INTERSTATE 5 COLUMBIA RIVER CROSSING

Geology and Groundwater Technical Report for the Final Environmental Impact Statement

May 2011

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Cover Sheet

Interstate 5 Columbia River Crossing

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

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List of Exhibits

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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

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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

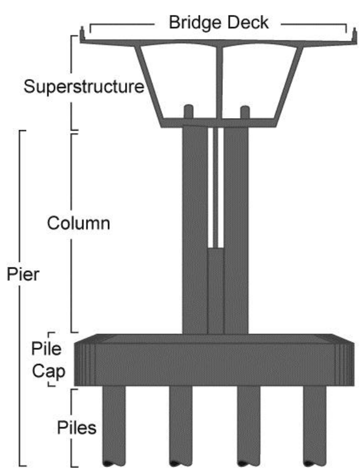
This section describes proposed construction techniques that would likely be used during the CRC project. The type, methods and specifications of these construction activities would be determined in PE preliminary engineering design reports and by the selected Contractors.

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

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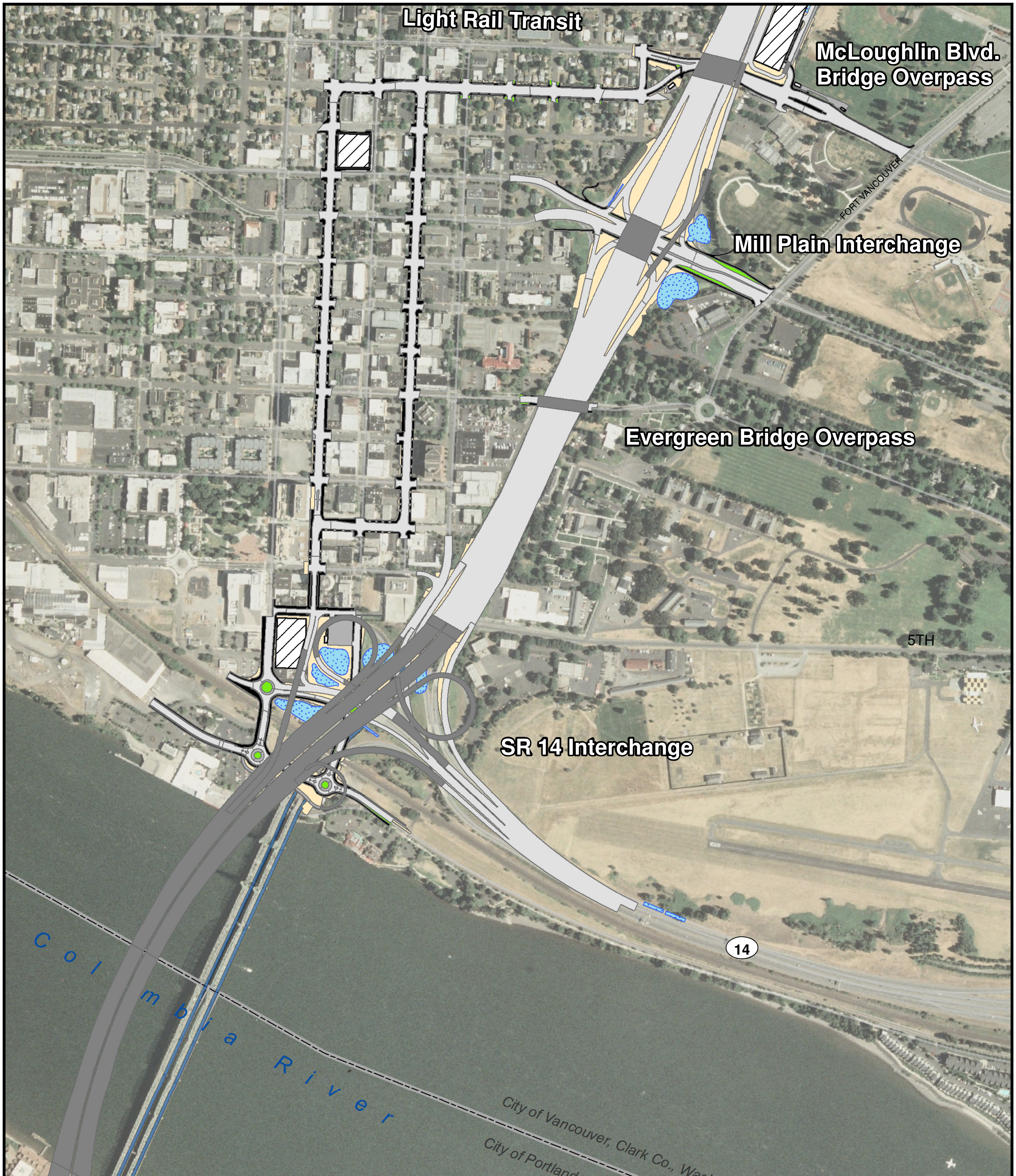

N
W E
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0 250 500
Feet

Legend

- Bridge
- Roadway
- Tunnel
- Sidewalk
- Structure
- Storm Water Treatment
- Vegetative Filter Strip
- Fill

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

Columbia River CROSSING

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

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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].

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[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.

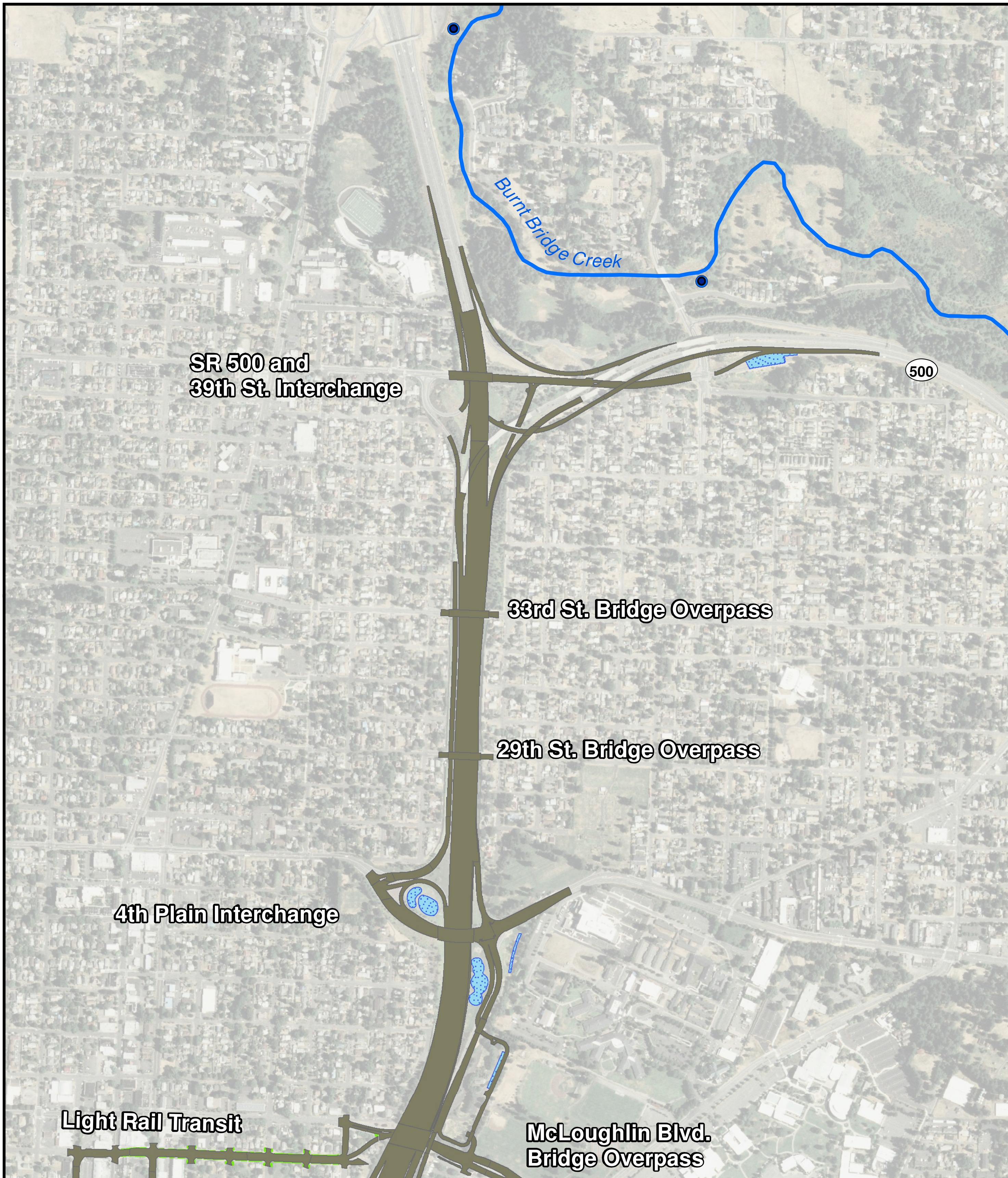
1.6.1 Geologic Hazards

- 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.



