 2 and 3)

A replacement river crossing (Exhibit 2.3-1) would include removing the existing I-5 bridges and building new bridges west of the existing I-5 bridges. Two new bridges would carry north and southbound interstate traffic, and the third would have a high-capacity transit guideway and an exclusive path for bicycles and pedestrians. North and southbound interstate traffic would each travel on a separate bridge approximately 99 feet wide. A third bridge approximately 52 feet wide would carry transit vehicles, bicyclists, and pedestrians. (Note: there is a possible design that would include placing transit vehicles under one of the highway bridges; see the stacked transit/highway bridge discussion below for this description.)

Bridge design will be determined later in the project, but the basic size and height requirements have been defined. The bridge spans over the river must be tall enough for large barges and tugboats to pass underneath without the need for a lift span (approximately 90 feet vertical clearance), but low enough to minimize interference with aircraft using the nearby Pearson Field or Portland International Airport. The bridges cannot include tall towers, such as those associated with cable-stay or suspension bridges, because these would pose a hazard to aircraft.

TERMS & DEFINITIONS

Bridge Terms



NOTE: The bridge type shown is for display purposes only.

For the Lincoln terminus, construction on northern Vancouver streets would need to be sensitive to the area's active urban environment. Multiple small work zones could focus construction activity and reduce the duration of disturbances to adjacent businesses and residents. Streets would be open to traffic and pedestrians when possible, but would likely need to close during some construction activities (through pedestrian access would always be maintained except for momentary disruptions). The construction sequencing of the new MAX tracks being built in downtown Portland is a good example of how construction could occur in this area, although the bus rapid transit option would be less disruptive and would require slightly less time to construct.

Roadway construction would include restriping or rebuilding the road surface, rebuilding sidewalks in some sections, and constructing station platforms. Streetscape improvements could include removing, replacing, or adding vegetation, curb extensions, new signs and signals, and other measures to improve access to, and use of, the transit stations. Stations, park and rides, and new structures could require pile driving and earthwork for clearing and grading these sites.

The project may include joint development opportunities, such as working with a developer to build transit-oriented development on or near the alignment. No sites or specific plans have been developed, so no specific site impacts can be analyzed at this time.

Transit construction will also require staging areas. Exact locations have not been determined. Where possible, staging activities will take advantage of land that is already in the public right-of-way or in public ownership and that is not being used for other purposes, such as vacant lots. Sites will be significantly smaller than the anticipated construction staging areas for bridge construction. If any sites are used that are close to transit stations, joint developments may be considered to create transit-oriented development on the site after the construction use is completed.

2.5 Alternatives Considered But Not Advanced

This section describes the range of transportation improvements that were initially considered but eliminated during screening and subsequent evaluation due to significant engineering problems, environmental impacts, cost, or failure to meet the project's purpose and need. These transportation improvements include ideas such as a third corridor for crossing the Columbia River (in addition to the current I-5 and I-205 corridors), low-level bridges, tunnels, and multiple transit modes. The process followed to identify and screen alternatives to develop the range of alternatives that are being evaluated in this DEIS complied with US Department of Transportation (USDOT) guidance on linking planning and NEPA requirements.

The following discussion is a chronological description of the transportation improvements evaluated and dropped through the process of developing the range of alternatives evaluated in this DEIS.

2.5.1 Early Studies

Elements of the CRC project have been proposed and studied since the early 1990s, as described in Chapter 1. In 2002, the I-5 Transportation and Trade Partnership produced an evaluation of multiple highway, transit and river crossing improvements in this corridor and other parts of I-5. This process gathered public and stakeholder input on issues and potential solutions for transportation problems in the I-5 corridor. The Partnership then made recommendations for improvements and identified the CRC project as a regional priority in its Final Strategic Plan. This led to the initiation of the CRC Environmental Impact Assessment process. A "Notice of Intent" to prepare an environmental impact statement was issued in September 2005.

2.5.2 Evaluation Criteria and Initial Component Screening

Starting in October 2005, CRC project staff began working closely with the public, stakeholders, and local jurisdictions to develop the project's purpose and need (see Chapter 1). In October 2005, the CRC Task Force adopted a "Vision and Values" document that outlined broad goals and priorities, and served as a basis for developing evaluation criteria to measure and compare performance of different alternatives. Based on this document, the project team worked with local agency sponsors, the CRC Task Force, and state and federal permitting agencies to develop the Evaluation Framework, which outlined a process for generating and evaluating possible alternatives. The statement of purpose and need was finished and approved by FHWA, FTA, and the project's local sponsoring agencies in January 2006.

CRC Task Force

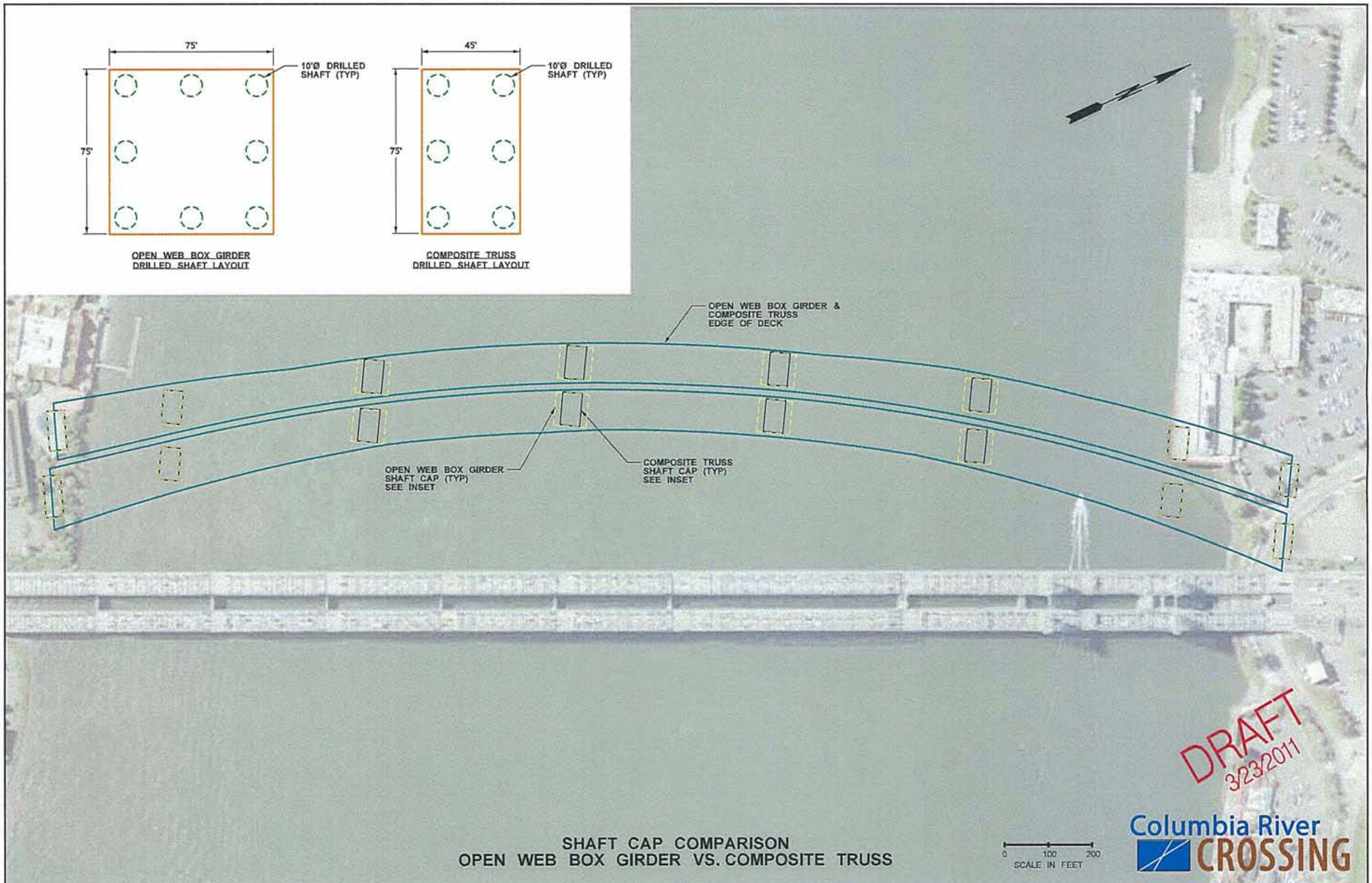
The 39-member CRC Task Force is composed of leaders representing a broad cross section of Washington and Oregon communities. Public agencies, businesses, civic organizations, neighborhoods, and freight, commuter, and environmental groups are represented on the Task Force. This group meets regularly to advise the CRC project team and provide guidance and recommendations at key decision points. The Public Involvement Appendix of this DEIS lists task force members.

