UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
Portland, OR 97232

Refer to NMFS Consultation No.:
WCR-2017-7795

October 1, 2018

William D. Abadie
Acting Chief, Regulatory Branch
U.S. Army Corps of Engineers
P.O. Box 2946
Portland, Oregon 97208-2946

Re: REVISED Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Construction and Operation of the Willamette Water Supply System, Clackamas and Washington Counties, Oregon (HUC 170900070402.) (COE Number NWP-2015-41).

Dear Mr. Abadie:

On September 12, 2018, the NOAA's National Marine Fisheries Service (NMFS) issued a Endangered Species Act Section 7(a)(2) biological opinion, and Magnuson-Stevens Fishery Conservation and Management Act essential fish habitat response for construction and operation of the Willamette Water Supply System.

The enclosed document contains a revised biological opinion that replaces the September 12, 2018 biological opinion to: (1) include more accurate temperature modeling that was not submitted with the biological assessment in the consultation request; and (2) correct a non-substantive error found in within the previous Reasonable and Prudent Measures, Section 2.9.3.

In this revised opinion, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of the 15 ESA-listed species below, or result in the destruction or adverse modification of their designated critical habitats.

1. Lower Columbia River (LCR) Chinook salmon (*Oncorhynchus tshawytscha*)
2. Upper Willamette River (UWR) Chinook salmon
3. Upper Columbia River (UCR) spring-run Chinook salmon
4. Snake River (SR) fall-run Chinook salmon
5. SR spring/summer Chinook salmon
6. Columbia River (CR) chum salmon (*O. keta*)
7. LCR coho salmon (*O. kisutch*)
8. SR sockeye salmon (*O. nerka*)
9. LCR steelhead (*O. mykiss*)
10. UWR steelhead
11. Middle Columbia River (MCR) steelhead
12. UCR steelhead

13. Snake River Basin (SRB) steelhead
14. Southern green sturgeon (*Acipenser medirostris*)
15. Southern eulachon (*Thaleichthys pacificus*)

As required by section 7 of the ESA, NMFS is providing an incidental take statement (ITS) with the opinion. The ITS describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with this program. The ITS also sets forth nondiscretionary terms and conditions, including reporting requirements, that the Federal action agency or applicant must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of the listed species considered in this opinion.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes three conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH. Section 305(b)(4)(B) of the MSA requires Federal agencies to provide a detailed written response to NMFS within 30 days after receiving these recommendations.

If the response is inconsistent with the EFH conservation recommendations, the Corps must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the action and the recommendations. In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we request that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

Please contact Annie Birnie at 503-230-5407 or annie.birnie@noaa.gov if you have any questions concerning this section 7 consultation, or if you require additional information.

Sincerely,

Barry A. Thom
Regional Administrator

cc: Niki Iverson, City of Hillsboro
Kristine Marshall, David Evans and Associates
Michael LaDoucer, U.S. Army Corps of Engineers

REVISED Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response

Construction and Operation of the Willamette Water Supply System
Clackamas and Washington Counties, Oregon (HUC 170900070402)
(COE Number NWP-2015-41)

NMFS Consultation Number: WCR-2017-7795

Action Agency: U.S. Army Corps of Engineers

Affected Species and NMFS' Determinations:

ESA-Listed Species	ESA - Status	Is the action likely to adversely affect this species or its critical habitat?	Is the action likely to jeopardize this species?	Is action likely to destroy or adversely modify critical habitat for this species?
Lower Columbia River Chinook salmon	T	Yes	No	No
Upper Willamette River Chinook salmon	T	Yes	No	No
Upper Columbia River spring-run Chinook salmon	E	Yes	No	No
Snake River spring/summer run Chinook salmon	T	Yes	No	No
Snake River fall-run Chinook salmon	T	Yes	No	No
Columbia River chum salmon	T	Yes	No	No
Lower Columbia River coho salmon	T	Yes	No	No
Snake River sockeye salmon	E	Yes	No	No
Lower Columbia River steelhead	T	Yes	No	No
Upper Willamette River steelhead	T	Yes	No	No
Middle Columbia River steelhead	T	Yes	No	No
Upper Columbia River steelhead	T	Yes	No	No
Snake River Basin steelhead	T	Yes	No	No
Green sturgeon	T	Yes	No	No
Eulachon	T	Yes	No	No

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

Issued By:

Barry A. Thom
Regional Administrator

Date: October 1, 2018

TABLE OF CONTENTS

1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3 below.

1.1 Background

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 et seq.), and implementing regulations at 50 CFR 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). A complete record of this consultation is on file at the Oregon Washington Coastal Office in Portland, Oregon.

1.2 Consultation History

The Willamette Water Supply System (WWSS) includes a primary partnership between the Tualatin Valley Water District (TVWD) and the City of Hillsboro to increase water supply to Washington County. Other water providers in the region are considering partnering as well.

Pre-consultation began between the NMFS and the Corps in late 2015. The following meetings and site visits were attended by the NMFS, the Corps, the applicant, state natural resource agencies, and consultants through 2016 and 2017:

Nov 24, 2015	Initial meeting
May 26, 2016	Intake discussion
Sep 19, 2016	Impacts and Conservation Measures meeting
Dec 6, 2017	Project site visits
Jan 25, 2017	Fisheries focused meeting
Mar 2, 2017	Stream crossing site visits

The Corps requested formal consultation on the issuance of a permit for the WWSS project on August 18, 2017, including with its request a biological assessment. On April 18, 2018, NMFS received a submission from Oregon Department of Environmental Quality (ODEQ) providing information and analysis considered relevant to the ongoing consultation.

This opinion is based on information provided in the BA, field investigations and meetings with the applicant. We also considered other sources including information from recovery plans, water quality assessments and recommendations by ODFW, and information submitted during the consultation process. Consultation was initiated on April 18, 2018.

A complete record of this consultation is on file at the Oregon Washington Coastal Office in Portland, Oregon.

1.3 Proposed Federal Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). "Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration (50 CFR 402.02). There are no interdependent or interrelated actions associated with the proposed action.

The Corps requested formal consultation on the issuance of a permit for the Willamette Water Supply System, which has four primary components:

1. **Raw Water Facilities** – Refers to the proposed modifications to the existing Willamette River intake including (1) replacement of the existing fish screens with larger capacity screens, (2) seismic stability improvements, (3) raw water pump station upgrades, (4) new electrical and hydraulic surge control facilities for the pump station, (5) stormwater management facilities, and (6) associated raw water pipelines that will convey water from the Willamette River through the upgraded raw water pump station.

   The raw water facilities (RWF) are immediately adjacent to the Willamette River near the Willamette River Water Treatment Plant (WRWTP). Two raw water pipelines will exit the raw water pump station to convey water to the existing WRWTP and the proposed WWSS Water Treatment Plant, described below. Owners of the RWF will include TVWD and the Cities of Wilsonville, Sherwood, Hillsboro, Beaverton, and Tigard, with the exception of the raw water pipeline serving the WWSS WTP, which will be owned by TVWD and the City of Hillsboro. The existing water rights associated with the RWF (Permits S-46319, S-49240, S-54940, S-45565 relocation pending) authorize the use of up to 332.7 cubic feet per second (cfs), or 179 million gallons per day (mgd), for municipal purposes. The proposed withdrawal capacity of the RWF is 150 mgd (232 cfs).

2. **WWSS Water Treatment Plant (WWSS WTP)** – Refers to the proposed water treatment plant, including a finished water pump station that will be located in Washington County near the city of Sherwood. The WWSS WTP will receive water from the raw water pipeline, perform treatment to meet or exceed drinking water standards, and then pump that water into the finished water pipeline. This facility will serve TVWD and Hillsboro with phased construction anticipated to expand the capacity to 120 mgd.

3. **Reservoir Facilities** – Refers to the two aboveground water storage tanks proposed to be constructed in the Cooper Mountain area of Washington County. The storage tanks will receive and store finished water that has been treated at the WWSS WTP. Water will exit

the storage tanks and feed the northern sections of the water pipeline. The Reservoir Facilities will serve TVWD and Hillsboro. The storage capacity will be 30 million gallons (mg) and will be distributed between two water storage tanks.

4. **Transmission Pipelines** – Refers to the transmission pipelines connecting the RWF, the WWSS WTP, the Reservoir Facilities, and the Project Participants' existing water distribution systems. The Transmission Pipelines will convey raw water from the RWF to the WWSS WTP, and finished water from the WWSS WTP to the Reservoir Facilities and the existing water distribution system tie-ins. These pipelines will serve TVWD and Hillsboro, and will also tie in to the Joint Water Commission's and City of Beaverton's transmission systems to allow for emergency access between the systems. The capacity within individual pipeline sections will vary by location, but the overall system will provide approximately 105.7 mgd of water transmission capacity.

A more detailed description of each project component was provided in the BA from the applicant, and is summarized below.

1.3.1 Raw Water Facilities

Modifications to the existing raw water facilities located on the Willamette River in the City of Wilsonville will include (1) modifications to the existing raw water intake, including replacement of the existing fish screens with larger capacity screens and replacement of screen protection piles, (2) site seismic improvements, and (3) modifications to the existing raw water pump station at the WRWTP, including construction of associated facilities.

Raw Water Intake Modifications. The existing WRWTP raw water intake will be modified to increase its capacity from 70 mgd to 150 mgd. Within the river, the existing intake includes two 66-inch-diameter tee-screens with a total permitted design capacity of 70 mgd, or 35 mgd each screen, and with openings small enough to prevent debris and aquatic organisms from being drawn into the raw water facilities. The existing screen system protects anadromous juvenile fish for withdrawals up to 70 mgd, using Oregon Department of Fish and Wildlife (ODFW) and NMFS standards (NMFS 2011) to meet fish passage requirements. As part of the modifications to increase withdrawal capacity, two new 78-inch-diameter tee-screens will be bolted on in place of the existing screens. The existing screens are protected from impacts by ten H-piles, up to ten of these H-piles would need to be modified to accommodate the new, larger screens. The proposed screens will be designed to meet ODFW and NMFS fish screen criteria.