Bio-Retention Pond or Swale

Vegetative Filter Strip

Impervious Pollutant Generating Surface

Outfalls

Creek

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

Columbia River CROSSING

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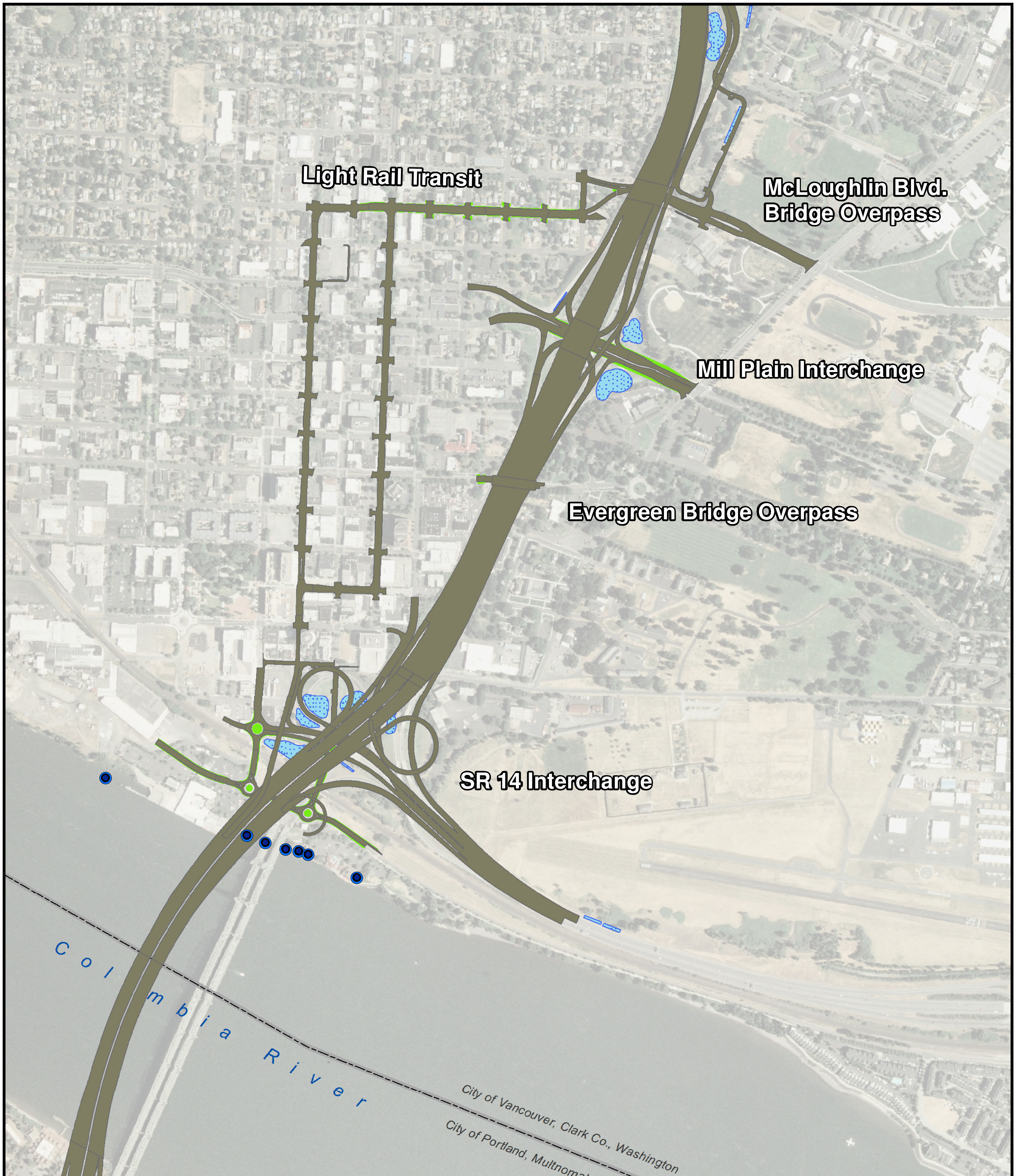

Exhibit 1-7b. Columbia River to McLoughlin Boulevard Stormwater Systems

Columbia River CROSSING

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

N
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0 250 500
Feet

- Bio-Retention Pond or Swale
- Vegetative Filter Strip
- Impervious Pollutant Generating Surface
- Outfalls
- Creek

Columbia River CROSSING

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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.

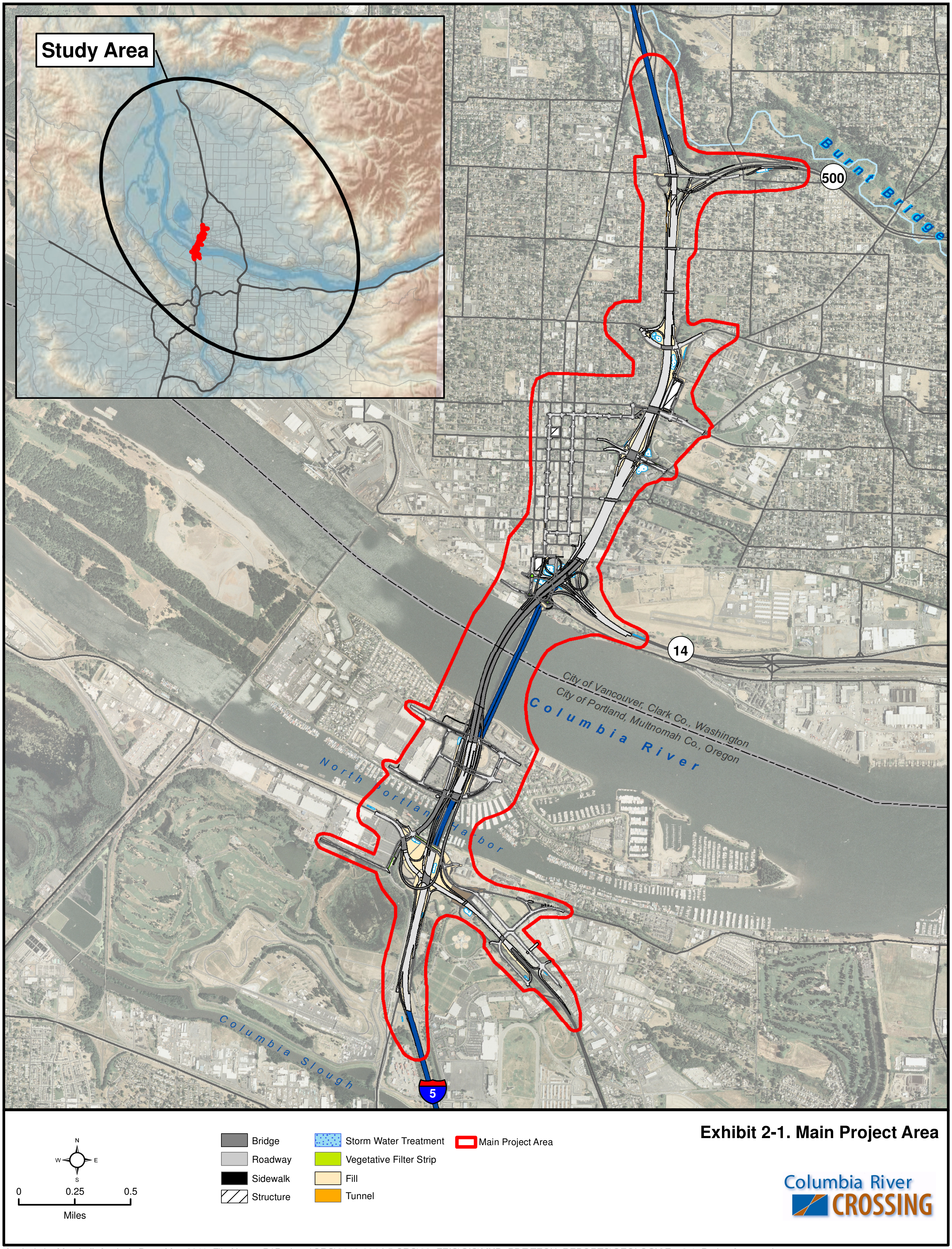

Exhibit 2-1. Main Project Area

Analysis by Marshall; Analysis Date: May 2011; File Name: P:\Projects\CRC\3012-004 I-5 CRC\09_FEIS\GIS\MXD_PDF\TECH_REPORTS\GEOLOGY\Ex_2-1_ProjectArea.mxd

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.

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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).