The project team began the process of developing alternatives by identifying possible transportation components (for example, transit technologies, and river crossing types and locations). Over 70 such components were identified in the 2002 I-5 Transportation and Trade Partnership Final Strategic Plan and through additional public and stakeholder outreach.

Project staff performed two rounds of evaluation and screening to narrow these options. Only transit and crossing components were screened. Other elements that have since been included in the alternatives evaluated in this DEIS, such as pedestrian, bike, and roadway improvements, were advanced without screening. The initial screening in April 2006 eliminated river crossing types and transit modes that did not meet the project's purpose and need[4], including:

- A replacement tunnel, which would fail to serve most of the current vehicle trips
- High-level bridges that would encroach on protected airspace for Pearson Airfield
- Transit Modes that do not effectively serve the specific needs of this region, such as high-speed rail, ferry service, monorail, magnetic levitation railway, commuter rail in freight rail corridor, and heavy rail

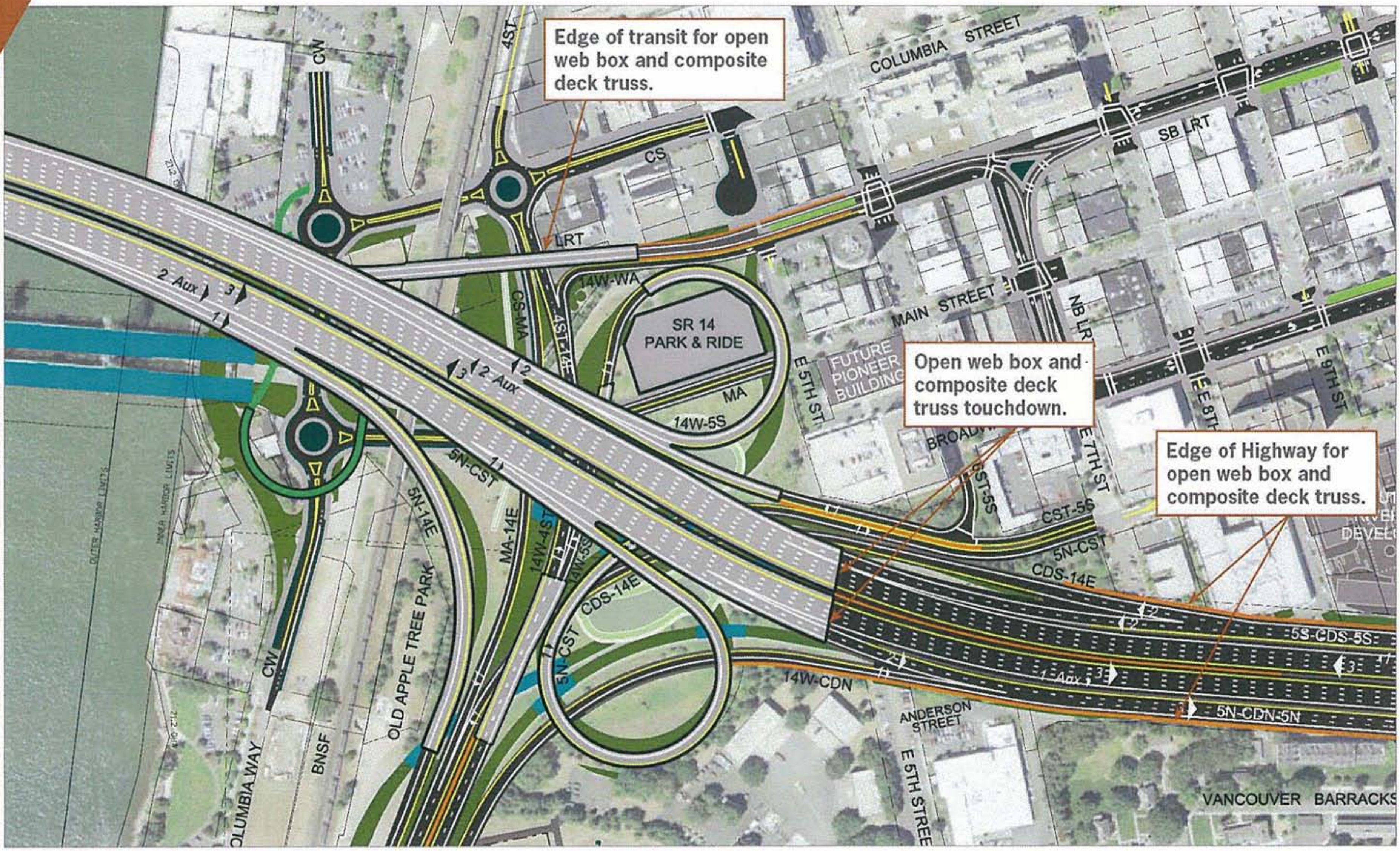
[4] Step A Screening Report, CRC, 2006.


75'
10'Ø DRILLED SHAFT (TYP)
75'
OPEN WEB BOX GIRDER DRILLED SHAFT LAYOUT
45'
10'Ø DRILLED SHAFT (TYP)
75'
COMPOSITE TRUSS DRILLED SHAFT LAYOUT
OPEN WEB BOX GIRDER & COMPOSITE TRUSS EDGE OF DECK
OPEN WEB BOX GIRDER SHAFT CAP (TYP) SEE INSET
COMPOSITE TRUSS SHAFT CAP (TYP) SEE INSET
DRAFT 3/23/2011
SHAFT CAP COMPARISON
OPEN WEB BOX GIRDER VS. COMPOSITE TRUSS
0 100 200
SCALE IN FEET
Columbia River CROSSING