Replacement of the screens and modification of the screen protection H-piles will be accomplished by the contractor working from a barge. Divers will remove and replace the screens using an onboard crane, so there will be no disturbance to the riverbank. Two construction methods are under consideration to modify up to ten of the screen protection H-piles to accommodate the larger screens: (1) Divers will cut the existing H-piles and attach brackets to extend the area protected by the piles. (2) The existing H-pile will be extracted with a vibratory hammer or cut 2 feet below riverbed if the pile cannot be completely removed. The new pile will be installed with a vibratory hammer and then set with an impact hammer. The pile may be concrete or steel pipe 24 inches in diameter or smaller, steel H-pile designated HP24 or smaller, or wood that has not been treated with preservatives or pesticides. Sound attenuation methods will be used when using an impact hammer. Though the number piles driven below OHW will be determined during final design, the TVWD provided a conservative estimate of 10, assuming 600 impact strikes per pile, for a total of 6000 strikes. All construction activities in the Willamette River mainstem will be conducted in the June 1 to October 31 work window.

The existing screens are cleaned with an airburst system, which releases pressurized air into the screen interior. Two compressors in the raw water pump station deliver air to the screens via two 12-inch air pipelines. Components of the airburst cleaning system (e.g., air tanks and compressors) are housed within the existing raw water pump station and existing pipelines. The airburst cleaning system function would remain unchanged after the intake modifications. Due to the increased capacity of the screens, the intake airburst system capacity will need to be increased, likely with the addition of an air receiver tank that will be located near the existing air receiver tank. Operation staff determines the frequency of screen-cleaning according to intake flow, debris in the river, and the season of the year. Screens are typically cleaned weekly to clear accumulated debris.

Site Seismic Improvements. The riverbank adjacent to the existing WRWTP intake has the potential for related slope failure, and for the slide mass to bury and damage the intake. Site seismic improvements will be constructed as part of the project to address seismic and structural vulnerabilities at the WRWTP intake and raw water pump station. A subsurface wall of piles will be constructed on the Willamette River riverbank to protect the existing intake from damage that would result during a seismic event. A second subsurface wall of piles will be constructed near the top of the slope to protect the raw water pump station, the structures associated with the pump station, and the WWSS pipeline exiting the pump station from damage due to slope failure during a seismic event. Construction of the seismic improvements would last approximately 12 months.

Access to the construction area for seismic improvements will be via existing unpaved access roads that will be improved by laying down temporary crushed rock and geotextile. The construction area will accommodate access roads and work platforms for a drill rig and crane used to install the piles. The access roads will be approximately 20 feet wide for the wall of piles on the Willamette River riverbank and 40 feet wide for the wall of the piles near the top of the slope, and will require localized leveling of the slope. The total construction area for seismic improvements would affect approximately 0.5 acre of forested riparian area. Of this area, approximately 400 square feet are below OHW elevation. Construction below OHW elevation will occur during the Willamette River in-water work window.

Approximately sixteen 4-foot-diameter tangent piles will be built into the bank above the intake screens to stabilize the potential failure zone. The piles will be constructed near the toe of the riverbank and will extend approximately 50 feet deep. Of the 16 piles, 1 pile is anticipated to be located below OHW elevation. The pile wall will be buried approximately 1 foot below grade, and the ground level will be restored to preconstruction elevations.

The tangent pile wall will be constructed using a track-mounted drill rig that would be placed parallel to the wall construction. An auger will be used to drill shafts, and then a steel casing will be installed to protect the soil from caving into the shaft. Concrete will be pumped in to backfill the shaft, creating the piles. After construction, the slope will be regraded and the hillside revegetated with appropriate riparian species and in accordance with local jurisdictional requirements. No vibratory or impact hammers will be used to install the tangent pile.

The raw water pump station and the locations for proposed associated structures are also at risk of damage from potential slope failure. Approximately thirty-seven 10-foot-diameter piles, each extending approximately 120 feet deep, will be constructed near the top of the slope. The piles will be located no closer than 15 feet from the intake pipe. Within 15 feet of the intake pipe, a jet grout block approximately 36 feet by 50 feet by 35 feet will be installed underground to connect two segments of the pile wall while protecting the intake pipe. Together, the drilled shafts and jet grout block will extend approximately 450 feet along the top of the slope in two segments. This 10-foot-diameter pile wall will be constructed similar to the method described above for the 4-foot-diameter pile wall. The jet grout block will also be constructed using a track-mounted drill rig placed parallel to the wall construction. Jet grouting consists of injecting liquid concrete into the soil to create a soil/concrete mixture below the ground surface. During this process, a borehole is drilled to the desired depth, and then concrete (sometimes mixed with water and air) is pumped into the borehole. As the injection equipment rotates and is withdrawn from the borehole, a column of loosened soil mixed with concrete is created.

Raw Water Pump Station. The pump station facilities will include the existing WRWTP raw water pump station building, new electrical and hydraulic surge control facilities, new pumps, a new raw water pipeline, stormwater management facilities, and new and modified access roads. To accommodate the installation of new pumps, the south and west walls and roof of the existing pump station building will be modified, and structural beams will be installed across the floor.

New electrical buildings will be installed, including one adjacent to the pump station building and one on the adjacent parcel to the north. Surge relief tanks will be installed on a pad near the pump station building. Pads will be constructed to accommodate backup generators and fuel on the northern parcel, adjacent to new access roads and a parking area. A raw water pipeline will convey water across the WRWTP property, from the pump station building to SW Industrial Way and then on to the WWSS WTP. A power duct bank will be constructed to connect facilities on the WRWTP property to facilities on the northern parcel, and will be installed within the raw water pipeline alignment.

The stormwater management facilities will follow the NMFS Standard Local Operating Procedures for Endangered Species (SLOPES V) stormwater design criteria. SLOPES V requires using continuous simulation modeling for detention (quantity) facility sizing. For the RWF site, water quality treatment, detention, and design discharge rates and volumes are modeled using the single-event-based Santa Barbara Urban Hydrograph (SBUH) Method. A bioretention pond is proposed to treat the 0.7 acre of new impervious surface (i.e., roofs and parking areas) located on the northern parcel. The pond will discharge to Arrowhead Creek. On the southern parcel, a bioretention pond is proposed to treat the 0.7 acre of new impervious area (i.e., roofs, access roads, and tanks). The pond will use the existing stormwater conveyance system that discharges to the unnamed tributary just north of the Willamette River.

Foundations of the new electrical buildings,, pads for the surge relief tanks, generators, and fuel tanks,, and the raw water pipeline and power duct bank will be pile-supported (as needed) to mitigate liquefaction and settlement risks during a seismic event. Fuel containment measures will be provided in accordance with applicable regulations. The new facilities will be constructed using typical construction methods for buildings, such as grading and erecting building sides. Expected construction equipment will include excavators, haul trucks, soil compactors, pavers, concrete trucks, dewatering pumps, cranes and/or lifts, and light and heavy duty general construction trucks. Construction of the raw water pump station facilities is expected to occur in stages and take up to five years.

The area of construction activities for the raw water pump station will be approximately 7 acres, including 0.5 acre of forested riparian area for the seismic improvements. The northern parcel will be utilized for a construction staging area.

The operations of the modified RWF might require additional power supplies. The need, location, and configuration of any new electrical transmission or distribution facilities would be determined by the power supplier rather than the Project Participants and is, therefore, not considered part of the Project and would be permitted separately by the responsible parties. Expansion of the existing WRWTP is a separate, reasonably foreseeable action. This existing water treatment plant currently serves the Cities of Wilsonville and Sherwood. The current capacity is 15 mgd, however, space is available for expansion to a capacity of approximately 60 mgd. The Cities of Wilsonville and Sherwood anticipate participating in a phased expansion of the WRWTP. The City of Tigard is reviewing its options to participate in a future expansion of the WRWTP. These future activities are not part of the Project and would be permitted independently by the responsible entities.

1.3.2 Willamette Water Supply System Water Treatment Plant

The proposed WWSS WTP will be near the City of Sherwood. The initial capacity of the new WWSS WTP will be 60 mgd, with planned expansions to an ultimate capacity of 120 mgd. The WWSS WTP will be expanded in multiple stages, but all construction and new facilities are anticipated to fall within the original footprint. Based on preliminary design, the WWSS WTP includes an administration building, maintenance and storage areas, a chemical building, filters and supporting facilities, UV disinfection, clearwells, a pump station, surge tanks, a dual-purpose stormwater and overflow detention basin, solids-handling facilities, paved access roads and parking areas, and electrical buildings with supporting equipment and backup power generation. Chemical delivery and storage facilities will include overflow and spill containment features.

The stormwater design will meet NMFS SLOPES V criteria. The WWSS WTP site will include approximately 10 acres of new impervious surface for buildings and parking areas. A bioretention pond is proposed to treat and detain the stormwater runoff from the site. The pond will discharge to a future SW 124th Avenue roadside ditch (currently under construction), which discharges to Hedges Creek, a tributary of the Tualatin River.

The WWSS WTP will be constructed using typical construction methods for buildings, such as grading, laying spread footing foundations, and erecting building sides. Construction equipment is expected to include excavators, loaders, water trucks, bulldozers, haul trucks, soil compactors, pavers, concrete trucks, dewatering pumps, cranes and/or lifts, and light and heavy duty general construction trucks. If blasting or other specialized equipment is required to excavate rock, all of the operations, including transportation, storage, and handling of explosives and blasting materials, will comply with county, state, and federal regulations.