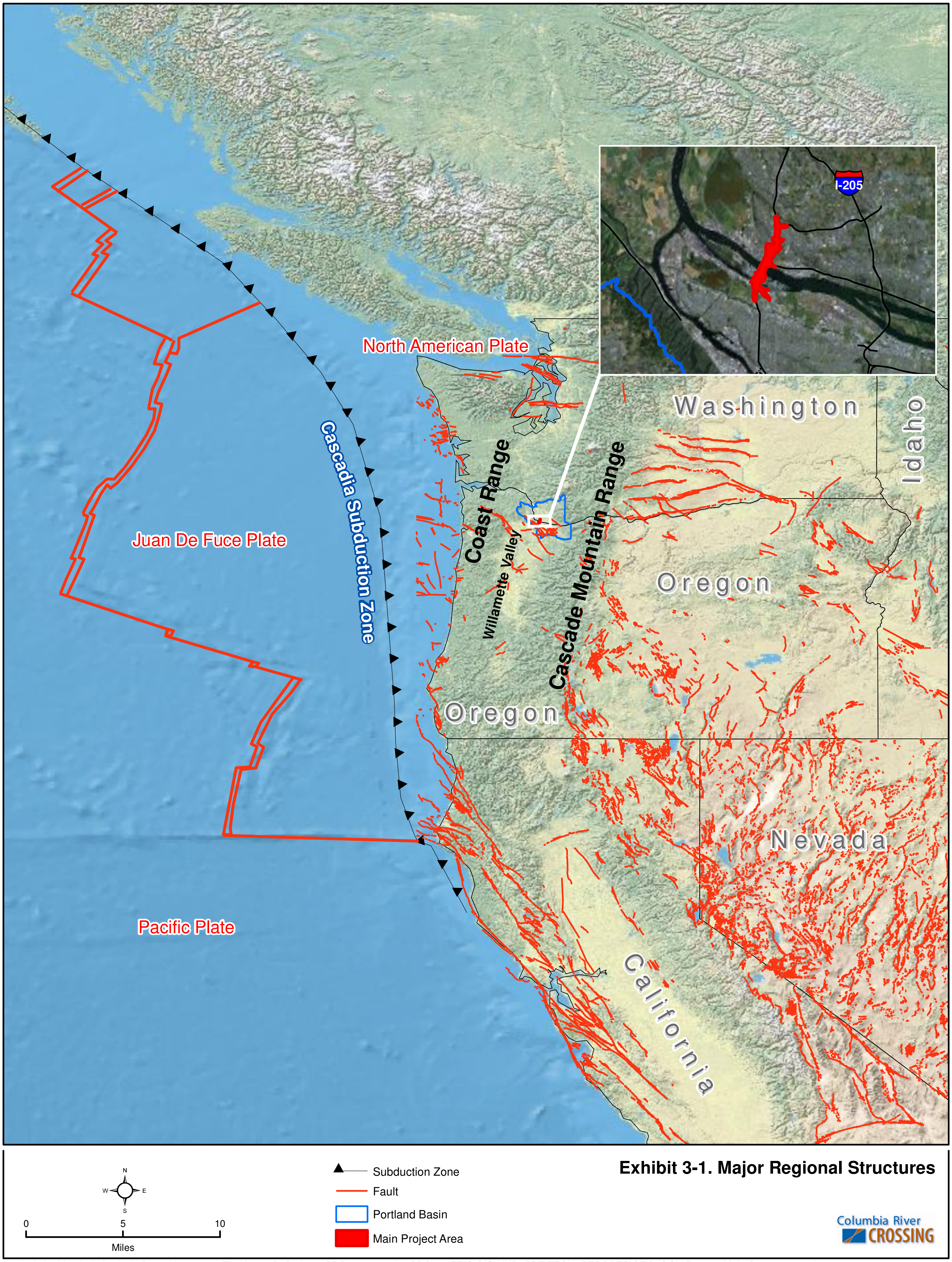
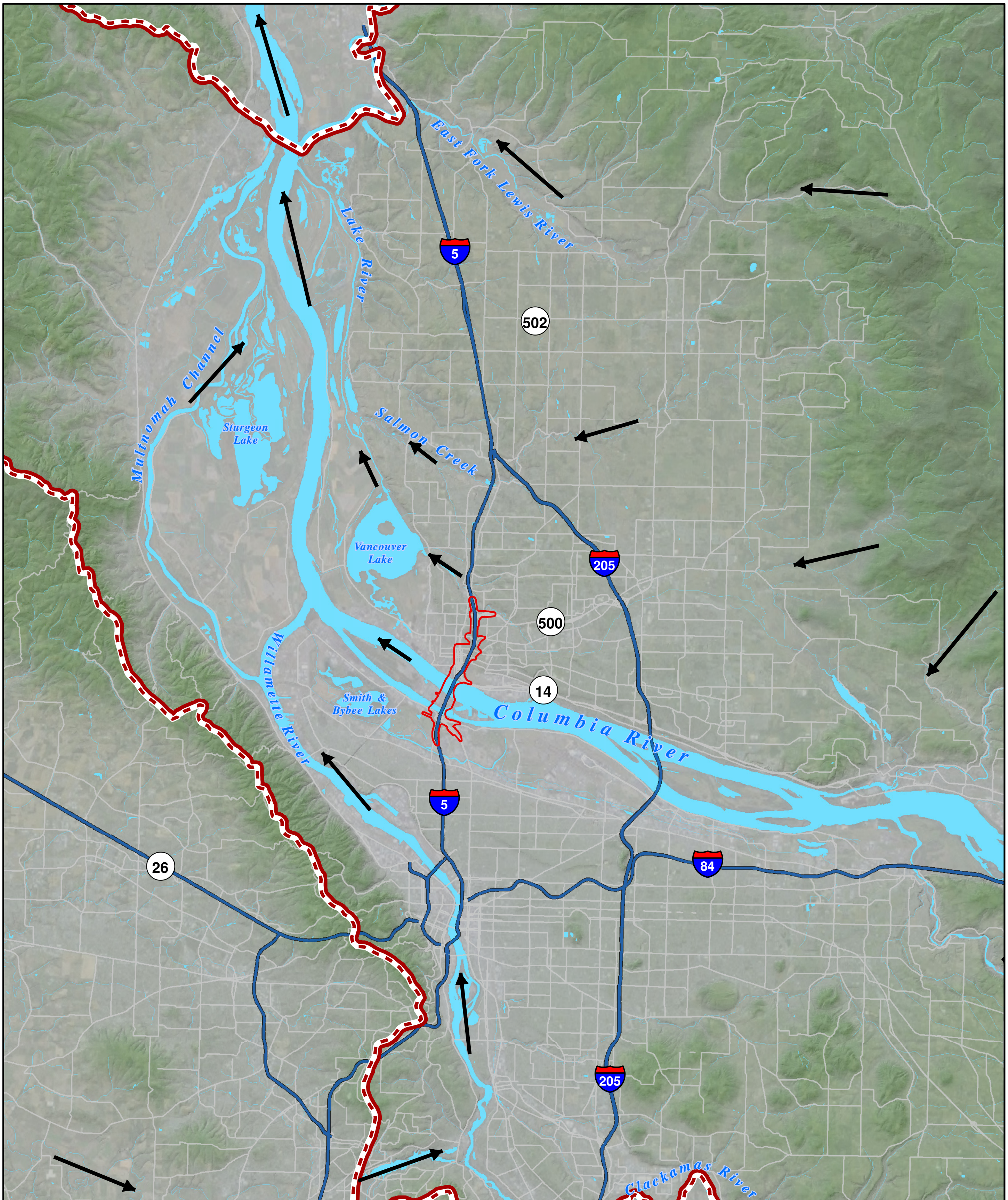


Exhibit 3-1. Major Regional Structures



N W E S

0 1 2
Miles

Direction of Surface Water Flow
Main Project Area
Portland Basin

Exhibit 3-2. Topography and Drainage

Columbia River CROSSING

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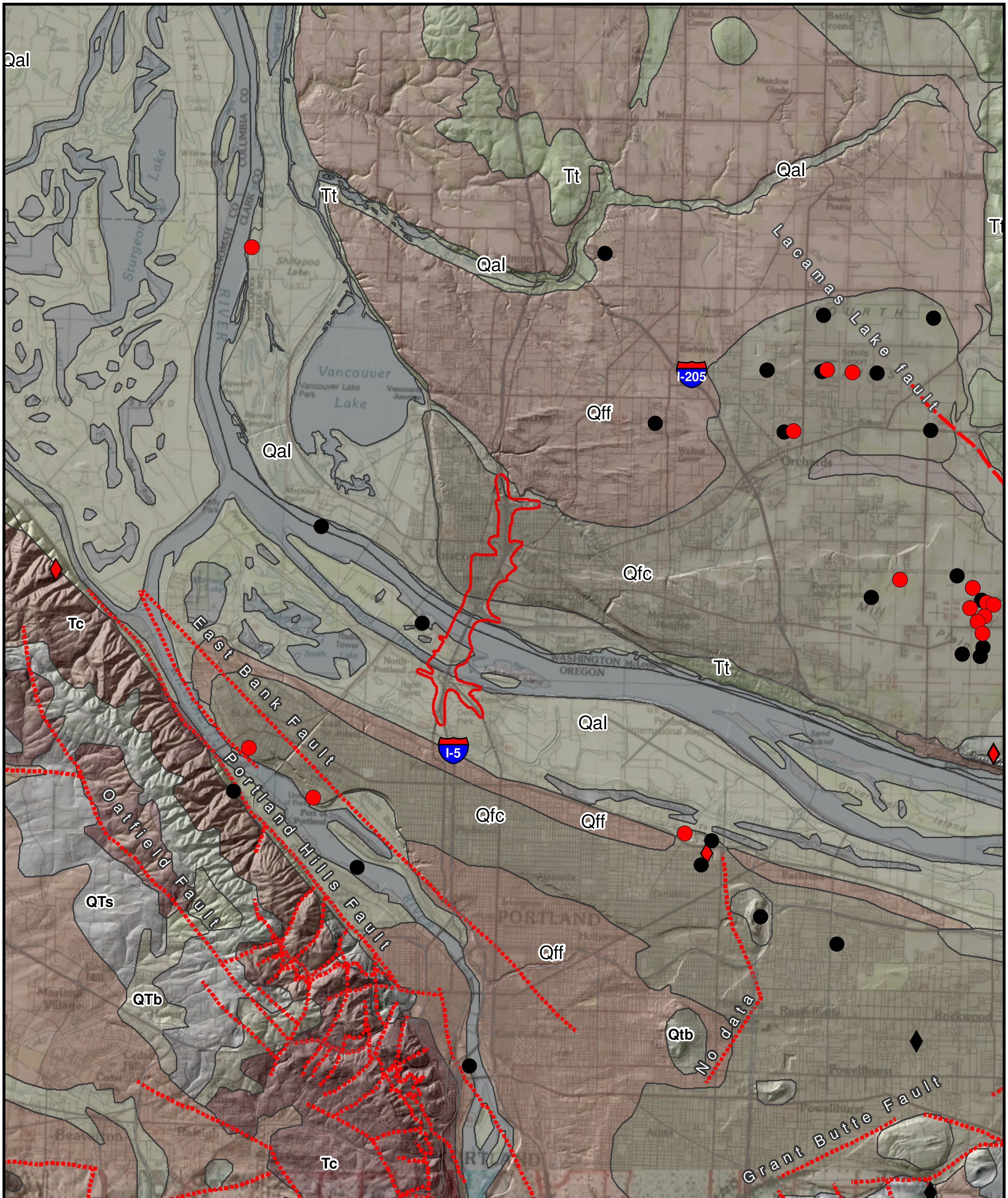