Columbia River CROSSING

Washington Touchdown Comparison

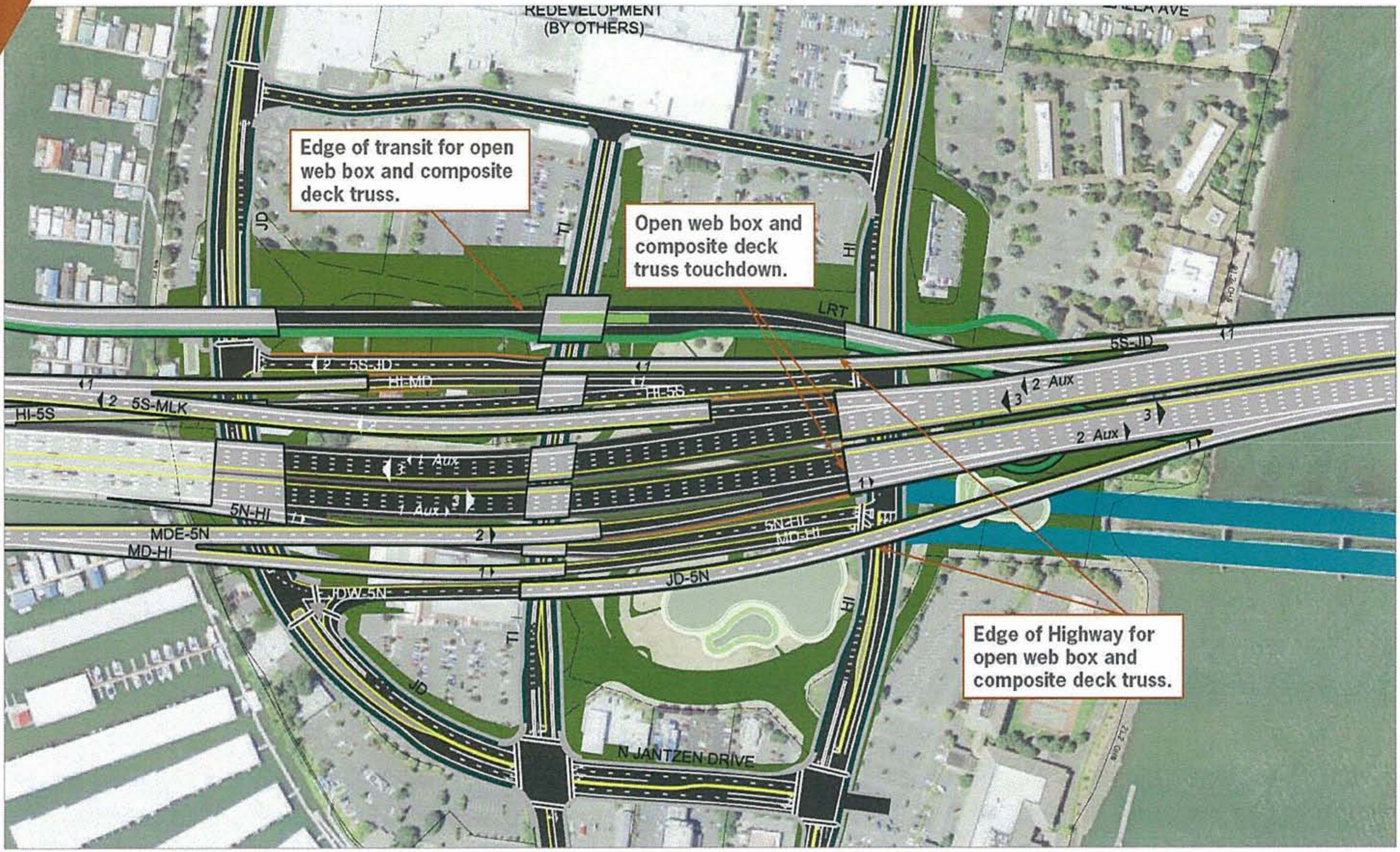
EXHIBIT 1 Open Web Box Versus Composite Deck Truss



Columbia River CROSSING

Oregon Touchdown Comparison

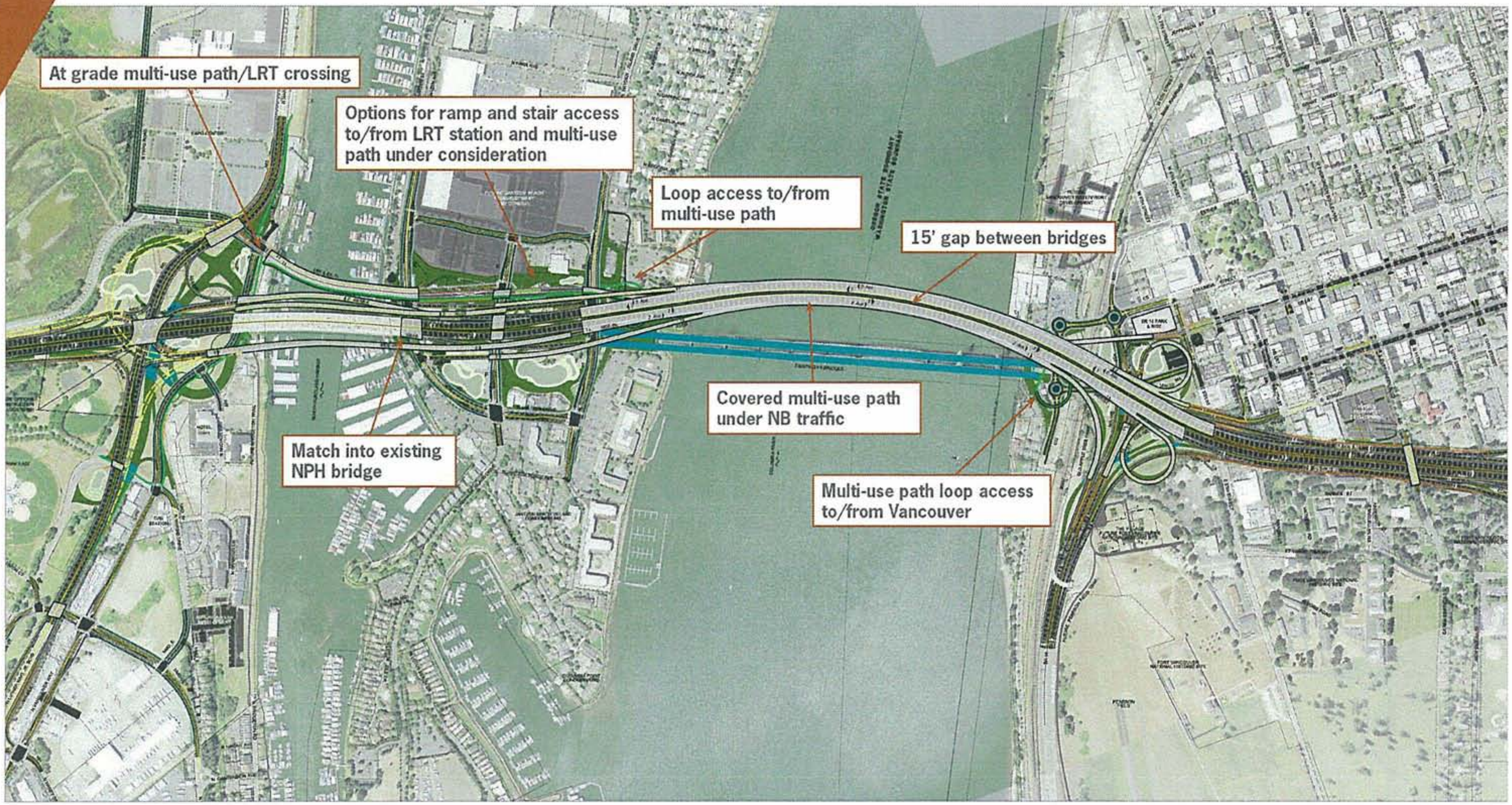
EXHIBIT 2 Open Web Box Versus Composite Deck Truss