Construction of the WWSS WTP is expected to take approximately three years, and will affect approximately 20 acres. Of this area, impervious surfaces will account for approximately 10 acres, and the remaining approximately 10 acres will be landscaped.

1.3.3 Reservoir Facilities

The reservoir facilities, which will consist of two aboveground water storage tanks, are proposed to be constructed in the Cooper Mountain area. They will receive and store finished water that was treated at the WWSS WTP and conveyed in the southerly section of the water transmission pipeline. Water will exit the reservoir and feed the northern sections of the water pipeline.

The storage capacity at the reservoir facilities will be 30 mg distributed between two 300-foot-diameter water storage tanks, each of which will have 15 mg of storage capacity. Access to the reservoir facilities site will be via a new gravel maintenance road. Construction of the facility is expected to take approximately two and one-half years.

A newly constructed 1.04 mg detention basin will detain and treat stormwater runoff from the site after construction of the water storage tanks, as well as contain water from rare occurrences where the tanks might overflow. The tank overflows and drain piping will discharge directly to the detention basin facility. Discharge from the stormwater detention basin will be to the existing drainage along SW Grabhorn Road.

Construction of the tanks will permanently disturb approximately 4.3 acres. Of this, 3.6 acres will become impervious surface due to the surfaces of the water storage tanks, gravel access road, and parking area, and approximately 0.7 acre will be used as a stormwater detention pond. An additional 2.4 acre of temporary disturbance will be landscaped with native vegetation following construction.

The temporary construction staging area for work on the reservoir facilities is anticipated to require approximately 7 acres, of which up to 0.3 acre is located within the reservoir facilities' site, and the remainder is on the property to the west, across SW Grabhorn Road. A wetland and an intermittent drainage system located in the northwest corner of the property would be avoided. Both staging areas would be graded to establish final contours and revegetated with native plantings upon completion of the work.

1.3.4 Transmission Pipelines

The WWSS will include approximately 30 miles of transmission pipelines to convey raw water from the RWF located at the WRWTP north to the WWSS WTP and finished water from the WWSS WTP to the reservoir facilities, and then to existing TVWD and Hillsboro distribution systems. The WWSS includes 12 turnouts for connecting the transmission pipelines to existing water distribution systems. Turnouts consist of a short length of pipe and a below-grade meter vault and, in some cases, a below-grade pressure-regulating or flow-control station.

Any modifications to existing water distribution systems beyond the meter vault would be permitted and constructed separately, and are not considered part of the WWSS. The turnouts are not located in any resource crossings and will not be discussed further in this document. Pipeline construction will largely utilize open-trench construction methods. At resource crossings, construction will include open-trench as well as trenchless methods, as described in this section. The following sections describe general construction methods for open-trench and trenchless crossings of resources, and provide site-specific details for selected representative perennial stream crossings, as shown in Table 1. Resource crossings include both wetland, riparian area, and stream channel crossings.

Table 1. Selected Resource Crossings.

Resource Crossing[1]	Crossing Method	Pipe Diameter[2] (inches)	Approximate Resource Crossing Length[3] (feet)
Arrowhead Creek at Arrowhead Creek Lane	Jack and Bore	66	30 feet (210 feet between shafts)
Tualatin River at SW Roy Rogers Road*	Microtunnel	66	400 feet (2,300 feet between shafts)
Chicken Creek at SW Roy Rogers Road*	Open Trench	66	200 feet
McKernan Creek at SW Grabhorn Road	Open Trench	66	62 feet
Butternut Creek in South Hillsboro*	Microtunnel	66	200 feet (900 feet between shafts)
Beaverton Creek at NW Cornelius Pass Road*	Open Trench	48	200 feet
Rock Creek at NW Cornelius Pass Road	Open Trench	48	50 feet
Beaverton Creek at SW Millikan Way*	Microtunnel	54	200 feet (600 feet between shafts)

Notes:
[1] In this column, an asterisk (*) indicates that listed fish are present at this crossing.
[2] Does not include casings, where applicable.
[3] Includes stream channel (OHW elevation) and adjacent wetlands, where applicable.

Open-Trench Construction.

Open-trench construction is the standard installation method for large-diameter pipelines. This section describes general construction methods for open-trench crossings using welded steel pipe. Open-trench construction is a multi-step process that generally includes the following:

1. Identify and isolate sensitive areas before construction begins. Install erosion and sediment control measures around and on the site.
2. Clear and level the work area so construction equipment can operate safely.
3. Excavate the pipeline trench to a depth below the bottom of the pipe and bedding material. The length of excavated trench is typically kept to a maximum of two to three times the length of one pipe but may be longer depending on construction sequencing requirements. Excavation is generally through mechanical means with excavators and other large construction equipment, although drilling and controlled blasting can be required in areas with competent bedrock (basalt). If blasting or other specialized equipment is required to excavate rock, then the operations, including transportation, storage, and handling of explosives and blasting materials, must comply with county, state, and federal regulations. All trenches greater than 5 feet deep require shoring, shielding or sloping to protect workers who enter the trench. Shoring and shielding are typically installed as soon as the trench is excavated to its final depth. The trench sides may be sloped or shielding may be installed as the trench is excavated to prevent the sides from sliding into the excavation.
4. Place pipeline bedding material into the bottom of the trench and compact the bedding, creating a solid base for workers and equipment as well as creating a foundation for the pipe to rest upon.
5. Bring one length of pipe onto the site and place them into the trench. Typical pipe lengths are 20 to 50 feet, however, the length of these pipes may be customized in some areas to allow greater flexibility during construction. Once a pipe length is placed at the correct elevation and at the correct slope, the next pipe length is lined up, the pipes are prepared to be joined (spigot is inserted into bell for a bell/spigot joint, or another pipe joint method might be used, although all of the methods require welding), and the pipe’s elevation and slope are checked.
6. Join the two pipe lengths together by welding the pipes at the bell/spigot joint (or similar joint type), once on the interior of the pipe and once on the exterior for typical double lap-welded joints. The soundness of the welds is tested for leaks using pressurized air in the space between the two welds and using other non-destructive testing methods including magnetic particle, dye penetrant, and radiographic testing.
7. Pipes are delivered to the site with coatings and linings already applied, generally, a polyurethane coating on the outside and a cement mortar lining on the inside of the pipe. Pipe ends are left as bare steel for future welding of joints. After weld testing is completed, the joint lining and coating systems on the interior and exterior, respectively, are installed to provide a continuous protection system for the steel pipeline.
8. Backfill the trench in lifts to specified compaction requirements to the surface, removing shielding or shoring as the backfill material is installed. Generally, the

backfill is a granular material, however, controlled low-strength material (low-strength concrete) is also acceptable.

9. Regrade and revegetate the work area or pave in roadway areas.

Transmission Pipeline Open-Trench General Construction Methods at Resource Crossings.

This section describes general methods for open-trench construction at resource crossings, including work areas and staging areas, trench sizing and protection, dewatering, work area isolation, backfill, blowoff valve construction, and site restoration and revegetation. Open-trench construction below OHW (also referred to as the regulated work area) will be completed within the ODFW in-water work window for the affected Willamette River tributary or Tualatin River tributary. Although blasting is identified as a potential method for open-trench construction, blasting will not occur at any stream crossing where listed fish are known to occur or in designated critical habitat. Geotechnical investigations have not been completed for many of the crossings, therefore, if blasting is identified as a potential construction method at any resource crossing in this package where listed fish or designated critical habitat occur, formal consultation with NMFS will be re-initiated.

1. Work Areas and Staging Areas.

Work areas for pipelines and appurtenances (e.g., blowoff valves) will be contained within public rights-of-way where feasible, and temporary and permanent easements will be obtained from public and private entities, as needed. Where the pipeline crosses BPA or railroad right-of-way, a land use agreement or similar authorization will be obtained.

Permanent easements along the pipeline will typically be not less than 50 feet wide, with additional temporary (construction) easements as needed to enable construction. The total work area widths would vary depending upon site-specific conditions, such as topography and the need to avoid existing facilities or conform to property boundaries. Additional considerations at crossings, such as soil conditions and access limitation, will further shape the necessary work area widths. The total work area is intended to provide space for equipment operation and staging areas during construction. The total work area width will not exceed 75 feet at the stream crossings where ESA-listed fish are present. If additional staging area is necessary during construction, the contractor would be responsible for identifying, securing, maintaining, and restoring those locations according to the project’s specifications.

2. Trench Sizing and Protection.

Required trench width is a function of pipeline diameter, geotechnical properties of the surrounding soils, backfill material, trench protection methods, contractor construction methods, and inspection requirements, but will typically be 8 feet to 12 feet wide. Beneath an active stream channel, the depth of earth cover over the pipe would typically be a minimum of twice the pipe diameter. Beyond the active channel, minimum cover would vary according to local conditions, but would typically not be less than 4 feet deep.

Trench protection methods are determined by soil conditions and trench depth, and are designed to prevent cave-ins. Trench protection methods at resource crossings would include one or more of the following: trench boxes, soldier piles and lagging, sheet piles, or other engineered retaining structures. Soldier piles and lagging utilize vertical steel piles, typically H-piles, with horizontal lagging (usually wood, steel, or precast concrete panels) set between the piles to retain soil walls, followed by excavation of the soil contained within the piles and lagging. Sheet piling consists of steel sheet sections with interlocking edges that are hammered or pressed into place, followed by excavation of the soil contained within the sheet piles. Trench protection components would be removed as the trench is backfilled.

3. Dewatering.

High groundwater is frequently encountered in open-trench construction through resource crossings, and its management is essential in order to provide safe construction conditions and quality pipeline installation. In areas of known, persistent high groundwater, pre-drainage methods can involve using wells or well points (pre-drilled temporary wells) to lower local groundwater elevations before the trench is excavated. Wells or well point systems are designed to meet construction safety needs as well as to protect adjacent natural resources. Where listed species are present, changes in stream flow within active channels will be monitored, and corrective action taken if needed to maintain streamflows. The dewatering means and methods will be determined by the contractor, and could include the use of sheet piles between well points and the active channel to limit the effects of dewatering on streamflows.