N
W E
S
0 0.5 1
Miles

Area of Potential Impact
- Main Project Area
- Potentially Seismogenic Fault

Geologic Units
- Qal - Quarternary Alluvium
- Qp - Peat Deposits
- Qaf - Alluvial Fan Deposits
- Qfc - Catostrophic Flood Deposits Coarse Grained Facies
- Qff - Catostrophic Flood Deposits Fine Grained Facies
- Tt - Troutdale Fm
- QTb - Boring Volcanics
- QTs - Sandy River Mudstone
- Tc - Columbia River Basalt

Surface Mine Sites
- active, rock
- active, sand and gravel
- terminated, sand and gravel
- terminated, rock

Exhibit 3-3. Geologic Units and Crustal Fault Locations

Columbia River CROSSING

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

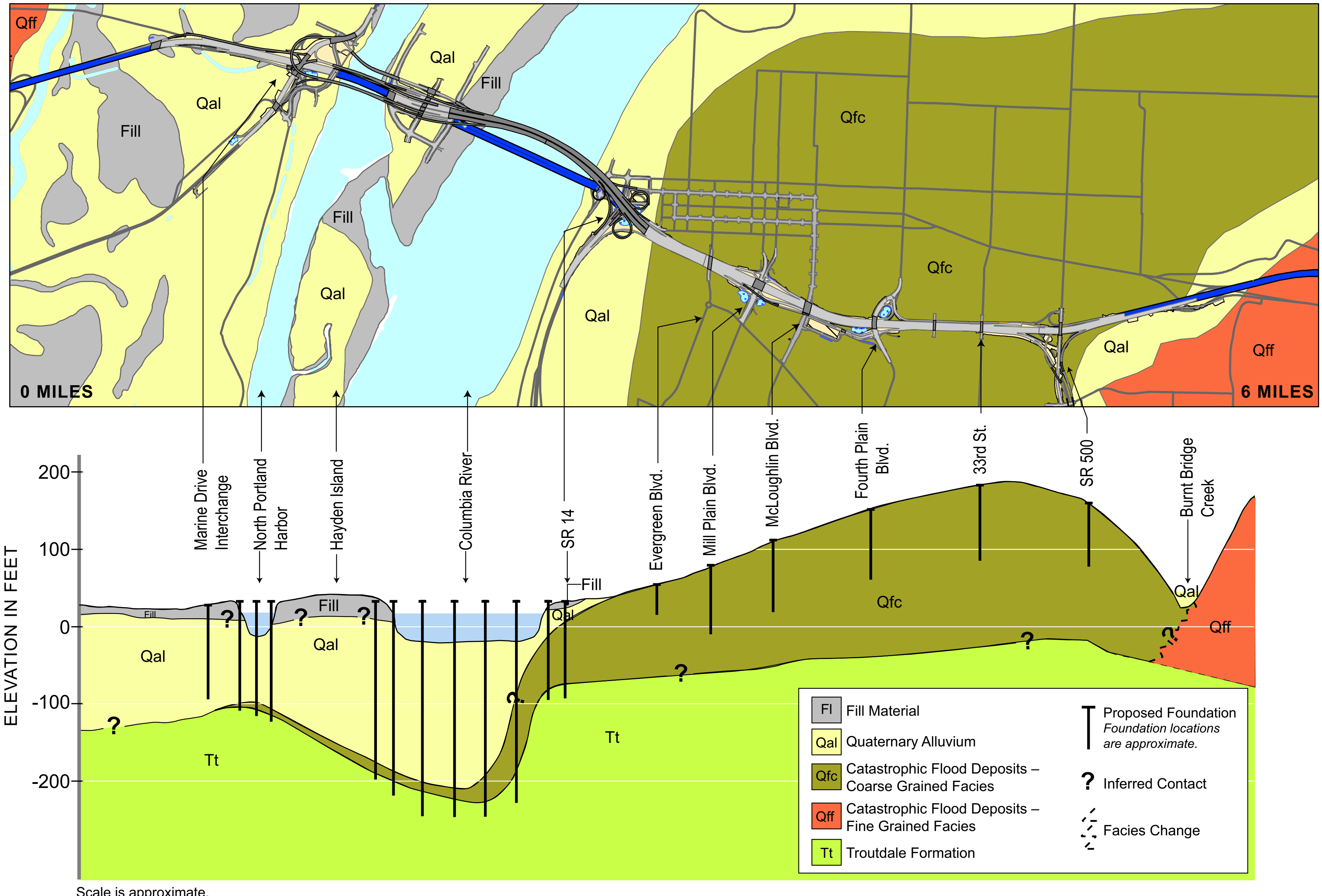


Exhibit 3-4. Generalized Schematic Subsurface Profile

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.

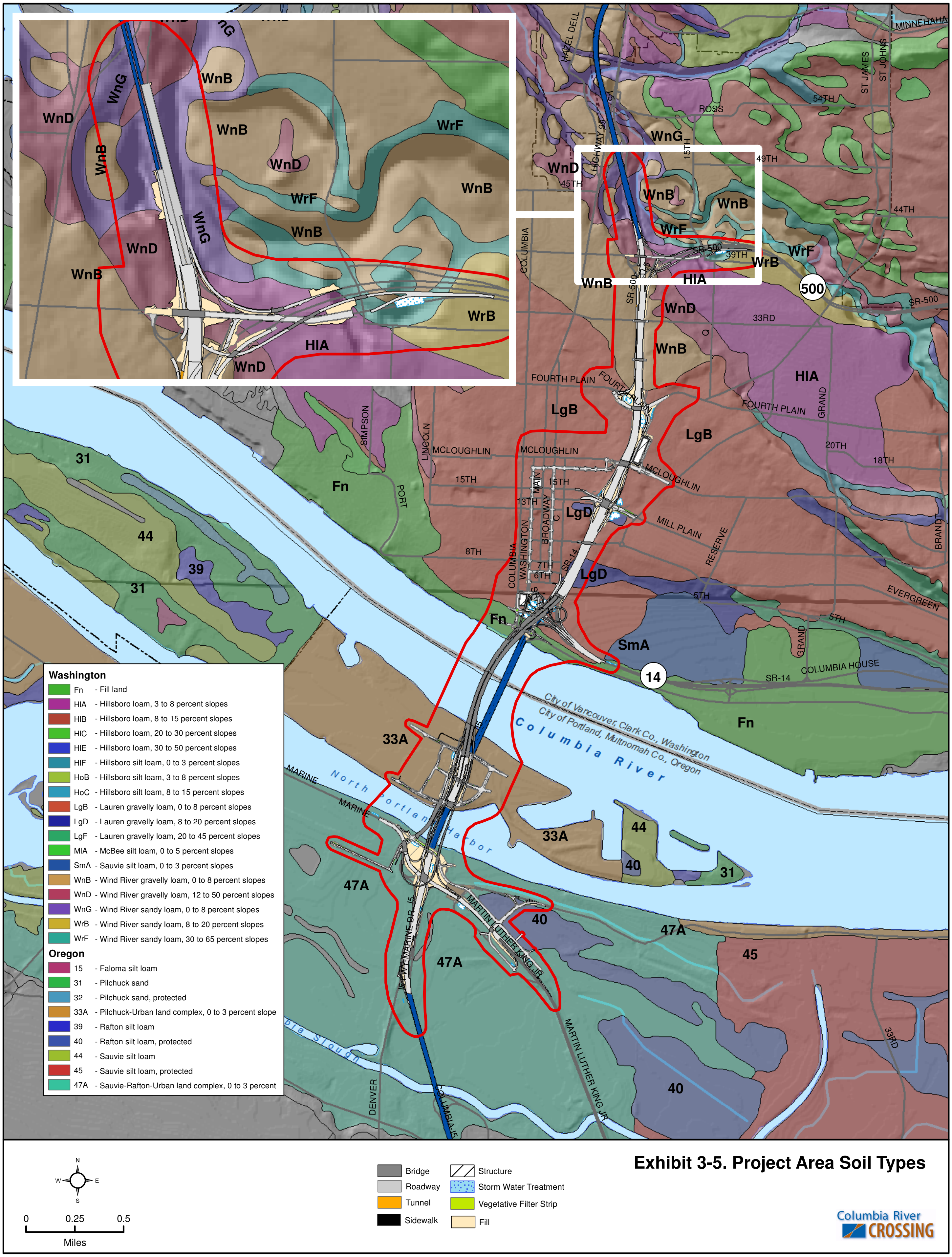


Exhibit 3-5. Project Area Soil Types

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.