DRAFT 03/28/11

Columbia River CROSSING

LPA Option A - March 2011



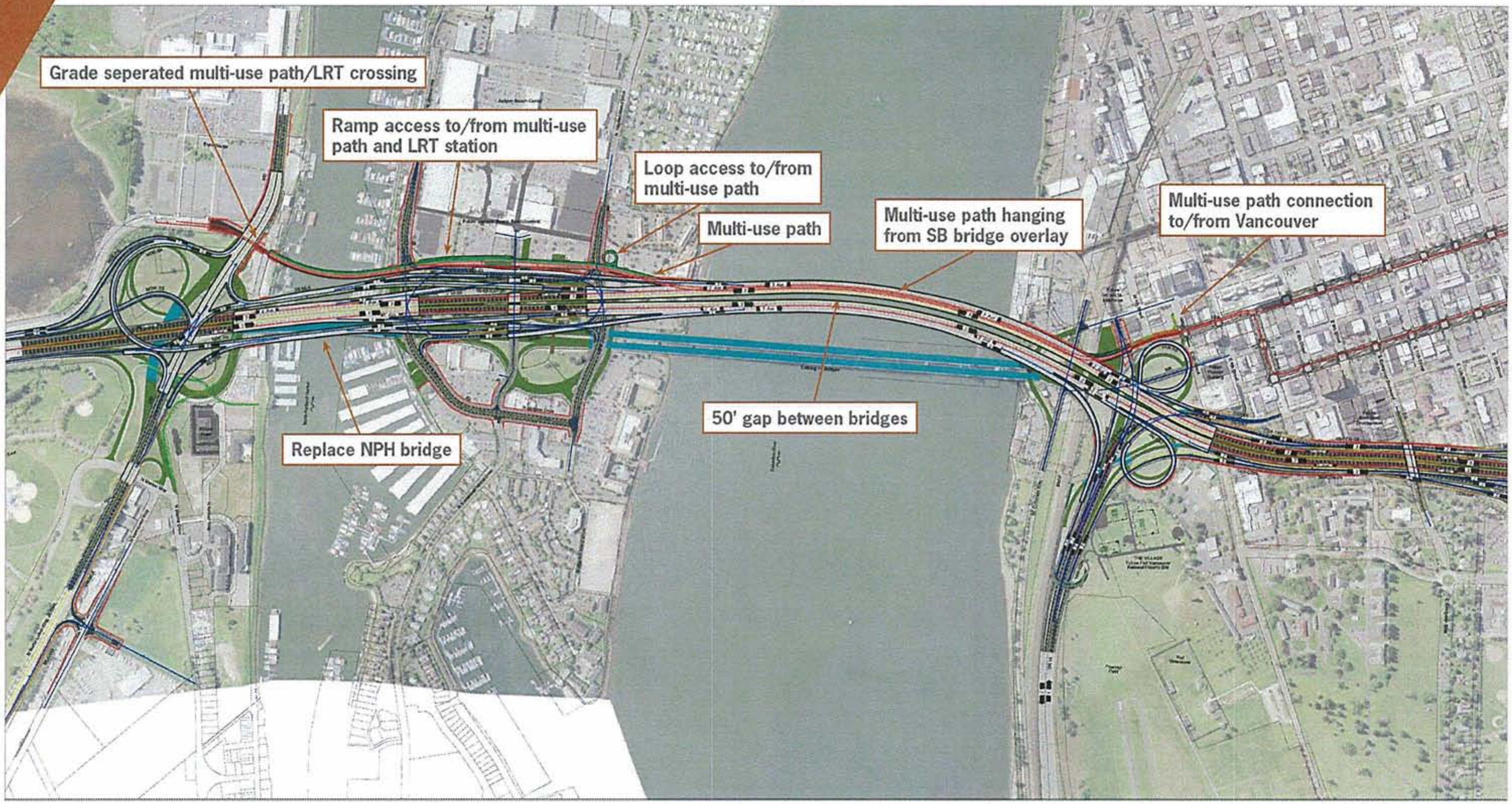
PROJECT PARTNERS Washington State Department of Transportation Oregon Department of Transportation Federal Transit Administration • Federal Highway Administration City of Vancouver • City of Portland • SW Washington Regional Transportation • Council Metro • C-TRAN • TriMet