A common method for controlling groundwater intrusion into the open pipeline trench is to use pumps at the bottom of the excavation area (in a sump) to draw down groundwater below the open trench bottom. Typically, the water is pumped out by sump pumps able to pump soil or other debris in the groundwater. Sump pump systems have limited capacity and are not capable of significantly changing the water table to the extent that wetlands or streams would be affected. Groundwater collected from well points and sump pump systems generally is pumped into a temporary retention pond or tank for treatment before being discharged to upland areas or routed to appropriate storm drains, upon meeting discharge requirements. Discharge of groundwater is coordinated with local agencies through erosion and sediment control permitting. After treatment, if required, water can be discharged to a stream, river, wetland, open area, or storm drain system.

4. Work Area Isolation.

Isolating work areas during open-trench construction within an active channel generally involves shifting flows from one side of a stream to the other as construction progresses to protect the work area and surrounding environments. Several methods can be used to reroute or temporarily isolate streams and fish from the work area, including pipes, cofferdams, diversion ditches, silt curtains, sheet piles, sand bags, inflatable dams, or similar methods. To minimize disturbance to downstream fish populations and habitats, the discharge point from the temporary diversion is located immediately downstream of the worksite.

Fish passage requirements for all open-trench waterway crossings will be determined through the ODFW Fish Passage Permit application process. Provisions for downstream fish movement will be required during in-water construction unless one of the following conditions occurs and the method is approved by ODFW: (1) The ability to completely block fish movement will be limited in duration to no more than ten days and will only be allowed when water quality conditions preclude the likelihood that salmonids will use the area, and (2) upstream fish movement will be required in locations where blocking upstream movement, even for short durations, will unduly stress salmonids using the area.

5. Trench Backfill.

Backfill materials for the pipe bedding and pipe zone will be composed of granular material (aggregate) or controlled low-strength material (low-strength concrete). Native soils from on-site excavation materials are typically not considered suitable for bedding and pipe zone materials, though may be used, where deemed appropriate during final design, for backfill above the pipe zone in areas not sensitive to settlement.

Aggregate backfill is typically more porous than native soils, and in places where aggregate is used for backfill, the pipe zone could act as a conduit for groundwater flow. To limit groundwater flow through the pipe zone, low-permeability concrete trench cutoff walls (constructed from low-strength concrete) will be installed in trenches that are backfilled with aggregate. Trench cut-off walls are installed at specific intervals and locations to prevent subsurface water from wetlands and waterways from being channeled through the pipeline trench.

6. Blowoff Valve Construction and Operation.

Blowoff valves provide an outlet to drain a transmission pipeline during testing, commissioning, and maintenance activities. Blowoff valves will not occur below OHW, however, they could be located on streambanks or in adjacent wetlands.

Blowoffs are constructed with one or more isolation valves and a vertical casing pipe that extends to the ground surface. During blowoff events, the construction or maintenance crew connects discharge piping to the vertical casing when water is under pressure. After the transmission line is depressurized, a sump pump can be lowered into the vertical casing to pump out the remaining water. Blowoffs located within urban areas direct outflow toward street storm drains whenever possible. Discharge rates will be coordinated with the jurisdictional utility agency to avoid overloading the downstream system.

If a storm or sanitary sewer system is unavailable for discharge, and it is necessary to discharge to upland areas, wetlands, or surface waters, the water will be dechlorinated and treated (settled or filtered), as needed, to meet water quality and discharge regulations. Residual chlorine that might remain in the water will be removed if necessary by adding ascorbic acid (vitamin C) or sodium bisulfate to the water. Discharge rates at each drain location will be controlled by throttling valves installed on the drain locations. Blowoff valves that discharge directly to a drainage will be designed to prevent soil erosion or channel erosion. Blowoff discharge rates will not exceed the bankfull discharge rate for the receiving channel, in order to prevent soil or channel erosion. Bankfull discharge will be estimated using local stream gage data, previous drainage studies, or published regional regression equations.

7. Restoration and Revegetation

A conceptual post-construction site restoration plan has been developed for proposed pipeline crossings of resources (i.e., wetlands, creeks, and riparian areas) associated with the Project. The aquatic habitat, including stream channel and streambanks, will be restored to conditions that are equivalent to or better than preconstruction conditions. The floodplains and streambanks impacted during construction will be reshaped to match upstream and downstream conditions. Design criteria will follow stream restoration guidelines and focus on bio-engineered stabilization techniques such as woody plantings and live stakes, brush layering or brush mattresses, quickly establishing herbaceous cover, erosion control fabric, and coir lift. The Washington Department of Fish and Wildlife Integrated Streambank Protection Guidelines (Cramer, 2003) and Stream Habitat Restoration Guidelines (Cramer, 2012) and Natural Resources Conservation Service (NRCS) Stream Corridor Restoration Guidelines (FISRWG, 1998) are examples that will be considered during design.

Site-Specific Construction Methods for Selected Open-Trench Crossings.

This section describes site-specific information for open-trench pipeline crossings of resources at the following perennial stream crossings:

1. Chicken Creek at SW Roy Rogers Road (PLM_4.0)
2. McKernan Creek at SW Grabhorn Road (PLM_5.0)
3. Beaverton Creek at NW Cornelius Pass Road (PLW_2.0)
4. Rock Creek at NW Cornelius Pass Road (PLW_2.0)

Detailed plan sheets and cross sections for these crossings are on file at the Oregon Washington Coastal Area Office in Portland.

1. Chicken Creek at SW Roy Rogers Road.

The Chicken Creek at SW Roy Rogers Road crossing alignment parallels the Chicken Creek bridge and will be offset approximately 45 feet from the edge of the existing bridge deck to allow for future widening of the bridge by Washington County. The natural resources at Chicken Creek include forested and emergent wetlands on the floodplain bench, and forested and pasture/farmed riparian areas. Because of the presence of wetlands on both the north and south sides of Chicken Creek, the length of the resource crossing will be approximately 200 feet, 30 feet of which will be crossing the actual creek. The pipe diameter at this crossing will be 66 inches.

The overall open-trench construction is anticipated to take two to three months, with construction in the stream channel completed during the in-water work window for Tualatin River tributaries of July 15 to September 30. The total area of temporary disturbance due to construction and staging will be 0.7 acre, and the overall construction footprint at the stream crossing will require a 75-foot-wide corridor for pipeline installation. Temporary cuts from the top of the north slope and regrading on the toe will be required in order to create a staging area work bench at the north side of Chicken Creek. Because of the steep terrain, providing equipment access from the south is unlikely, therefore, a temporary construction access across Chicken Creek will be needed.

Installation of the pipeline across Chicken Creek will require excavation of the channel for the 30-foot in-channel crossing, which will be restored to mimic preconstruction contours after installation. The trench will be approximately 12 feet wide, and the pipe will be placed a minimum of 11 feet (two pipe diameters) below the Chicken Creek active stream channel or deep enough to avoid active scour. The in-water work area will be isolated using sheet pile cofferdams or by constructing an isolation barrier using a combination of concrete barrier, sandbags, and plastic sheeting. Once this isolation measure is installed, fish will be removed from the isolated work area before excavation of the trench and installation of the pipe, and released outside the work area. A turbidity curtain (or other erosion control method) will be installed outside the cofferdam to capture potential sediment originating from the work area.

At this crossing, geotechnical investigation determined that measures for slope stability will be needed for seismic resiliency. A tangent pile wall will be installed on the south side to provide this required slope stability. On the north side, either a jet-grouted ground improvement or a tangent pile wall will be used to provide seismic resiliency. The jet-grouted ground improvement would be provided for an area of approximately 25 feet by 50 feet and would extend below the pipe. To prevent a preferential pathway for groundwater flow along the pipeline trench on both sides of the crossing, trench cutoffs will be installed, generally constructed from controlled low-strength material (such as low-strength concrete) and are approximately 3 feet thick, and are constructed at a minimum of 2 feet below the trench bottom to 3 feet above the pipeline.

A blowoff will be required at a low point of the Chicken Creek crossing. The blowoff would likely be placed on the north side of the creek in order to provide for maintenance access, and would be outside of the wetland area.

2. McKernan Creek at SW Grabhorn Road.

A portion of the pipeline will be installed across McKernan Creek and adjacent wetlands at SW Grabhorn Road, and will be approximately perpendicular to the stream channel. The length of the resource crossing will be approximately 62 feet, with a pipe diameter of 66 inches. Beneath the active stream channel, the depth of earth cover over the pipe will be a minimum of twice the pipe diameter, or deep enough to avoid active scour.

The construction footprint for this crossing will temporarily impact the stream channel and adjacent wetlands. The overall open-trench construction will take up to one month, with construction in the stream channel completed during the in-water work window of July 15 to September 30.

In-water work will be isolated from flowing water using sheet pile cofferdams or a combination of concrete barrier, sandbags, and plastic sheeting or temporary culverts. A turbidity curtain (or other erosion control method) will be installed outside the cofferdam to capture potential sediment originating from the cofferdam.

Trench dewatering will be accomplished using a sump pump, pre-drainage (pre-drilled temporary wells) or well points, as determined during final design and construction bidding, in accordance with BMPs described in Section 1.3.5. Following construction, the trench will be backfilled around the pipeline, and the soils recompacted. A blowoff will be required at a low point near the McKernan Creek crossing. The blowoff would likely be placed north of the creek to provide for maintenance access and would be located outside of the wetland. The aquatic habitat, including stream channel and streambanks, will be restored to conditions that are equivalent to or better than preconstruction conditions. The construction area would be regraded to mimic preconstruction contours and revegetated.