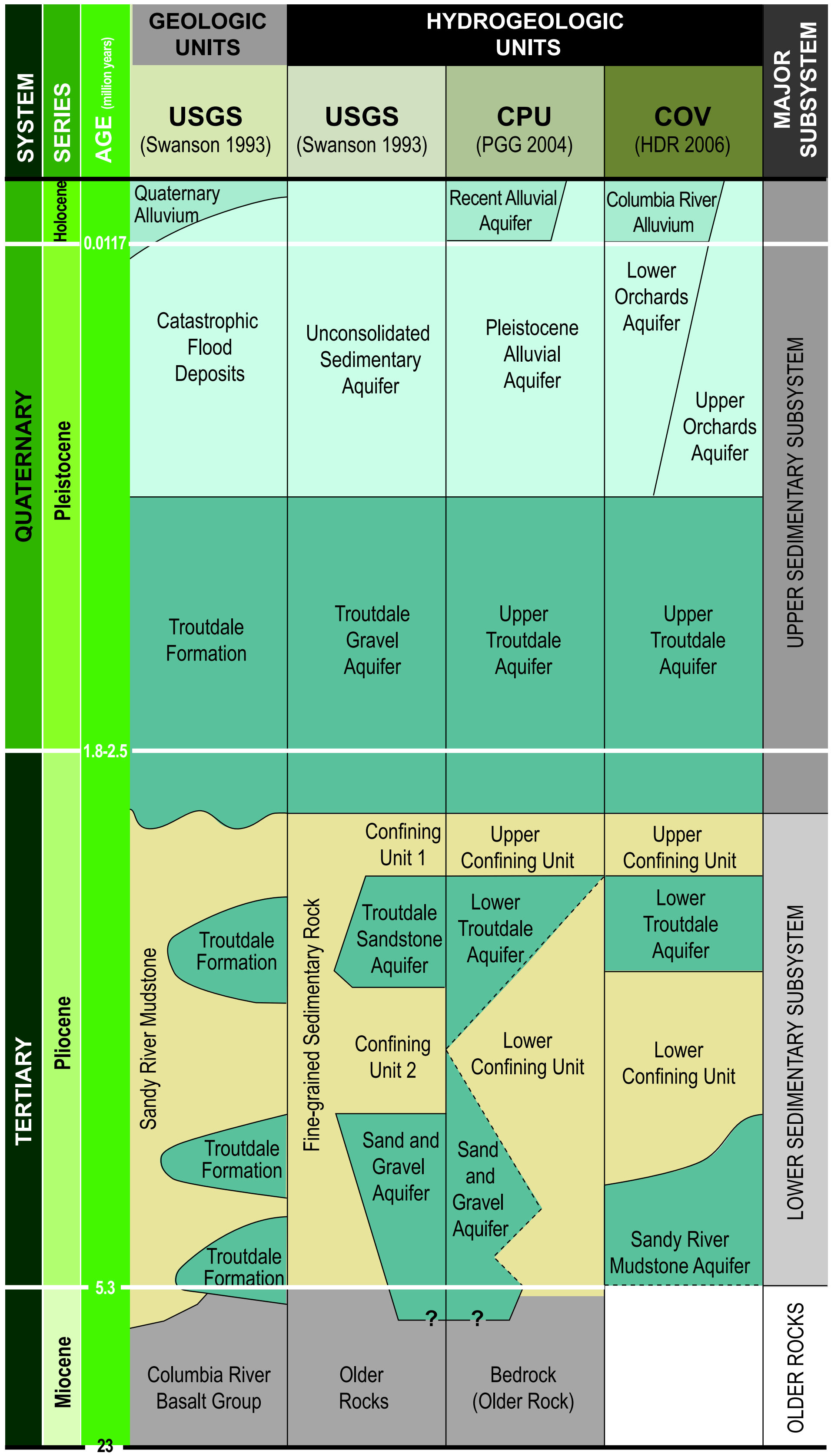


Exhibit 3-7. Geological Units and Comparison of Hydrogeologic Unit Terminology
Geology Technical Report

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.

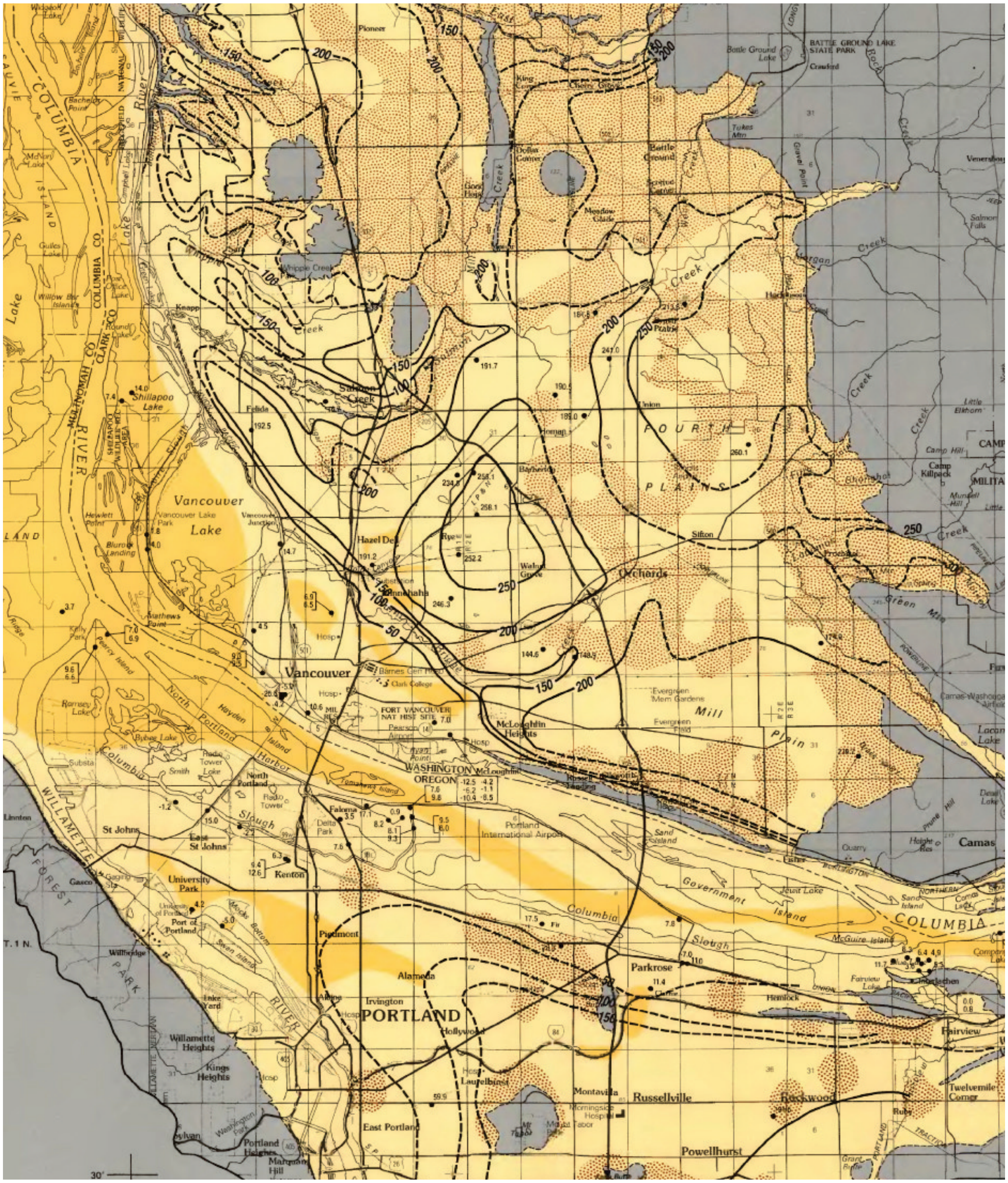
The groundwater table elevation along the banks of the Columbia River and North Portland Harbor is influenced by river stage elevation which is in turn influenced by tidal fluctuations, precipitation events, and upstream dam releases. The rapid response between changes in river stage and corresponding 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.