DRAFT 04/01/11

6469

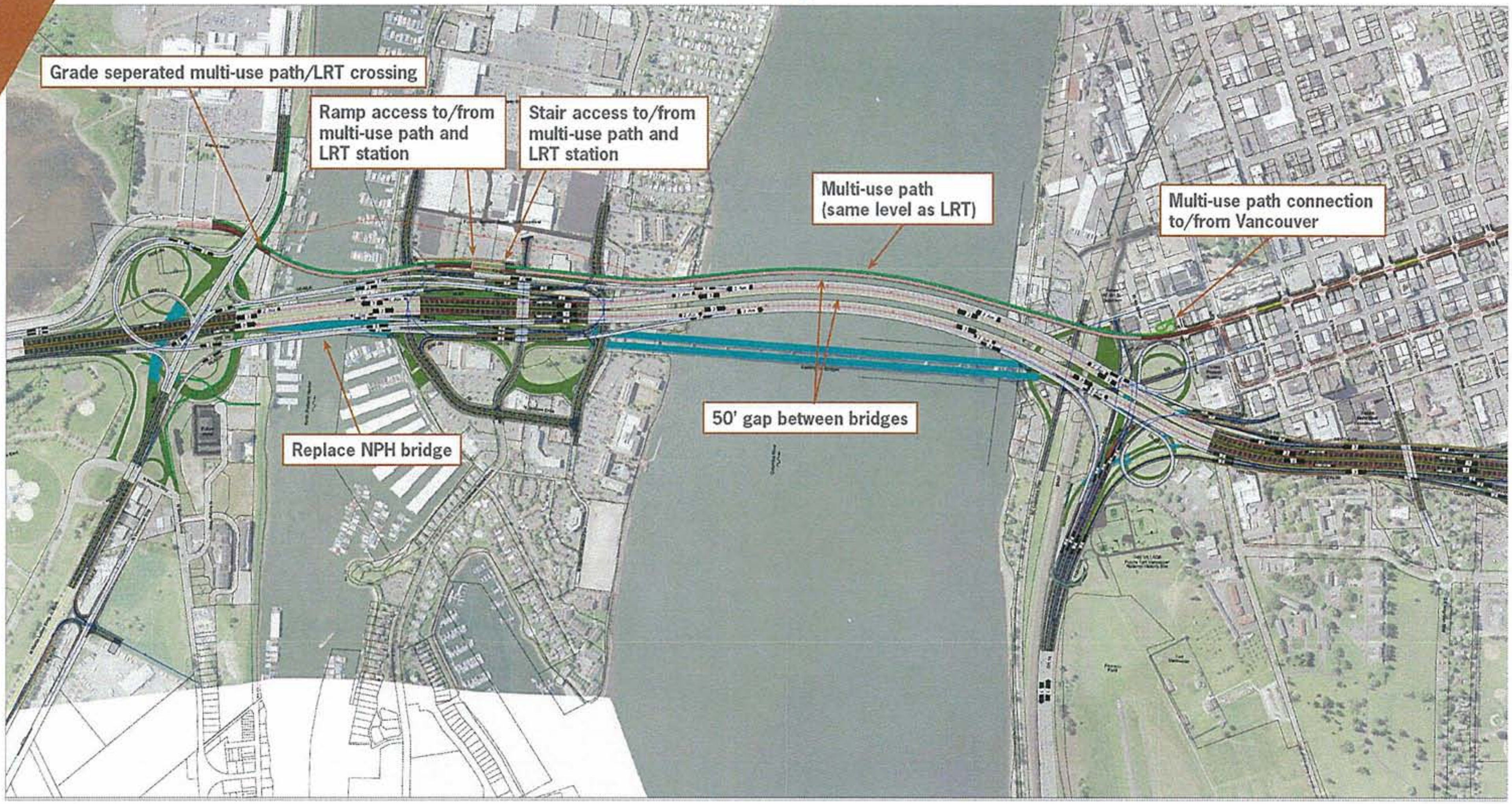
Columbia River CROSSING

2 Bridge Alternative - August 2008



Columbia River CROSSING

3 Bridge Alternative - May 2008

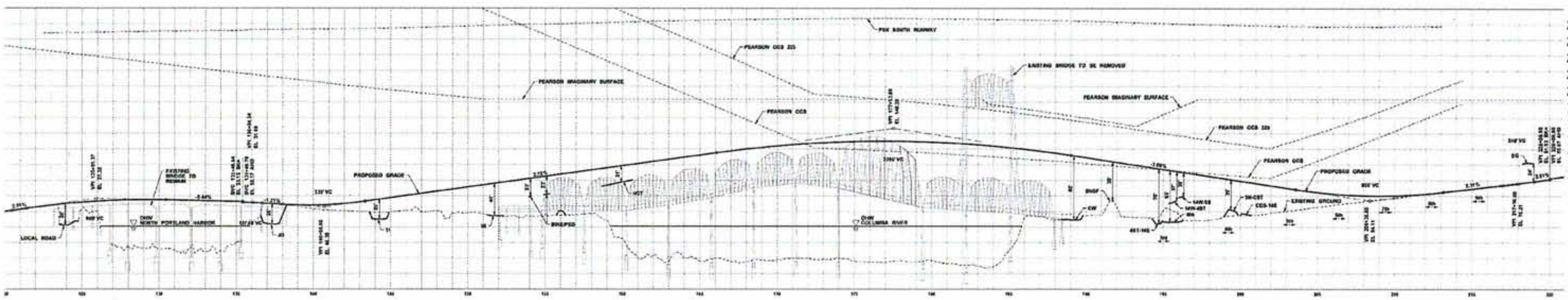


PROJECT PARTNERS Washington State Department of Transportation | Oregon Department of Transportation | Federal Transit Administration • Federal Highway Administration
City of Vancouver • City of Portland • SW Washington Regional Transportation • Council Metro • C-TRAN • TriMet

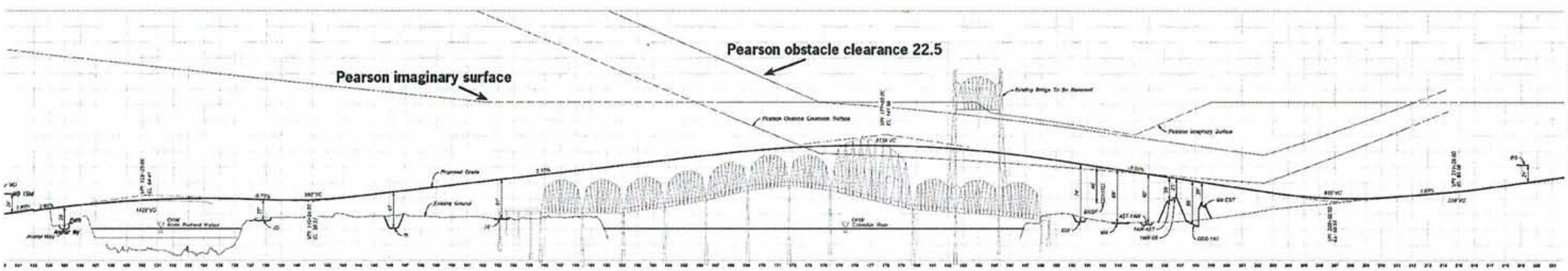
DRAFT 04/01/11

Columbia River
CROSSING

Profiles 2008-2011



LPA Profile - March 2011



2 and 3 Bridge Alternative Profile - 2008

U.S. Department
of Transportation

Federal Aviation Administration

Northwest Mountain Region
Colorado, Idaho, Montana
Oregon, Utah, Washington,
Wyoming

1601 Lind Avenue, S. W., Ste 315
Renton, Washington 98057

June 20, 2008

RECEIVED
JUN 23 2008
Columbia River Crossing

Ms. Heather Gundersen
CRC Environmental Project Manager
Columbia River Crossing
700 Washington Street, Ste. 300
Vancouver, WA 98660

Dear Ms. Gundersen:

Interstate 5 Columbia River Crossing (CRC) Project
Draft Environmental Impact Statement (EIS)

We have reviewed the May 2008 draft EIS for the CRC project. In accordance with the February 14, 2006, letter (Attachment 1) from the Federal Aviation Administration (FAA), Northwest Mountain Region Administrator, our review was limited to aeronautical-related issues. Specifically, FAA's interest in this project primarily concerns the potential effects of the proposed bridge structure, including temporary construction equipment (cranes), on the navigable airspace and navigational aids, especially those associated with Portland International Airport (PDX) and Vancouver's Pearson Field (VUO).

Previously, we had conducted an aeronautical feasibility study on three conceptual alternatives (see Attachment 2, June 14, 2006, determination letter) and had commented informally on the June 2007 draft Aviation Technical Report (see Attachment 3, partial email correspondence). Those attachments are included again for your convenience.

Our understanding of the alternatives is that none will penetrate the airport imaginary surfaces (14 CFR Part 77) any more than the existing bridge structures, and that the replacement alternatives would actually reduce the amount of penetration by removing existing bridge structures. From an aeronautical standpoint only, we would prefer a bridge option that would prevent or reduce airspace obstruction to the maximum extent practicable. Our specific comments on the draft EIS are as follows:

1. Page 2-17, last para. (also, page 5-27, para. 4) – We understand the trade-off between river- and air-navigation requirements and concur with the statements precluding tall towers and cable-stay or truss-type construction.

2. Page 3-93, para. 3 – As noted above, the replacement alternatives, 2 and 3, reduce airspace obstruction more than any alternatives leaving in place the existing bridge structures, and therefore are preferable for that purpose.

3. Page 3-93, para. 4 (also, page 5-68, para. 4) – The final design should seek to reduce the penetrations of the approaches/ramps (as well as the bridge structure itself) insofar as possible.

4. Page 3-95, para. 5 – Form FAA Form 7460-1, *Notice of Proposed Construction or Alteration*, will have to be filed with FAA for each temporary construction crane, indicating its maximum height and lateral extent of the boom. The form can be filed online; presently, the online filing address is: https://oeaaa.faa.gov/oeaaa/external/portal.jsp.

5. Page 3-96, para. 2 – We concur with the statements regarding obstruction lighting and the prevention of light glare that could affect air navigation.

6. Page 5-68, para. 5 – The aforementioned Form 7460-1 will also have be filed with FAA for the actual construction of the bridge structures. We recommend that it be filed at not later than a 10-percent design stage, or as soon as the footprint and elevation profiles are tentatively established.

If you have any questions, please contact me at (425) 227-2615.

Sincerely,

Don M. Larson

Don M. Larson
Regional Capacity Program Manager

Enclosures

ATTACHMENT 1

U.S. Department
of Transportation
**Federal Aviation
Administration**

Northwest Mountain Region
Colorado, Idaho, Montana, Oregon
Utah, Washington, Wyoming

1601 Lind Avenue, S. W.
Renton, Washington 98055-4056
Tel: (425) 227-2007
Fax: (425) 227-1007

FEB 2 4 2006

Mr. R. F. Krochalis
Regional Administrator
Federal Transit Administration
915 Second Ave., Ste. 3142
Seattle, WA 98174

Dear Mr. Krochalis:

This is in response to your letter of December 14, 2005, regarding the I-5 Columbia River Crossing project. The Federal Aviation Administration (FAA), Northwest Mountain Region, accepts your invitation to serve as a cooperating agency in the National Environmental Policy Act (NEPA) environmental impact statement (EIS). FAA's interest in this project concerns the potential effects of the proposed bridge structure, including temporary construction equipment (cranes), on the navigable airspace and navigational aids, especially those associated with Portland International Airport (PDX) and Vancouver's Pearson Field (VUO). Our review and comments on this study's documents will be limited to aeronautical-related issues, and this should be outlined in a memorandum of understanding (MOU) between our agencies at the outset. Please provide a draft MOU for our review, or let us know if we should prepare it.

The Seattle Airports District Office (ADO) will be the lead for the FAA in this process, and will coordinate involvement of the other operating divisions (Air Traffic, Airway Facilities, Flight Procedures and Flight Standards) as necessary. In fact, we have already begun our advisory participation, as the Columbia River Crossing study team presented a briefing to FAA interdivisional staff here at the Regional Office on December 9, and received our initial feedback and interest in continued participation at that time. Our principal contact person will be Don Larson for airport/airspace planning and notice of proposed construction. Please feel free to contact him directly at (425) 227-2652.

Thank you for the invitation to participate in this project as a cooperating agency.