3. Beaverton Creek at NW Cornelius Pass Road.

The crossing at Beaverton Creek at NW Cornelius Pass Road will be approximately 200 feet with a pipe diameter at this crossing of 48 inches. Beneath the active stream channel, the depth of earth cover over the pipe will be a minimum of twice the pipe diameter, or deep enough to avoid active scour.

Open-trench construction would likely take up to three months, with construction in the stream channel completed during the in-water work window of July 15 to September 30. To protect a nearby apartment building during pipeline installation, storm drain structures will need to be removed and relocated, and a secant wall shoring would need to be installed near the southwest abutment of the Beaverton Creek bridge. Also, the construction of a blowoff will be necessary at the low point near Beaverton Creek within the floodplain.

The aquatic habitat, including the stream channel and streambanks, will be restored to conditions that are equivalent to or better than preconstruction conditions. The construction area would be regraded to mimic preconstruction contours and revegetated.

4. Rock Creek at NW Cornelius Pass Road.

The crossing at Rock Creek at NW Cornelius Pass Road will be approximately 50 feet with a pipe diameter of 48 inches. Beneath the active stream channel, the depth of earth cover over the pipe will be a minimum of twice the pipe diameter, or deep enough to avoid active scour, as indicated by a subsequent site-specific analysis.

The overall open-trench construction will take up to one month, with construction in the stream channel completed during the in-water work window of July 15 to September 30.

It will be necessary to relocate a short section of 8-inch-diameter sewer pipe before installing the proposed 48-inch-diameter pipeline. The pipeline was purposefully aligned near the creek to allow for sufficient clearance to cross above an existing 48-inch-diameter Clean Water Services (CWS) sewer interceptor and to avoid existing trees in a riparian area around the creek.

The aquatic habitat, including stream channel and streambanks, will be restored to conditions that are equivalent to or better than preconstruction conditions. The construction area would be regraded to mimic preconstruction contours and revegetated.

Trenchless Crossings.

This section describes general construction methods for trenchless crossings, including discussions of work areas and staging areas, shaft construction and protection, dewatering, shaft backfill, and restoration and revegetation, and also provides more detailed descriptions for selected crossings.

Trenchless crossing methods will be used at several locations along the pipeline to avoid and minimize impacts. Several factors are used to determine the most appropriate type of trenchless crossing method, such as the type of feature being crossed (e.g., natural resource, railroad, highway), subsurface geotechnical conditions, the pipe diameter, and the length of a given crossing.

Shallow crossings for the Project generally include crossings beneath some wetlands and streams, as well as railroads, major roadways, and major utilities along the pipeline alignment. Shallow crossings are generally anticipated to be less than 25 to 30 feet deep to the top of the pipe (but not less than twice the diameter of the pipeline at resource crossings), and they allow simpler shoring and dewatering designs than deep crossings. Trenchless methods appropriate for shallow resource crossings primarily include jack and bore (also called auger boring) and pipe ramming. Where groundwater conditions are appropriate, a shielded tunnel boring machine can be used. Deeper crossings typically require microtunneling or horizontal directional drilling (HDD). At this time, HDD is not anticipated for use in constructing the Project, however, specific methods of construction will be determined during final design and construction bidding. These trenchless methods are briefly defined as follows:

- **Jack and Bore –** Jack and bore is a trenchless pipe installation method in which sections of a steel pipe casing are pushed into the soil from an entry shaft, while a rotating auger inside of the casing conveys the spoils back to the entry shaft. The pipe is then placed inside the casing, and the casing is sealed.

- **Pipe Ramming –** Pipe ramming is a trenchless pipe installation method that utilizes a hammering technique. A pneumatic hammer or a hydraulic hammer delivers successive blows to a casing pipe that is fitted with a cutting shoe that shears the soil with each blow. A soil plug is formed in the pipe as the casing is hammered, the soil plug offsets the pressures from soil overburden and groundwater, and helps to prevent settlement at the face of the excavation. Auger flights are used to remove soil from inside the pipe as soil accumulates. The pipe is then placed inside the casing and the casing is sealed.

- **Shielded Tunneling –** Shielded tunneling is a trenchless pipe installation method that utilizes a shielded, open-faced tunnel boring machine. Excavated materials are removed from the front of the tunnel boring machine by mechanical means and carted back to the entry shaft. A tunnel boring machine can be used in shallow tunnels where there is no concern about groundwater levels and where there may be cobbles that need to be removed from the face of the machine.

- **Microtunneling –** Microtunneling is a trenchless pipe installation method that utilizes a closed face, slurry-type microtunnel boring machine (MTBM). The MTBM utilizes a slurry to apply a positive, stabilizing pressure at the tunnel face, in order to balance the surrounding soil and groundwater pressures. A slurry is also typically pumped (under low pressure) into the annular space outside of the casing to reduce friction loads and help keep required jacking forces down. Excavated materials are removed from behind the MTBM and transported back to the entry shaft in a slurry suspension through a closed network of pipes. A minimum vertical cover beneath resource crossings would be two pipeline diameters, in part to reduce the risk of slurry escaping to the surface during microtunneling (i.e., inadvertent returns). The possibility of inadvertent returns (drilling fluid released at the ground surface) occurring is in part related to the contractor's operating pressure at the MTBM while excavating. For microtunneling, the contractor would submit its anticipated slurry operating pressures for review, according to technical specifications, before construction began. The risk of inadvertent returns is lower for microtunneling, because the required slurry pressure is much less than that required for HDD.

- **Horizontal Directional Drilling–** HDD is a trenchless pipe installation method that utilizes a horizontal drill rig with a steerable drill head that is launched from a shallow pit near the ground surface. This drilling method does not need entrance or exit shafts. A borehole is first created at the entry site by implementing a pilot bore along the intended pipeline alignment. The borehole is created with a drill rig and high-pressure drilling fluid (typically a bentonite suspension). The drilling fluid is pumped through a pilot bore as the borehole is created in order to transport spoils back to the drill pit. As described for microtunneling, the contractor would submit its anticipated operating pressures for review before construction, in order to reduce the risk of inadvertent returns. Once the pilot bore has been established, reamers are typically pulled through the existing bore to increase the diameter of the borehole. The drilling fluid is separated from the spoils as it exits the borehole in this process and is recycled to circulate in the bore to aid further reaming, as required to reach the desired bore diameter. The diameter is typically increased in small increments in order to maintain borehole stability. Once the borehole is completed, the pipe is welded together along the surface and pulled into its designed location.

1. Work Areas and Staging Areas.

Work areas for shaft construction or HDD pipe-joining activities will be contained within public rights-of-way where feasible, and temporary and permanent easements will be obtained from public and private entities. Permanent easements will typically be not less than 50 feet wide,

centered above the pipeline, but they would vary depending upon site-specific conditions, such as avoiding existing facilities or conforming to property boundaries. Temporary easements will be used in addition to the permanent easements or public rights-of-way at the shaft locations to provide space for equipment operation and staging areas during construction. Generally, a minimum work area of approximately 60 feet by 150 feet is required at an entry shaft, whereas the space requirements for the exit shaft work area are smaller—a minimum of 50 feet by 80 feet. The entry and exit shaft work areas are located outside the stream channels. The minimum work area dimensions would be larger if the site has steep contours or other restrictions. If additional staging area is needed during construction, the contractor would be responsible for identifying, securing, maintaining, and restoring those locations according to the project specifications. Additional staging areas will not be located within resource areas.
Stream/river morphology significantly impacts the layout of deep crossings. The alignments of deep trenchless crossings will extend beyond the limits of stream floodplains, with shafts set back from the floodplain side slopes in order to minimize slope instability and seismic risks. During shaft construction or HDD pipe-joining activities, the work area will be graded to establish appropriate contours for construction, and to provide for the safe and efficient movement and operation of machinery.

2. Shaft Construction and Protection

Jack and bore, pipe ramming, shielded tunneling, and microtunneling methods involve excavating underground from an entry shaft to a receiving shaft to avoid disturbing surface features between the two shafts (as noted above, HDD does not require shafts).
Entry shafts are typically 20 feet by 40 feet, and exit shafts are typically 12 feet by 15 feet for a 66-inch-diameter pipe. Additional area is necessary for staging in order to provide sufficient room to accommodate excavation and tunneling equipment.

The appropriate shaft construction methods for each crossing will be determined during final design and construction bidding, but may include any of the following:

- **Secant Piles –** Secant pile shafts involve the construction of auger-drilled, poured-in-place concrete piles, followed by excavation of the soil encircled by the pile-formed wall.

- **Cutter Soil Mix –** The cutter soil mix method mixes grout and soil to form interlocked structural soil cement panels in place, followed by excavation of the soil contained by the panels.

- **Caisson –** An open caisson (cylinder) is sunk in place by excavating the soil within the caisson, with the top and bottom open during construction. Caissons may be constructed of reinforced concrete or steel.

- **Interlocking Sheet Piles –** Sheet piling consists of steel sheet sections with interlocking edges that are driven into place, followed by excavation of the soil contained within the sheet piles. Horizontal walers are installed to brace the sheet piles.

- **Soldier Piles and Lagging –** Soldier piles and lagging utilize vertical steel piles, typically H-piles, with horizontal lagging (usually wood, steel, or precast concrete panels) set between the piles to retain soil walls, followed by excavation of the soil contained within the piles and lagging. Horizontal walers or tie-backs are installed to brace the soldier piles.

For each of these shaft construction methods, once the shaft has reached the desired depth, a concrete slab is placed at the bottom as a seal. Ongoing dewatering may be necessary within the work area and/or the shafts themselves, as described in the following section. In addition, jet grouting at the entrance and exit points may be used to help control groundwater for deep shafts.