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

N
W E
S

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

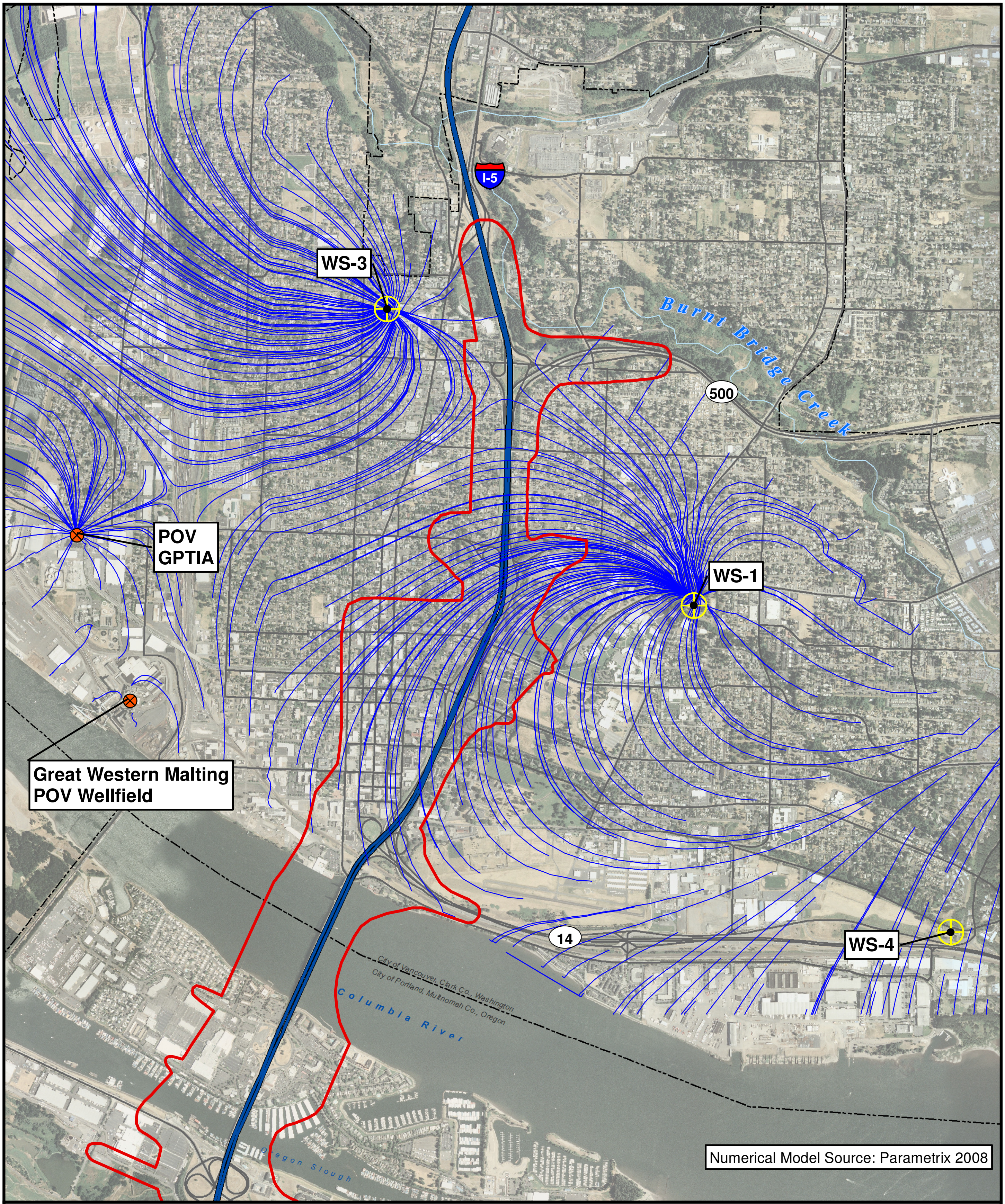
The purpose of a beneficial groundwater use survey is to identify the current use of groundwater in the vicinity of the LPA. A review of available well information identified approximately 73 potential wells in Washington and 49 wells in Oregon within one mile of the CRC LPA. Verification of the information 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.



N W E S

0 0.25 0.5
Miles

City of Vancouver Water Station
Extraction Well
Main Project Area
Extraction Well Flow Lines

Bridge
Roadway
Tunnel
Sidewalk

Structure
Storm Water Treatment
Vegetative Filter Strip
Fill

Legend

Exhibit 3-9. Extraction Well Simulated Flow Path Map

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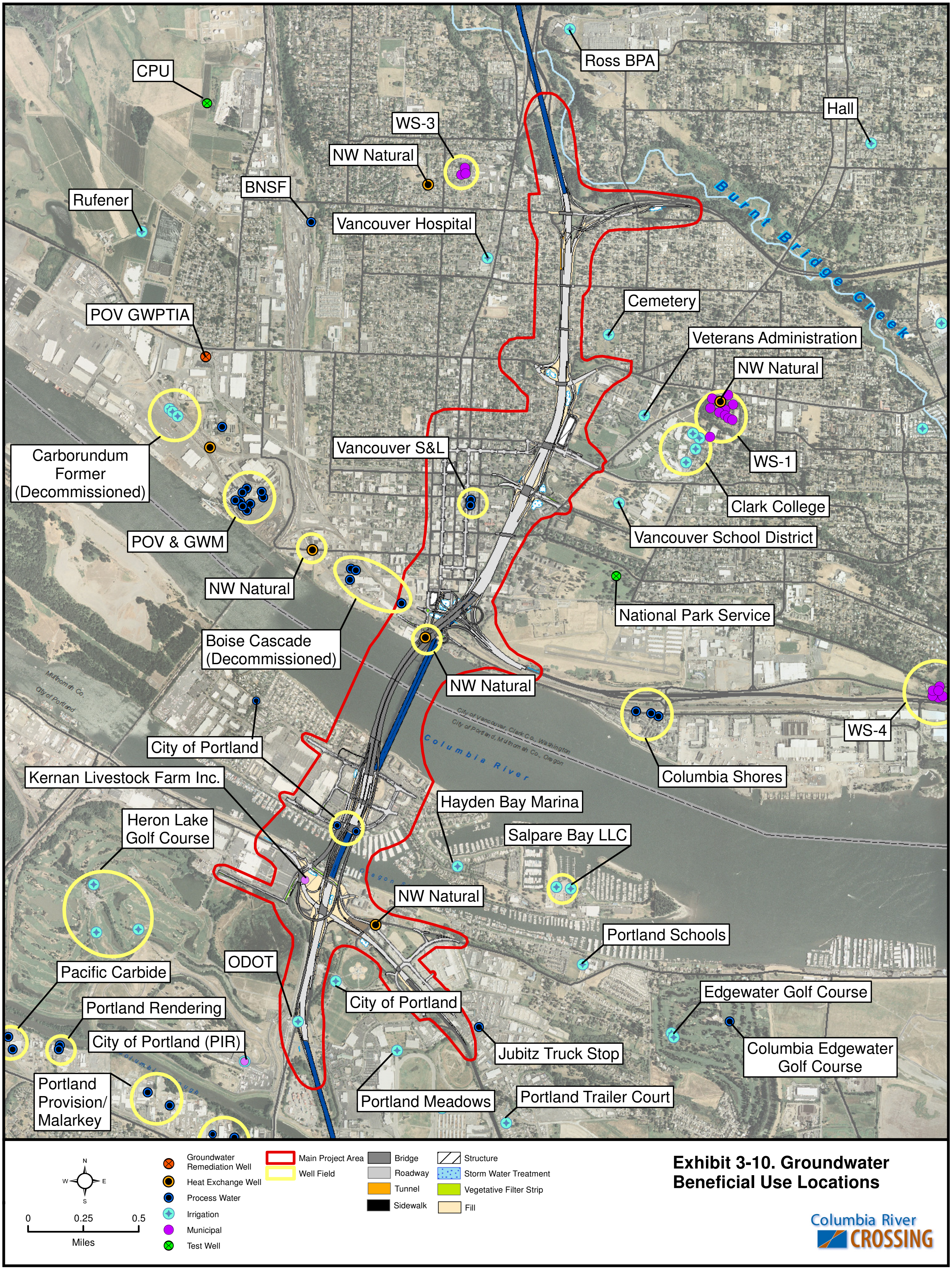