Sincerely,

for Douglas Murphy
Regional Administrator

ATTACHMENT 2

U.S. Department
of Transportation

**Federal Aviation
Administration**

Seattle Airports District Office
1601 Lind Avenue, S. W., Ste 250
Renton, Washington 98055-4056

June 14, 2006

Ms. Lynn Rust
Columbia River Crossing Project
700 Washington Street
Suite 300
Vancouver, WA 98660

Dear Ms. Rust:

Portland, Oregon – Vancouver, Washington
Airspace Analysis Results for Feasibility Studies
Columbia River Crossing Project

The Federal Aviation Administration (FAA) has completed its review of your request for feasibility studies, per FAA Order 7200-2E, para. 6-1-6, on three conceptual alternatives for a new bridge near Pearson Field (VUO), Vancouver, Washington, and over the Columbia River between Vancouver and Portland, Oregon, as shown on the plans attached to your *Notice*(s) *of Proposed Construction or Alteration* (FAA Form 7460-1) dated May 1, 2006. The findings and comments from these studies are consolidated into one report below.

Aeronautical Study No. 2006-ANM-272-NRA – Downstream mid-level replacement bridge "RC-3"

It has been determined that the critical location of this proposal is Point 309, an existing tower (to be removed with proposed demolition of the existing bridge), which penetrates the Part 77 transitional surface for Runway 8-26 at VUO by 66.6 feet. The future critical location would be Point 304, which would penetrate the VUO horizontal surface by 26.46 feet. The proposal would not penetrate any existing or future Part 77 surface for Portland International Airport (PDX).

Air Traffic Division (AT) states: This lat/long has PART 77 busts: horizontal by 63 feet and transition by 72 feet - a bit more than 27 feet identified; a formal obstruction evaluation (OE) aeronautical study will need to be conducted after this feasibility study. (Robert van Haastert, 907-271-5863)

Airway Facility Division (AF) states: The bridge will penetrate the obstacle clear zone of Pearson's RW 08 visual approach slope indicator (VASI). (Peter Markus, 425-227-1450)

Seattle Flight Procedure Office (SEA-FPO) states: Current VUO RWY 26 instrument flight rules (IFR) departure procedure (DP) climb gradient is 650'/nautical mile (NM); and, is controlled by the existing I5 Bridge. If the existing I5 bridge were not present, the climb gradient would be 269'/NM with the 535' mean sea level (MSL) Columbia River Crossing transmission line tower @453557N/1224312W becoming controlling. Approximate Climb Gradients: 435'/NM for option RC-3 (191.49'MSL @ 2975' from 30' elev threshold height—TH). 460'/NM for option RC-4 (approx 180' MSL @ 2700' from 30' elv TH). 710'/NM for option RC-8 (251' MSL @

2500' from 30' elv TH) Even though RC-3 is higher than RC-4, it results in a lower climb gradient because it is further from VUO's TH. Suggest proponent explore the 180' msl design (ala RC-4) constructed on the West side of the existing I5 bridge. That gradient would be approximately 410'/NM (approx 180' MSL @ approx 2975' from 30' elv TH). (Vic Zembruski, 425-227-2224)

Aeronautical Study No. 2006-ANM-273-NRA – Upstream mid-level replacement bridge "RC-4"

It has been determined that the critical location of this proposal is Point 309, an existing tower (to be removed with proposed demolition of the existing bridge), which penetrates the Part 77 transitional surface for Runway 8-26 at VUO by 66.6 feet. After removal of the existing bridge, no part of the replacement bridge would penetrate any existing or future Part 77 surface for either VUO or PDX.

Air Traffic Division (AT) states: This lat/long and elevation has PART 77 bust: VUO RWY 08 transition by 72 feet - a bit more than identified; a formal OE aeronautical study will need to be conducted after this feasibility study. (Robert van Haastert, 907-271-5863)

Airway Facility Division (AF) states: Tech-Ops has no objection provided the associated traffic lights and freeway signs do not penetrate the obstacle clear zone of Pearson's RW 08 VASI. (Peter Markus, 425-227-1450)

Seattle Flight Procedure Office (SEA-FPO) states: Current VUO RWY 26 IFR DP climb gradient is 650'/NM; and, is controlled by the existing I5 Bridge. If the existing I5 bridge were not present, the climb gradient would be 269'/NM with the 535' MSL Columbia River Crossing transmission line tower @453557N/1224312W becoming controlling. Approximate Climb Gradients: 435'/NM for option RC-3 (191.49' MSL @ 2975' from 30' elv TH). 460'/NM for option RC-4 (approx 180' MSL @ 2700' from 30' elv TH). 710'/NM for option RC-8 (251' MSL @ 2500' from 30' elv TH) Even though RC-3 is higher than RC-4, it results in a lower climb gradient because it is further from VUO's TH. Suggest proponent explore the 180' msl design (ala RC-4) constructed on the West side of the existing I5 bridge. That gradient would be approximately 410'/NM (approx 180' MSL @ approx 2975' from 30' elv TH). (Vic Zembruski, 425-227-2224)

Aeronautical Study No. 2006-ANM-274-NRA – Upstream low-level supplemental bridge "RC-8"

It has been determined that the critical location of this proposal is Point 801, which would penetrate the VUO transitional surface by 72.3 feet. The proposal would not penetrate any existing or future Part 77 surface for PDX.

Air Traffic Division (AT) states: This lat/long has PART 77 busts: horizontal by 69 feet and transition by 72 feet - a bit more than identified; a formal OE aeronautical study will need to be conducted after this feasibility study. (Robert van Haastert, 907-271-5863)

Airway Facility Division (AF) states: When the bridge is open for marine traffic, it will penetrate the obstacle clear zone of Pearson's RW 08 VASI (Peter Markus, 425-227-1450)

Seattle Flight Procedure Office (SEA-FPO) states: Current VUO RWY 26 IFR DP climb gradient is 650'/NM; and, is controlled by the existing I5 Bridge. If the existing I5 bridge were not present, the climb gradient would be 269'/NM with the 535' MSL Columbia River Crossing transmission line tower @453557N/1224312W becoming controlling. Approximate Climb Gradients: 435'/NM for option RC-3 (191.49' MSL @ 2975' from 30' elv TH). 460'/NM for

6486

option RC-4 (approx 180' MSL @ 2700' from 30' elv TH). 710'/NM for option RC-8 (251' MSL @ 2500' from 30' elv TH) Even though RC-3 is higher than RC-4, it results in a lower climb gradient because it is further from VUO's TH. Suggest proponent explore the 180' msl design (ala RC-4) constructed on the West side of the existing I5 bridge. That gradient would be approximately 410'/NM (approx 180' MSL @ approx 2975' from 30' elv TH). (Vic Zembruski, 425-227-2224)

The **Flight Standards Division** stated "no objection" on all three alternatives. If you have any questions on the foregoing comments, please contact the specialists at the numbers listed. Once a final plan has been decided upon for the bridge, a *Notice of Proposed Construction or Alteration* (FAA Form 7460-1) must be submitted to FAA for a formal OE aeronautical study, preferably not later than at a ten-percent design stage. If you have any other questions please contact me at (425) 227-2652.

Sincerely,

ORIGINAL SIGNED BY
DON M. LARSON

Don M. Larson
Airport Planner

6488

ATTACHMENT 3

Steve Karnes/ANM/FAA
ATO, Western System Support Group
04/14/2008 12:49 PM

To Don Larson/ANM/FAA@FAA
cc
bcc
Subject Fw: Columbia River Crossing - 2nd Feasibility Study Request & Draft Aviation Technical Report

Hi Don,

Here is the e:mail trail that Lynn last rec'd from Robert. I had a telephone conversation with her and that was all she needed. She did mention that they planned to have the Draft EIS ready by May 2nd.