3. Dewatering.

In trenchless construction using shafts, high groundwater must be managed so that safe construction conditions and quality pipeline installation can be provided. Pre-drainage methods might involve using dewatering wells to lower local groundwater elevations before excavating shafts for trenchless construction. Dewatering wells are designed to meet construction requirements as well as protect adjacent natural resources. Alternatively, shafts may be designed to be watertight and not require substantial dewatering.

A common method to control groundwater intrusion into the shaft itself is to use pumps at the bottom of the shaft (in a sump) to remove groundwater that may leak into the shaft. Typically, the water would be pumped out by solids-handling sump pumps. Sump pump systems have limited capacity and are not capable of significantly changing the water table to the extent that wetlands or streams would be affected.

Groundwater collected from wells or well points and sump pump systems generally is pumped into a temporary retention pond or tank for treatment before being discharged to upland areas or routed to appropriate storm drains, upon meeting discharge requirements. Discharge of groundwater is coordinated with local agencies through erosion and sediment control permitting. After treatment, if required, water may be discharged to a stream, river, wetland, open area, or storm drain system.

Site-Specific Construction Methods for Selected Trenchless Crossings.

This section describes site-specific information for trenchless crossings at the following sites:

1. Arrowhead Creek at Arrowhead Creek Lane
2. Tualatin River at SW Roy Rogers Road
3. Butternut Creek in South Hillsboro
4. Beaverton Creek at SW Millikan Way

Detailed plan sheets and cross sections for these crossings are on file at the Oregon Washington Coastal Area Office in Portland.

1. Arrowhead Creek at Arrowhead Creek Lane.

Arrowhead Creek will be crossed at Arrowhead Creek Lane using jack and bore methods. The length of the resource crossing will be approximately 30 feet, with shafts located approximately 210 feet apart. The pipe diameter at this crossing will be 66 inches.

The pipe jacking and receiving pits will be located on either side of the creek, outside of the wetland boundaries. The pit on the jacking side will need to be approximately 20 feet by 40 feet to allow for 5 feet on each side of the casing. The retrieval shaft could be smaller (12 feet by 15 feet), because it only needs to be big enough to drop in the first section of the water supply pipe and weld the joints together. Once the pipe is hydrostatically tested, the surrounding space will be filled with controlled low-strength material to hold the pipe in place and prevent corrosion. All construction will be approximately 5 to 10 feet away from the existing road foundation wing walls. Additionally, construction fencing, and erosion and sediment control measures will be installed around the entire work area to avoid disturbing anything within the floodplain boundary outside of the work zone.

2. Tualatin River at SW Roy Rogers Road.

The Tualatin River will be crossed using the microtunneling trenchless method. The crossing will be in a straight line between a jacking shaft and a reception shaft. The resource crossing will be approximately 400 feet, with shafts located approximately 2,300 feet apart. The horizontal alignment is governed by right-of-way constraints and shaft locations. The primary right-of-way constraints are the roadway bridge foundation, roadway embankment limits, and the Refuge boundaries. The alignment will therefore extend along the east side of Roy Rogers Road, staying outside the limits of the bridge foundation and avoiding the Refuge.

The profile of this crossing will consist of a shallow, inclined grade extending from the north to the south bank of the river and then a curve that transitions to a steeper grade. This profile will minimize the shaft depth at both ends. The profile will be governed by depth of cover, embankment stability, and liquefaction considerations, as follows:

- Provide a minimum depth of two casing diameters below the bottom of the Tualatin River to stay below scour (indicated by a subsequent site-specific analysis) and the liquefaction zone.
- Maintain the pipeline 20 feet below the roadway embankment to avoid the area most subject to deformation during a seismic event.
- Slope the tunnel to reduce the depth of the south shaft and allow for pipeline drainage for inspection and maintenance.

The estimated construction schedule is seven months, and will include the following activities: mobilization, shaft construction, jacking shaft setup, microtunneling, installation of the 66-inch-diameter pipeline and backfilling inside the casing, and pipeline shaft riser installation and shaft backfilling. The staging and construction areas will be located well above the Tualatin River OHW elevation of 118 feet (NAVD88). No in-water work will occur at this crossing.

The jacking shaft site will require an approximately 2-acre staging area in order to accommodate a crane, pipe truck access and pipe storage, and other equipment. The jacking shaft will be approximately 35 feet in diameter, not including the thickness of the shaft support system, and will have an anticipated depth of 80 to 90 feet. The reception shaft site located on the south side of the Tualatin River will require a staging area of approximately 0.5 acre. The staging area will be sized to allow for construction of the shaft, to accommodate a crane to remove the MTBM from the shaft, and to allow for construction of the transition between the tunnel and open-cut pipeline sections. The reception shaft will be approximately 25 feet in diameter, not including the thickness of the shaft support system, and will have an anticipated depth of 40 to 50 feet.

The locations of the construction shafts are outside of the floodplain.

3. Butternut Creek in South Hillsboro.

The pipeline will cross Butternut Creek in a straight line between a jacking shaft and a reception shaft. The specific method of trenchless construction will be determined during final design and construction bidding, but it is anticipated to be microtunneling. The resource crossing will be approximately 200 feet, with shafts located approximately 900 feet apart. The pipe diameter at this crossing will be 66 inches.

The majority of construction activities will take place from the north side of the crossing, where there is more room to stage construction. The south side is more restrictive for staging, because there are more trees and vegetation.

The northern shaft location will provide a work area that is considered sufficient for staging construction, and that will provide considerable flexibility for making adjustments to the work area to improve construction access and materials storage. The site will require temporary grading, including cut slopes, to develop a suitable work area. The southern shaft location will provide an accessible shaft location that will be situated within the construction easement. The northern shaft will be approximately 90 feet deep, while the southern shaft will be approximately 100 feet deep. These shafts will utilize sheet piles to restrict water flow into the shaft. Very little routine dewatering will be required within the shafts, and any dewatering will adhere to BMPs.

4. Beaverton Creek at SW Millikan Way.

The pipeline crossing across Beaverton Creek at SW Millikan Way will be approximately perpendicular to the stream channel. Beneath the active stream channel, the depth of earth cover over the pipe would be a minimum of twice the pipe diameter, or deep enough to avoid active scour, as indicated by a subsequent site-specific analysis. The specific method of construction will be determined during final design and construction bidding, but it is anticipated to be microtunneling. The resource crossing will be approximately 200 feet, with shafts located approximately 600 feet apart. The pipe diameter at this crossing will be 54 inches.

Regardless of the specific construction method selected, jacking and receiving shafts will be excavated on either side of the creek and outside of the jurisdictional wetlands. The jacking shaft, construction access and staging, and most construction activities are anticipated to occur on the south side of the creek. The jacking shaft and adjacent staging area will be approximately 0.3 acre, and the receiving shaft area will also be approximately 0.3 acre. Within each of those areas, the site will be graded temporarily to improve accessibility for construction vehicles and establish a suitable work area.

The jacking and receiving shafts are anticipated to be approximately 30 feet to 40 feet deep. Shoring will be used to stabilize the walls of these shafts and to limit groundwater infiltration. Dewatering pumps will be used to remove water entering the shafts from incidental groundwater or surface water intrusion, and casing and carrier pipe will be installed. Following construction, the shafts will be backfilled around the pipeline, and the soils recompacted. The construction area will be regraded to mimic preconstruction contours and revegetated.

Construction and Pre-Operational Dewatering of the Pipeline.

Dewatering the transmission pipelines will be part of construction and pre-operational maintenance of the pipeline. During construction, water from hydrostatic (pressure) testing of individual work packages will be discharged to allow access to the interior of the pipeline for repairs or inspection or to allow connection of adjoining work packages. After construction but prior to placement in service, the pipeline will be dewatered periodically for inspection or to renew the water in order to maintain water quality conditions consistent with design criteria until operations commence. When the pipeline is dewatered, the pipeline owners will coordinate with regulatory authorities to determine the allowable rates of discharge to drain the pipeline. Residual chlorine that may remain in the water will be removed if necessary by adding ascorbic acid (vitamin C) or sodium bisulfate to the water. Alkalinity adjustments may also be required to meet regulatory requirements for the discharge. Discharge rates at each dewatering location will be controlled by dewatering pumps or throttling valves at the dewatering locations. Discharge rates will not exceed the bankfull discharge rates for the receiving channel, in order to prevent soil or channel erosion. Bankfull discharge rates will be estimated using local stream gage data, previous drainage studies, or published regional regression equations. If discharge is to stormwater systems, discharge rates will be coordinated with the jurisdictional utility agency to avoid overloading the downstream system.

Operational Dewatering of the Pipeline.

Dewatering the Transmission Pipelines will be part of the regular operations and maintenance of the pipeline. Dewatering will rarely occur during the service life of the pipe, typically, it will occur during extraordinary or emergency circumstances that require access to the interior of the pipeline for repairs or inspection. If the pipeline is dewatered for maintenance or inspection over the service life of the pipe, the pipeline owners will coordinate with regulatory authorities to determine the allowable rates of discharge to drain the pipeline. Residual chlorine that may remain in the water will be removed if necessary by adding ascorbic acid (vitamin C) or sodium bisulfate to the water. Discharge rates at each drain location will be controlled by throttling valves installed on the drain locations. As discussed above, discharge rates will not exceed the bankfull discharge rates for the receiving channel, in order to prevent soil or channel erosion. Bankfull discharge rates will be estimated using local stream gage data, previous drainage studies, or published regional regression equations. If discharge is to stormwater systems, discharge rates will be coordinated with the jurisdictional utility agency to avoid overloading the downstream system.