Exhibit 3-10. Groundwater Beneficial Use Locations

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

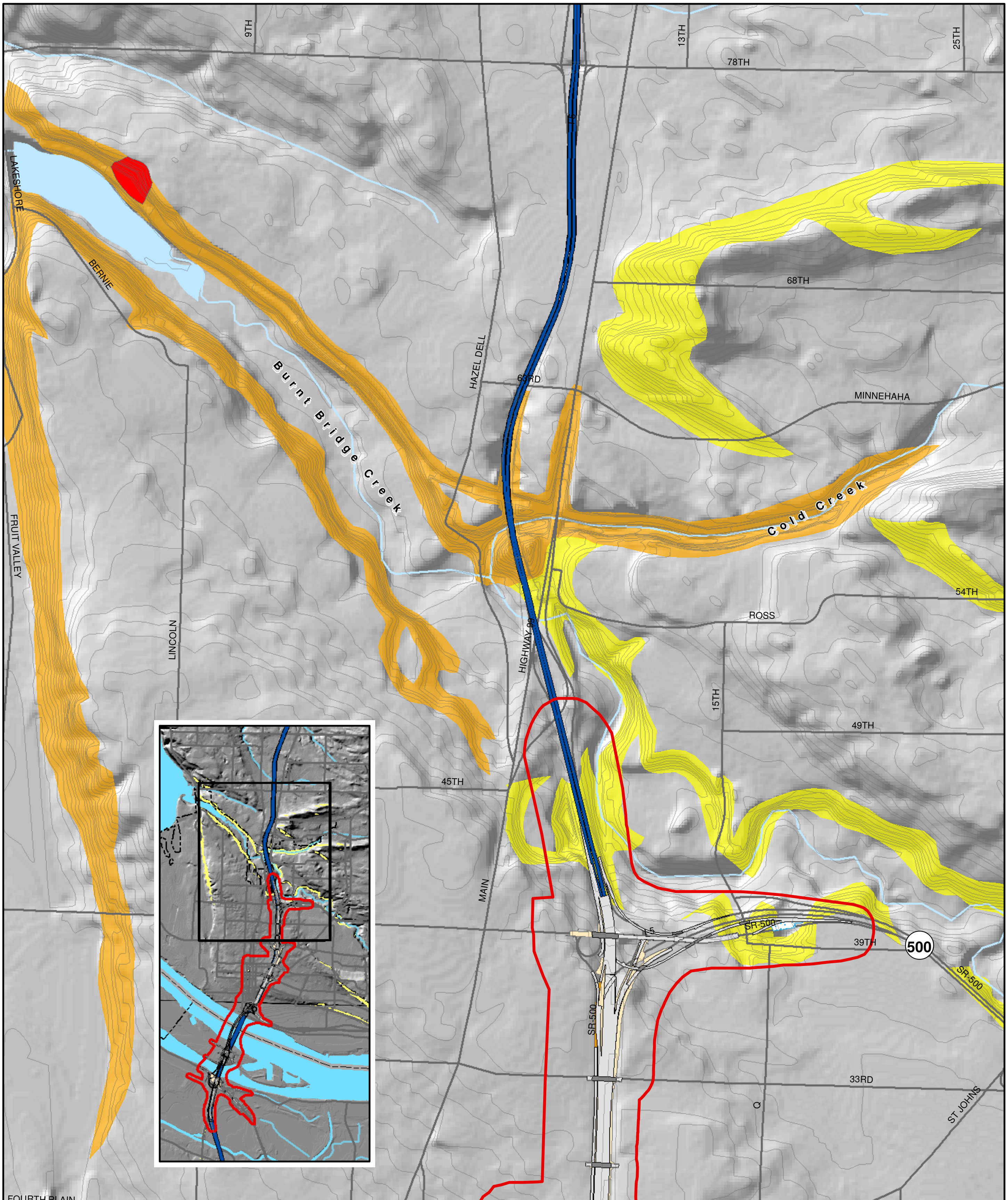
Exhibit 3-12 displays the locations of steep slopes in the project area. Steep slope hazard areas are typically defined as areas where there is no mapped or designated landslide hazard, but where there are slopes equal to or greater than 25 percent (Das 1983). Steep slopes have the potential to cause 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.



Main Project Area

Slopes

- 25 - 40 percent
- 40 - 100 percent
- Landslide

- Bridge
- Roadway
- Tunnel
- Sidewalk
- Structure
- Storm Water Treatment
- Vegetative Filter Strip
- Fill

0 0.125 0.25
Miles

Exhibit 3-12. Steep Slopes and Landslides

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Analysis by MSMarshall; Analysis Date: December 2010; File Name: P:\GIS\CRC\GIS\MXD_PDF\TECH_REPORTS\GEOLOGY\Ex_3-12_Slopes-Landslides.mxd

3.9.3 Non-seismic Ground Settlement

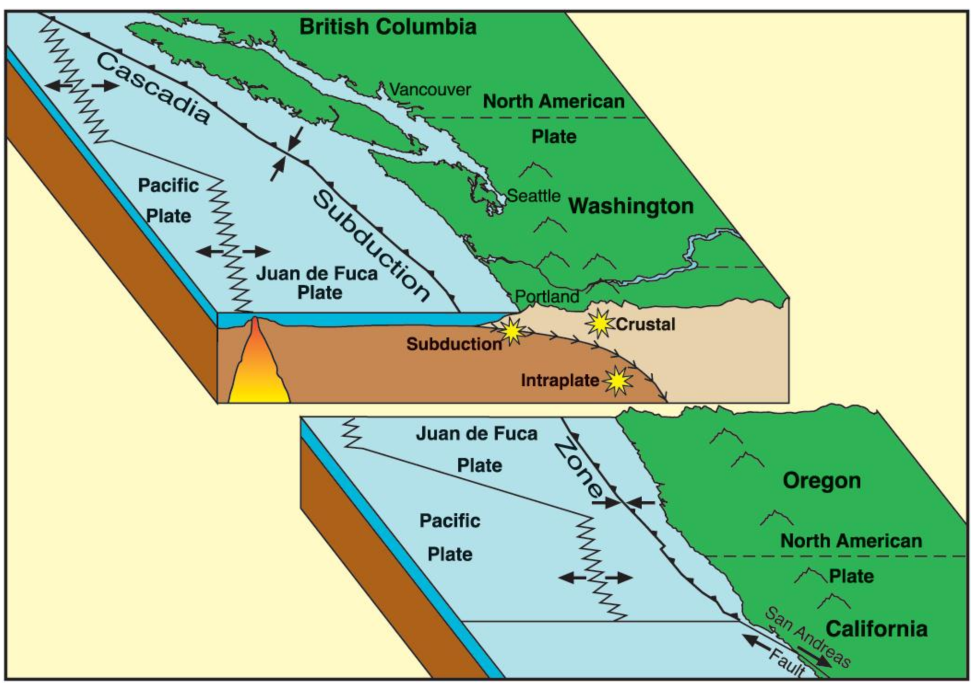
Non-seismic settlement or consolidation occurs in loose, soft soil material. The structure has the potential to settle after construction due to the introduction of added load (Johnson and DeGraff 1988). Settlement generally occurs slowly but over time can amount to more than most structures can tolerate. 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.

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
<u>Crustal</u>						
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.

<u>Ground Motion</u>

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).

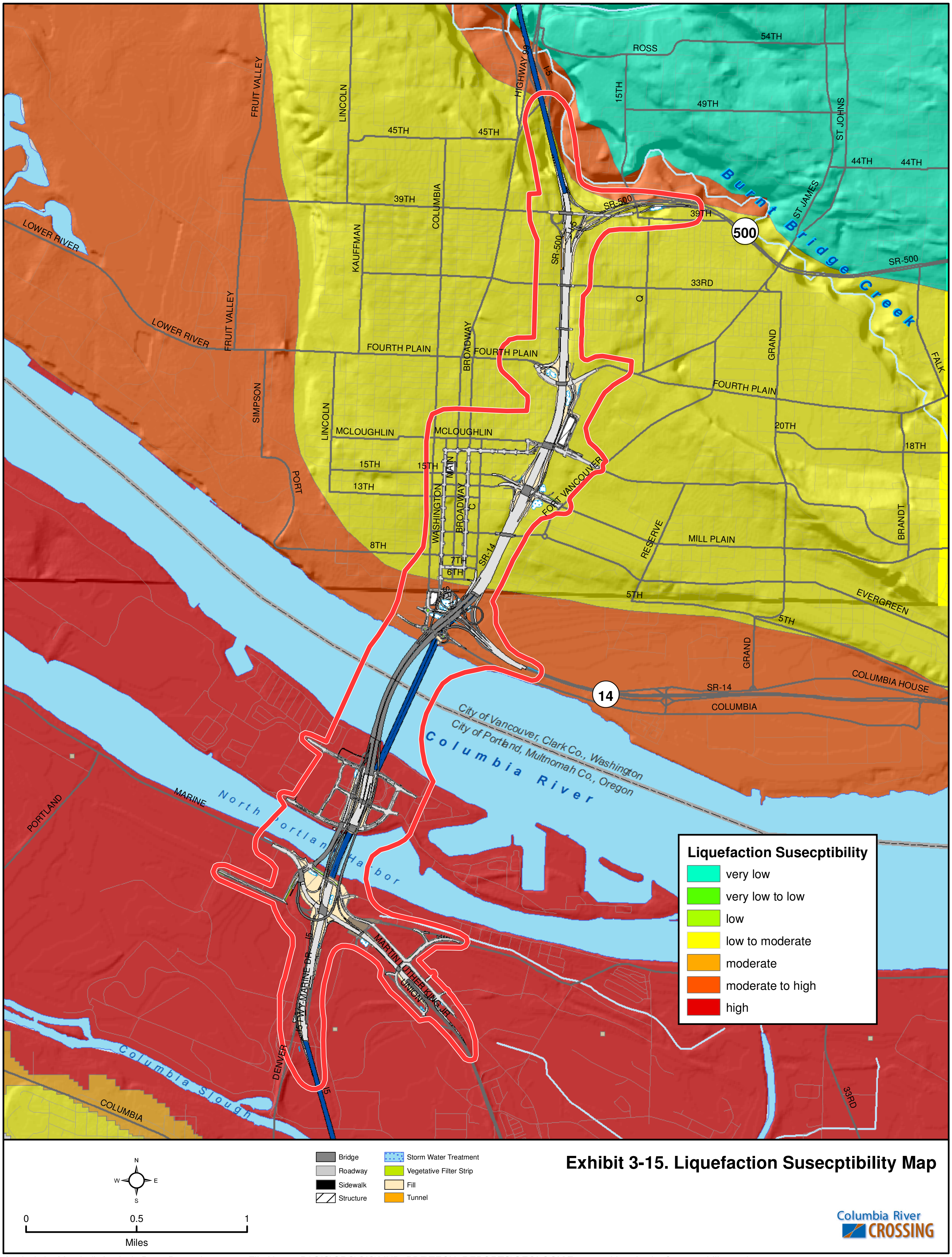


Exhibit 3-15. Liquefaction Susecptibility Map

Analysis by Marshall; Analysis Date: December 2010; File Name: P:\GIS\CRC\GIS\MXD_PDF\TECH_REPORTS\GEOLOGY\Ex_3-15_LiquefactionSusceptability.mxd

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

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[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).