Steve Karnes
X 4513

----- Forwarded by Steve Karnes/ANM/FAA on 04/14/2008 12:46 PM -----

"Rust, Lynn" <RustL@columbiarivercrossing.org>
04/14/2008 12:40 PM

To Steve Karnes/ANM/FAA@FAA
cc
Subject RE: FW: Fw: Columbia River Crossing - 2nd Feasibility Study Request & Draft Aviation Technical Report

Lynn Rust
Assistant Deputy Project Director
I-5 Columbia River Crossing Project
360-816-2177

From: robert.van.haastert@faa.gov [mailto:robert.van.haastert@faa.gov]
Sent: Wednesday, January 09, 2008 8:59 AM
To: Rust, Lynn
Cc: Steve.Karnes@faa.gov
Subject: RE: FW: Fw: Columbia River Crossing - 2nd Feasibility Study Request & Draft Aviation Technical Report

Hi Lynn,

Will an email work for you? If so, the FAA has no objections nor comments on the proposed Columbia River Crossing Draft Aviation Technical Report.

FAA point of contact: Steve Karnes, Western Service Area, System Support Group. Telephone: 425-917-6736; email: Steve.Karnes@faa.gov

Steve coordinated with the local FAA facilities and did all of the actual 'grunt' work.

When you have a final product, and if it is available in electronic format (pdf or word document), can you email us a copy or send a CD?

FAA / Western Support Group (AJO2-W2)
Attn: Steve Karnes
1601 Lind Avenue, SW
Renton, WA 98055

Robert van Haastert
Obstacle Evaluation Service, Anchorage
Specialist: AK, AZ, CO, ID, MT, OR, UT, WA, & WY
phone: (907) 271-5863, fax: (907) 271-2850
Sign up for emailannouncement of Public Notices at
https://oeaaa.faa.gov/oeaaa/external/searchAction.jsp?action=showSearchCircularizationForm

"Rust, Lynn"
<RustL@columbiarivercrossing.org>

01/09/2008 07:26 AM

To Robert van Haastert/AAL/FAA@FAA
cc
Subject RE: FW: Fw: Columbia River Crossing - 2nd Feasibility Study Request & Draft Aviation Technical Report

Hello Robert,

I got your voice mail yesterday. Thank you. I like to here no objections. Did you have any comments on the tech report?

Are you or will you send us written correspondence to close the loop on this? Or an email?

Thanks again.

Lynn Rust
Assistant Deputy Project Director
I-5 Columbia River Crossing Project
360-816-2177

6492

HDR | ONE COMPANY
Many Solutions℠

Project: Columbia River Crossing	Computed:	Date: March 23, 2011
Subject: River Bridge Conceptual Design	Checked:	Date:
Task: Composite Deck Truss Foundation	Sheet:	of

COLUMBIA RIVER CROSSING

MAIN RIVER CROSSING

CONCEPTUAL DESIGN

COMPOSITE DECK TRUSS FOUNDATION

March 2011

HDR Engineering, Inc.

626 Columbia St NW
Suite 2A
Olympia, WA, 98501-9000

Phone (360) 570-4400
Fax (360) 570-7253
www.hdrinc.com

HDR | ONE COMPANY *Many Solutions*℠

Table of Contents

Project: Columbia River Crossing	Computed: C. Werts	Date: March 23 2011
Subject: River Bridge Conceptual Design	Checked:	Date:
Task: Composite Deck Truss Foundation	Sheet:	of

TABLE OF CONTENTS

626 Columbia St NW
Suite 2A
Olympia, WA 98501-9000

Phone (360) 570-4400
Fax (360) 570-7253
www.hdrinc.com

HDR | ONE COMPANY *Many Solutions*℠

Foundation Study

Project: Columbia River Crossing	Computed: C. Werts	Date: March 23 2011
Subject: River Bridge Conceptual Design	Checked: R. Turton	Date: March 23, 2011
Task: Composite Deck Truss Foundation	Sheet:	of

1. FOUNDATION STUDY OVERVIEW

Task Description:

The purpose of this task is to provide preliminary design calculations for the composite steel deck truss alternative to determine the required size of foundations and number of shafts at each foundation for the Columbia River Crossing (CRC) river bridge.

Method:

An elastic response spectrum analysis (RSA) was performed on the global bridge model using LARSA, through an iterative process with foundation springs generated from an inelastic foundation analysis of each pier using FB-MultiPier, to estimate the foundation demands and capacities and determine the adequacy of the design foundations.

Assumptions:

In order to perform an expedited foundation analysis, the following assumptions were made:

1. The overall bridge length, pier locations and resulting span lengths were taken to be the same as the locally preferred alternative (LPA) that was previously analyzed as the open web alternative. The typical spans are 465' and the end spans are approximately 270' for a total bridge length of approximately 2865'.
2. The plan and profile for the composite deck truss was the same as the LPA.
3. Model geometry was rotated in plan so that the X axis is a line from Pier 1 to Pier 8 and the longitudinal earthquake is in line with the structure.
4. The superstructure geometry and properties for the open web were used to model the composite deck truss. The RSA analysis and substructure response is not particularly sensitive to the changes in superstructure stiffness for this bridge structure. The flexural stiffness about the weak axis of the superstructure cross section would be the most different, however, the bearings do not transfer moment between the superstructure and the substructure at any piers so this does not have a significant effect on the longitudinal mode shapes. The flexural stiffness about the strong axis would be very similar to the open web cross section, and is relatively rigid in comparison with the substructure, so it should not have a significant impact on the transverse mode shapes. Vertical modes are not considered at this time.
5. All piers consist of 2 columns sloped at 1:5, as shown in the previous LPA, with a pier cap beam at the top connecting them and bearings on top of the pier cap beam. The pier cap beams for Piers 1, 2, 7 & 8 were sized according to the previous design for the LPA. The pier cap beams for Piers 3, 4, 5 & 6 were 14' wide and 15' tall.
6. The columns for Piers 1, 2, 7 & 8 were sized according to the previous design for the LPA.
7. Piers 1, 2, 7 & 8 include guided bearings and shear keys that can transfer load vertically and normal to the bridge, but allow the superstructure to move along station without transmitting shear force to the substructure.

8. The columns for Piers 3, 4, 5 & 6 were similar to the previous design for the LPA with a 12' octagonal cross section. The effective flexural moment of inertia of the columns was taken as 0.4 times the gross inertia.
9. Piers 3, 4, 5 & 6 include pinned bearings that can transfer load in all directions but do not transfer moments along station.
10. A uniform dead load (mass) was applied to the superstructure in lieu of using the dead load self weight.
11. The additional load for the diaphragms at each pier was estimated as one half the weight of the diaphragms used in the previous design for the LPA. The previous design utilized very large, heavy concrete frame elements to transfer the loads from the substructure to the superstructure. The composite deck truss will rely on steel frame elements to transfer these loads and will be much lighter. Using one half the weight is conservative.
12. Foundation design using RSA for the Columbia River Crossing is controlled by the soil condition considering full liquefaction and 10' of contraction scour. Previous analysis for the open web alternative indicated that the highest demand to capacity ratios for the shaft foundations were associated with this soil condition. This also included large deformations and shaft moments. The highest demands for the columns were associated with stiffer soil conditions with the no scour condition, however, the no scour condition was always associated with lower demand to capacity ratios for the shaft foundations. Since this task was focused on the sizing of the shaft foundations, only the liquefaction condition was considered.
13. The response spectra used for this task was based on FEE Site Class E, which is the recommended curve in the Geotechnical Report for Piers 2 to 5. Site Class E is the FEE curve with the highest spectral accelerations for any of the site classes. SEE curves are not used since they are used to analyze displacement demands for a displacement ductility analysis of the columns.
14. See geotechnical assumptions summary for the open web alternative (included in Appendix 4.1) for other general assumptions.
15. Vessel collision loading was not considered for this task, however, during the previous Type, Size & Location study performed on the open web alternative and the three bridge segmental alternative it was determined that 6 shafts was adequate for a foundation 45' wide shaft cap. The "Predictions of Vessel Collision Forces on Highway Bridge Piers" report by The Glosten Associates was based on contact area and therefore lower forces are associated with the smaller width shaft cap.
16. The shaft caps are based on the same 3D spacing and 7'-6" edge spacing included in the open web alternative.