1.3.5 Proposed Conservation Measures

The applicant proposes avoidance and minimization measures to incorporate into the Project to eliminate or reduce effects to listed and proposed species. These measures would address in-water work, erosion control, containment of construction materials, handling of contaminants or hazardous materials, and disturbance of upland, wetland, and riparian vegetation. BMPs would be employed to avoid and minimize the effects from those Project activities. Such measures would include:

a. Perform any in-water work (any construction activities below OHW elevation) during the following ODFW-designated and NMFS-approved windows:
    i. Willamette River: June 1–October 31
    ii. Willamette River tributaries: July 15–October 15
    iii. Tualatin River tributaries: July 15–September 30
b. Have a biologist qualified to conduct fish salvage on-site during work area isolation to assist in implementing conservation measures. Remove any fish present from the isolated work area by electrofishing and/or netting. Identify any captured fish and then release them unharmed, outside of the work area.
c. Install and remove work area isolation measures so that downstream water flows are maintained. Maintain and control water flow for the duration of the diversion to prevent downstream dewatering.
d. Minimize alteration or disturbance of streambanks and existing riparian vegetation.
e. Flag the permitted work area (also referred to as the in-water work area, OHW elevation, and jurisdictional waters or wetlands) before mobilizing equipment on-site.
f. Locate areas for storage of equipment and vehicles, other than track-mounted vehicles, outside of work hours, at least 150 feet away from the permitted work area, unless developed areas are available for staging and appropriate containment measures are in place to ensure containment and isolation of equipment and vehicles from the work area.
g. Locate areas for storing fuels and other potentially hazardous materials, and areas for refueling and servicing construction equipment and vehicles at least 150 feet away from the permitted work area, unless developed areas are available for staging, and appropriate containment measures are in place to ensure containment and isolation of potentially hazardous materials, equipment, and vehicles from the work area.
h. For track-mounted equipment, large cranes, and other equipment whose limited mobility makes it impractical to move them for refueling, take all feasible precautions to prevent and minimize the risk of fuel reaching the permitted work area, implement appropriate spill prevention measures and provide fuel containment systems designed to completely contain a potential material spill, as well as other pollution control devices and measures adequate to provide complete containment of hazardous material, and perform refueling operations to minimize the amount of fuel remaining in vehicles stored during non-work times.

i. Maintain hazardous material containment booms and spill containment booms on-site to facilitate the cleanup of hazardous material spills. Install hazardous material containment booms in areas where there is a potential for release of petroleum or other toxicants.
j. Prohibit underwater blasting.
k. Implement containment measures adequate to prevent pollutants or construction materials (such as waste spoils, petroleum products, concrete cured less than 24 hours, concrete cure water, silt, and welding slag and grindings) from entering the permitted work area or any regulated waters.
l. If flooding of the work area is expected to occur within 24 hours, evacuate all potential pollutants, equipment, and fuel from the anticipated inundation area.
m. Do not permit any equipment in the wetted channel (other than the Willamette River in order to modify piles and fish screen), unless the work to be performed using such equipment is isolated from the wetted channel.
n. Do not discharge contaminated or sediment-laden water from the Project or water contained within a cofferdam directly into any waters of the state until the water is satisfactorily treated (for example, by bioswale, filter, settlement pond, pumping to vegetated upland location, bio-bag, or dirt-bag), as appropriate.
o. Do not use treated timbers within the permitted work area for any purpose.
p. Do not apply fertilizer within 50 feet of any wetland or waterbody.
q. Before operating within 150 feet of the permitted work area, inspect and clean all construction equipment, check all construction equipment for fluid leaks, remove external oil, grease, dirt, and caked mud, do not discharge untreated wash and rinse water into the permitted work area, and establish temporary impoundments to catch water from equipment cleansing (which may only be performed at least 150 feet from the permitted work area and in a location that does not contribute untreated wastewater to any waters of the state unless otherwise noted).
r. Place waste materials and spoils above bank lines and away from any wetlands. If necessary, temporarily locate waste materials and spoils, before their removal from the Project site and disposal, above bank lines and away from any wetlands. Construction spoils will be disposed of in accordance with applicable regulations.
s. Minimize the operation of equipment in or on the water to the extent feasible.
t. For construction access roads and work areas near waterways and wetlands, use a rock work pad or other measures to minimize soil compaction from heavy equipment. Place a geotextile fabric, chain link fence, or other equally effective material under the temporary rock to protect existing ground and assist in removal of temporary work pad fill rock. Following construction, remove all of the temporary work pad materials, and regrade and restore the area according to the revegetation plans.
u. Mandate that diapering of vehicles and stationary equipment to catch any toxicants (for example, oils, greases, and brake fluid) be used when the vehicles have any potential to contribute toxic materials into aquatic systems.
v. Implement the following BMPs for trenchless (drilling, boring, or jacking) resource crossings:
    - Design, build, and maintain facilities to collect and treat construction and drilling discharge water using the appropriate technology applicable to site conditions.

- Provide treatment to remove debris, nutrients, sediment, petroleum hydrocarbons, metals, and other pollutants likely to be present. Use collection and proper disposal off-site as an alternative to treatment.
- Isolate drilling operations from wetted stream to prevent drilling fluids from contacting waters of the state and U.S.
- Prevent loss of drilling fluid to the subsurface formation. If necessary, use drill casing. If drilling fluid or waste is released to surface water, wetland or other sensitive environment, cease drilling operations until approval from the Owners' Representative is received to resume drilling. The Owners' Representative will notify the appropriate regulatory agencies of inadvertent release.
- Recover, recycle, or dispose of drilling fluids and waste as needed to prevent entry into flowing water.
- The contractor will submit its anticipated slurry operating pressures for review by the Owners' Representative, according to technical specifications, before construction begins.
- The contractor will implement an Erosion Control Plan to prevent the discharge of sediment to surface waters and ensure that turbidity does not exceed 10 percent above existing background conditions. The Project will comply with the National Pollutant Discharge Elimination System (NPDES) permit requirements.
- Identify and isolate sensitive areas before construction begins. Install erosion and sediment control measures around and on the site.

w. Implement the following BMPs when using a barge:
   - Before moving the barge to the project site, unless the barge is transported solely by water from within the state of Oregon, inspect the barge and ballast for invasive species to prevent introduction of invasive species to the Project site. Contact the Oregon State Marine Board if invasive species are found.
   - Prohibit barge grounding. Do not at any time allow barges to be grounded on the bed or banks of the waterway.
   - Do not use impact hammers for barge support/anchor (spud) placement.
   - Install and maintain containment measures to prevent barge surface runoff from flushing oil, fuel, or other contaminants into the water.
   - Secure all equipment, as well as containers with fuel, hazardous materials, or waste, to the barge deck.
   - If a fuel container is used on the barge, provide a double-walled fuel container and place an absorbent containment boom around the container when it is on the barge.
   - Provide individual containment for each piece of equipment on the barge, including containment pans or absorbent booms to contain minor spills locally.
   - Develop a spill mitigation plan prior to the start of work.

x. Implement one of the following sound attenuation methods when using an impact hammer to install the screen protection piles:
   - If the water velocity is 1.6 feet per second (fps) or less, surround the pile being driven by a confined or unconfined bubble curtain that will distribute small air bubbles around 100 of the pile perimeter for the full depth of the water column (see, e.g. NMFS and USFWS (2006), Wursig et al. (2002), and Longmuir and Lively (2001)).

- o If water velocity is greater than 1.6 fps, surround the pile being driven with a confined bubble curtain (e.g., surrounded by a fabric or non-metallic sleeve) that will distribute small air bubbles around 100 percent of the pile perimeter for the full depth of the water column.

2. ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures and terms and conditions to minimize such impacts.

2.1 Analytical Approach

This biological opinion includes both a jeopardy analysis and/or an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of" a listed species, which is "to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214).

The designation(s) of critical habitat for (species) use(s) the term primary constituent element (PCE) or essential features. The new critical habitat regulations (81 FR 7414) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Identify the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Describe the environmental baseline in the action area.
- Analyze the effects of the proposed action on both species and their habitat using an "exposure-response-risk" approach.
- Describe any cumulative effects in the action area.
- Integrate and synthesize the above factors by: (1) Reviewing the status of the species and critical habitat, and (2) adding the effects of the action, the environmental baseline, and cumulative effects to assess the risk that the proposed action poses to species and critical habitat.
- Reach a conclusion about whether species are jeopardized or critical habitat is adversely modified.
- If necessary, suggest a RPA to the proposed action.

2.2 Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that would be adversely affected by the proposed program. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential PBFs that help to form that conservation value.

One factor affecting the status of ESA-listed species considered in this opinion, and aquatic habitat at large, is climate change. Climate change is likely to play an increasingly important role in determining the abundance and distribution of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. The largest hydrologic responses are expected to occur in basins with significant snow accumulation, where warming decreases snow pack, increases winter flows, and advances the timing of spring melt (Mote *et al*. 2014, Mote *et al*. 2016). Rain-dominated watersheds and those with significant contributions from groundwater may be less sensitive to predicted changes in climate (Tague *et al*. 2013, Mote *et al*. 2014).

During the last century, average regional air temperatures in the Pacific Northwest increased by 1-1.4°F as an annual average, and up to 2°F in some seasons (based on average linear increase per decade, Abatzoglou *et al*. 2014, Kunkel *et al*. 2013). Warming is likely to continue during the next century as average temperatures are projected to increase another 3 to 10°F, with the largest increases predicted to occur in the summer (Mote *et al*. 2014). Decreases in summer precipitation of as much as 30% by the end of the century are consistently predicted across climate models (Mote *et al*. 2014). Precipitation is more likely to occur during October through March, less during summer months, and more winter precipitation will be rain than snow (ISAB 2007, Mote *et al*. 2013, Mote *et al*. 2014). Earlier snowmelt will cause lower stream flows in late spring, summer, and fall, and water temperatures will be warmer (ISAB 2007, Mote *et al*. 2014). Models consistently predict increases in the frequency of severe winter precipitation events (i.e., 20-year and 50-year events), in the western United States (Dominguez *et al*. 2012). The largest increases in winter flood frequency and magnitude are predicted in mixed rain-snow watersheds (Mote *et al*. 2014).

Overall, about one-third of the current cold-water salmonid habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (Mantua *et al*. 2009). Higher temperatures will reduce the quality of available salmonid habitat for most freshwater life stages (ISAB 2007). Reduced flows will make it more difficult for migrating fish to pass physical and thermal obstructions, limiting their access to available habitat (Mantua *et al*. 2010, Isaak *et al*. 2012). Temperature increases shift timing of key life cycle events for salmonids and species forming the base of their aquatic foodwebs (Crozier *et al*. 2011, Tillmann and Siemann 2011, Winder and Schindler 2004). Higher stream temperatures will also cause decreases in dissolved oxygen and may also cause earlier onset of stratification and reduced mixing between layers in lakes and reservoirs, which can also result in reduced oxygen (Meyer *et al*. 1999, Winder and Schindler 2004, Raymondi *et al*. 2013). Higher temperatures are likely to cause several species to become more susceptible to parasites, disease, and higher predation rates (Crozier *et al*. 2008, Wainwright and Weitkamp 2013, Raymondi *et al*. 2013).

As more basins become rain-dominated and prone to more severe winter storms, higher winter stream flows may increase the risk that winter or spring floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (Goode *et al*. 2013). Earlier peak stream flows will also alter migration timing for salmon smolts, and may flush some young salmon and steelhead from rivers to estuaries before they are physically mature, increasing stress and reducing smolt survival (McMahon and Hartman 1989, Lawson *et al*. 2004).

In addition to changes in freshwater conditions, predicted changes for coastal waters in the Pacific Northwest as a result of climate change include increasing surface water temperature, increasing but highly variable acidity, and increasing storm frequency and magnitude (Mote *et al*. 2014). Elevated ocean temperatures already documented for the Pacific Northwest are highly likely to continue during the next century, with sea surface temperature projected to increase by 1.0-3.7^{o}C by the end of the century (IPCC 2014). Habitat loss, shifts in species' ranges and abundances, and altered marine food webs could have substantial consequences to anadromous, coastal, and marine species in the Pacific Northwest (Tillmann and Siemann 2011, Reeder *et al*. 2013).

Moreover, as atmospheric carbon emissions increase, increasing levels of carbon are absorbed by the oceans, changing the pH of the water. Acidification also impacts sensitive estuary habitats, where organic matter and nutrient inputs further reduce pH and produce conditions more corrosive than those in offshore waters (Feely *et al*. 2012, Sunda and Cai 2012).

Global sea levels are expected to continue rising throughout this century, reaching likely predicted increases of 10-32 inches by 2081-2100 (IPCC 2014). These changes will likely result in increased erosion and more frequent and severe coastal flooding, and shifts in the composition of nearshore habitats (Tillmann and Siemann 2011, Reeder *et al*. 2013). Estuarine-dependent salmonids such as chum and Chinook salmon are predicted to be impacted by significant reductions in rearing habitat in some Pacific Northwest coastal areas (Glick *et al.* 2007).

Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances, and therefore these species are predicted to fare poorly in warming ocean conditions (Scheuerell and Williams 2005, Zabel *et al*. 2006). This is supported by the recent observation that anomalously warm sea surface temperatures off the coast of Washington from 2013 to 2016 resulted in poor coho and Chinook salmon body condition for juveniles caught in those waters (NWFSC 2015). Changes to estuarine and coastal conditions, as well as the timing of seasonal shifts in these habitats, have the potential to impact a wide range of listed aquatic species (Tillmann and Siemann 2011, Reeder *et al*. 2013).

The adaptive ability of these threatened and endangered species is depressed due to reductions in population size, habitat quantity and diversity, and loss of behavioral and genetic variation. Without these natural sources of resilience, systematic changes in local and regional climatic conditions due to anthropogenic global climate change will likely reduce long-term viability and sustainability of populations in many of these ESUs (NWFSC 2015). New stressors generated by climate change, or existing stressors with effects that have been amplified by climate change, may also have synergistic impacts on species and ecosystems (Doney *et al*. 2012). These conditions will possibly intensify the climate change stressors inhibiting recovery of ESA-listed species in the future.

2.2.1 Status of the Species

Table 2, below, provides a summary of listing and recovery plan information, status summaries and limiting factors for the species addressed in this opinion. More information can be found in recovery plans and status reviews for these species. These documents are available on the NMFS West Coast Region website (http://www.westcoast.fisheries.noaa.gov/).

Table 2. Listing classification and date, recovery plan reference, most recent status review, status summary, and limiting factors for each species considered in this opinion.

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Lower Columbia River Chinook salmon	Threatened 6/28/05	NMFS 2013	NWFSC 2015	This ESU comprises 32 independent populations. Twenty-seven populations are at very high risk, 2 populations are at high risk, one population is at moderate risk, and 2 populations are at very low risk Overall, there was little change since the last status review in the biological status of this ESU, although there are some positive trends. Increases in abundance were noted in about 70% of the fall-run populations and decreases in hatchery contribution were noted for several populations. Relative to baseline VSP levels identified in the recovery plan, there has been an overall improvement in the status of a number of fall-run populations, although most are still far from the recovery plan goals.	• Reduced access to spawning and rearing habitat • Hatchery-related effects • Harvest-related effects on fall Chinook salmon • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Contaminant
Upper Columbia River spring-run Chinook salmon	Endangered 6/28/05	Upper Columbia Salmon Recovery Board 2007	NWFSC 2015	This ESU comprises four independent populations. Three are at high risk and one is functionally extirpated. Current estimates of natural origin spawner abundance increased relative to the levels observed in the prior review for all three extant populations, and productivities were higher for the Wenatchee and Entiat populations and unchanged for the Methow population. However, abundance and productivity remained well below the viable thresholds called for in the Upper Columbia Recovery Plan for all three populations.	• Effects related to hydropower system in the mainstem Columbia River • Degraded freshwater habitat • Degraded estuarine and nearshore marine habitat • Hatchery-related effects • Persistence of non-native (exotic) fish species • Harvest in Columbia River fisheries

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Snake River spring/summer-run Chinook salmon	Threatened 6/28/05	NMFS 2016a (draft)	NWFSC 2015	This ESU comprises 28 extant and four extirpated populations. All expect one extant population (Chamberlin Creek) are at high risk. Natural origin abundance has increased over the levels reported in the prior review for most populations in this ESU, although the increases were not substantial enough to change viability ratings. Relatively high ocean survivals in recent years were a major factor in recent abundance patterns. While there have been improvements in abundance and productivity in several populations relative to prior reviews, those changes have not been sufficient to warrant a change in ESU status.	• Degraded freshwater habitat • Effects related to the hydropower system in the mainstem Columbia River, • Altered flows and degraded water quality • Harvest-related effects • Predation
Upper Willamette River Chinook salmon	Threatened 6/28/05	NMFS 2011	NWFSC 2015	This ESU comprises seven populations. Five populations are at very high risk, one population is at moderate risk (Clackamas River) and one population is at low risk (McKenzie River). Consideration of data collected since the last status review in 2010 indicates the fraction of hatchery origin fish in all populations remains high (even in Clackamas and McKenzie populations). The proportion of natural origin spawners improved in the North and South Santiam basins, but is still well below identified recovery goals. Abundance levels for five of the seven populations remain well below their recovery goals. Of these, the Calapooia River may be functionally extinct and the Molalla River remains critically low. Abundances in the North and South Santiam rivers have risen since the 2010 review, but still range only in the high hundreds of fish. The Clackamas and McKenzie populations have previously been viewed as natural population strongholds, but have both experienced declines in abundance despite having access to much of their historical spawning habitat. Overall, populations appear	• Degraded freshwater habitat • Degraded water quality • Increased disease incidence • Altered stream flows • Reduced access to spawning and rearing habitats • Altered food web due to reduced inputs of microdetritus • Predation by native and non-native species, including hatchery fish • Competition related to introduced salmon and steelhead • Altered population traits due to fisheries and bycatch

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
				to be at either moderate or high risk, there has been likely little net change in the VSP score for the ESU since the last review, so the ESU remains at moderate risk.	
Snake River fall-run Chinook salmon	Threatened 6/28/05	NMFS 2015a (draft)	NWFSC 2015	This ESU has one extant population. Historically, large populations of fall Chinook salmon spawned in the Snake River upstream of the Hells Canyon Dam complex. The extant population is at moderate risk for both diversity and spatial structure and abundance and productivity. The overall viability rating for this population is 'viable.' Overall, the status of Snake River fall Chinook salmon has clearly improved compared to the time of listing and compared to prior status reviews. The single extant population in the ESU is currently meeting the criteria for a rating of 'viable' developed by the ICTRT, but the ESU as a whole is not meeting the recovery goals described in the recovery plan for the species, which require the single population to be "highly viable with high certainty" and/or will require reintroduction of a viable population above the Hells Canyon Dam complex.	• Degraded floodplain connectivity and function • Harvest-related effects • Loss of access to historical habitat above Hells Canyon and other Snake River dams • Impacts from mainstem Columbia River and Snake River hydropower systems • Hatchery-related effects • Degraded estuarine and nearshore habitat.
Columbia River chum salmon	Threatened 6/28/05	NMFS 2013	NWFSC 2015	Overall, the status of most chum salmon populations is unchanged from the baseline VSP scores estimated in the recovery plan. A total of 3 of 17 populations are at or near their recovery viability goals, although under the recovery plan scenario these populations have very low recovery goals of 0. The remaining populations generally require a higher level of viability and most require substantial improvements to reach their viability goals. Even with the improvements observed during the last five years, the majority of populations in this ESU remain at a high or very high risk category and	• Degraded estuarine and nearshore marine habitat • Degraded freshwater habitat • Degraded stream flow as a result of hydropower and water supply operations • Reduced water quality • Current or potential predation • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
				considerable progress remains to be made to achieve the recovery goals.	• Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants