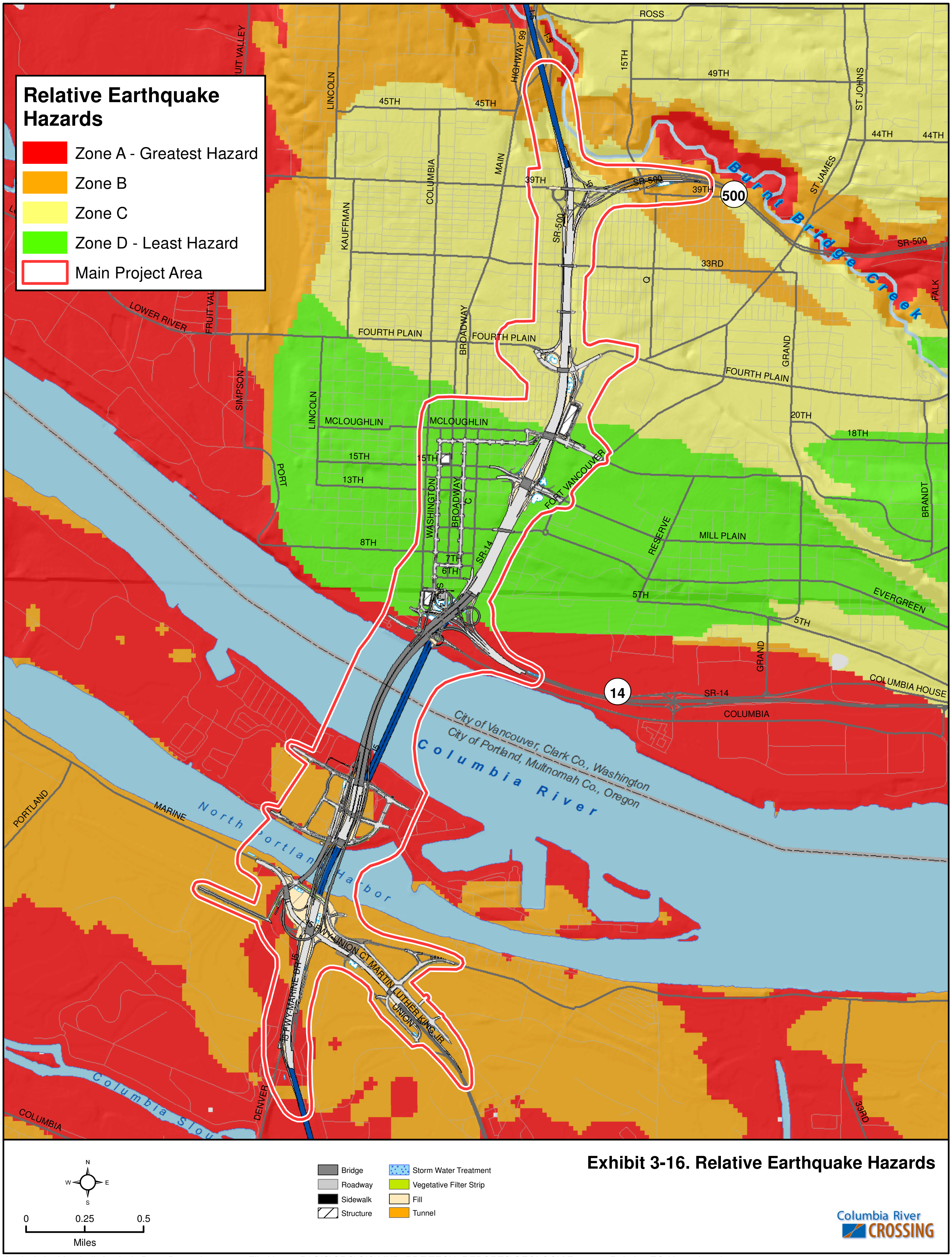

Exhibit 3-16. Relative Earthquake Hazards

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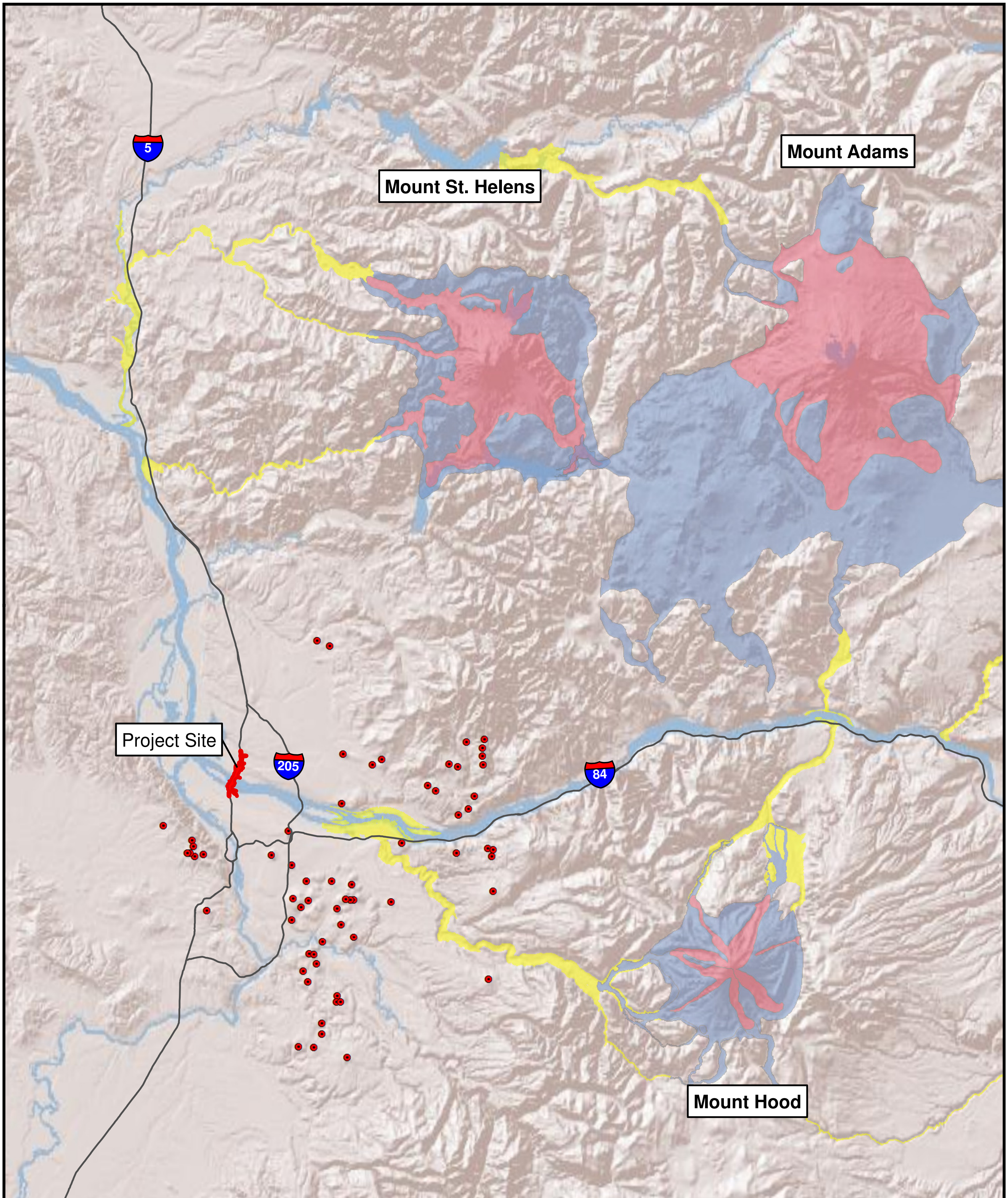

Exhibit 3-17. Volcanic Hazards

N
W E
S

0 5 10
Miles

Boring Volcanic Center

Hazard Zone

- Lava, Pyroclastic, and Lahar Flows
- Pyroclastic and Lahar Flows
- Lahar Flows

Columbia River CROSSING

Analysis by Marshall; Analysis Date: December 2010; File Name: P:\GIS\CRC\GIS\MXD_PDF\TECH_REPORTS\GEOLOGY\Ex_3-17_Volcanic-Hazard.mxd

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.

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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.

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