Limitations:

The following limitations should be observed:

1. The design of the columns will have an impact on the stiffness of the substructure and the overall demands. Larger columns will increase the overall stiffness of the structure and may therefore increase the demands on the shaft foundations. Therefore, the demands are approximate and may differ from the final demands.
2. The geometry and properties of the superstructure cannot be used to determine any forces or stresses for the superstructure members, although they are adequate to provide forces at the foundation level.
3. Strength loads have not been checked for the composite deck truss on the shaft foundations, but they are not anticipated to be critical to the design.
4. Vessel collision forces have not been checked for the shaft foundations on the composite deck truss, but they are not anticipated to be critical to the design.
5. No analysis has been performed for the no scour condition, but it is assumed that this will not control the foundation design based on prior analysis completed during the Type, Size & Location Study.

Discussion:

The conceptual foundation analysis performed indicated that shaft caps with 6 – 10' diameter shafts would be adequate to support the composite deck truss structure given the LPA layout and the assumptions as discussed above.

The weight of the composite deck truss alternative is significantly less than the open web alternative which leads to a number of advantages (Refer to table on page 2-4). First, the lighter weight structure has lower dead load so that the AASHTO Strength I and Strength IV demands on the foundation are significantly less and fewer shafts are required for service loads. Second, the smaller strength and service level demands on the columns means that the column size and reinforcement may be decreased. Smaller columns with less reinforcement decrease the plastic hinging demands on the shaft foundations. Third, the lighter superstructure and smaller caps decrease the elastic seismic demands on the structure. The weight of the shaft caps is significant for this structure and the influence of the shaft cap mass on the foundation demands is increased with the liquefaction condition.

In addition to the decrease in weight and the decrease in foundation stiffness, the substructure stiffness in the longitudinal direction decreased due to the change in articulation at the top of the columns. Piers 3, 4, 5 & 6 have pinned bearings at the top of the pier caps which is gives stiffness 4 times less in the longitudinal direction. The calculated stiffness of the columns in the longitudinal direction is based on $3*E*I/L^3$. The open web alternative had integral pier caps for Piers 3, 4, 5 & 6 which relates to a column stiffness of $12*E*I/L^3$. Therefore, the change in articulation has a significant impact on the longitudinal pier stiffness. Piers 1,2, 7 & 8 remained unchanged in the model. The decrease in longitudinal stiffness leads to a change in the longitudinal structure period to just over 4 seconds. This longer period is associated with a lower acceleration coefficient on the response spectrum, and therefore lower demands.

The actual demand to capacity ratios in the conceptual foundation analysis performed for the composite deck truss structure were less than 0.75 in both the transverse and the longitudinal direction. The demand to capacity ratio included in the output for the FB-MultiPier analysis is based the interaction diagram for biaxial loading of the drilled shaft and uses AASHTO resistance factors for the interaction. Therefore, given the margin between 0.75, the limit of 1.0 and the AASHTO resistance factors there is room for any minor changes in seismic demands due to changes in the column geometry.

Further analysis would include the updated modeling of the superstructure and the concurrent design of the columns, along with loading that would include service loading and vessel collision loading.

HDR | ONE COMPANY *Many Solutions*℠

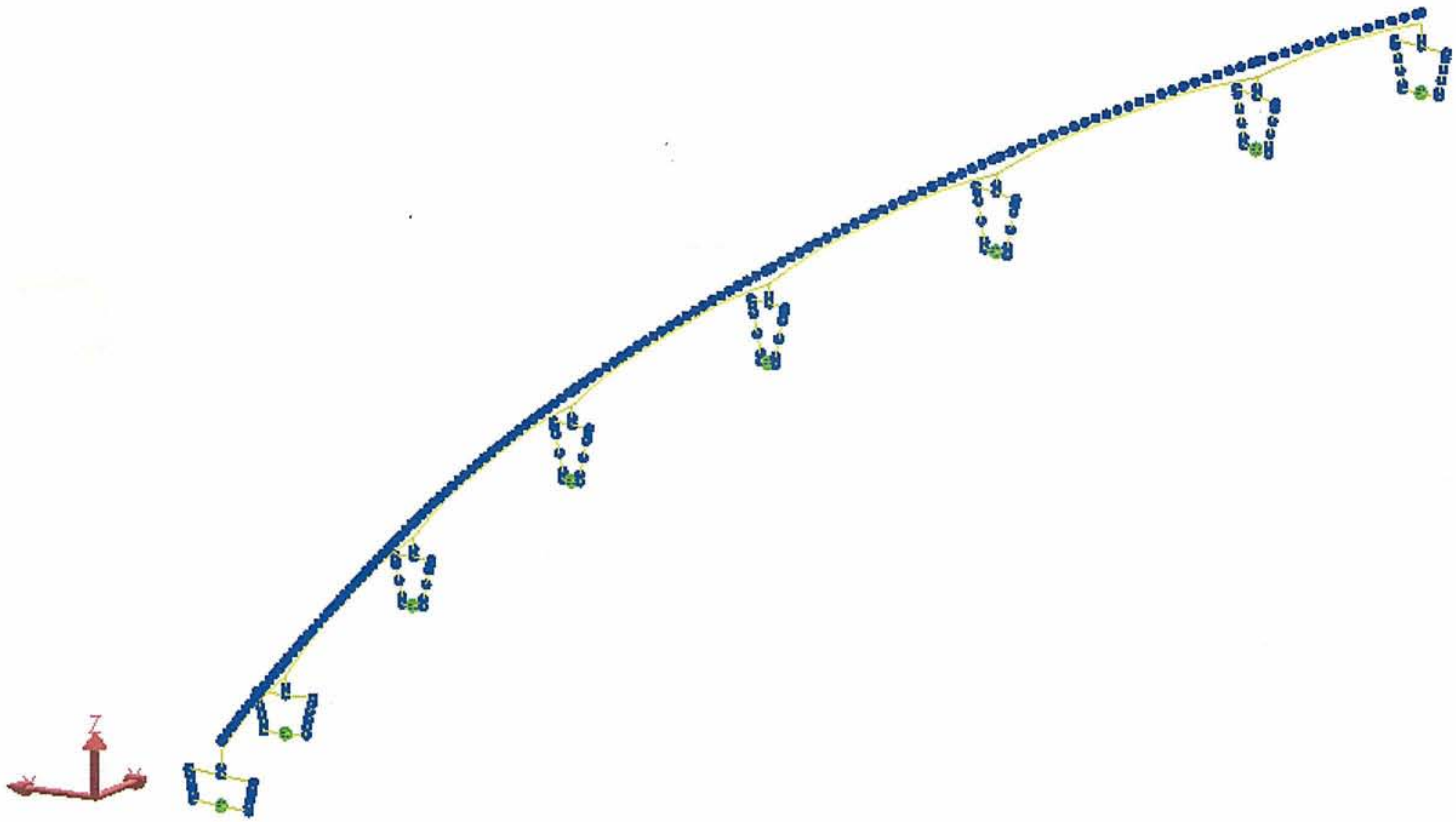
LARSA Global Analysis

Project:	Columbia River Crossing	Computed: C. Werts		Date:	03-23-2011
Subject:	River Bridge Preliminary Design	Checked:		Date:	
Task:	Composite Deck Truss Alternative	Sheet:		of	

2. LARSA Global Analysis

Graphics View 1

Zoom 3.052X



Graphics View 1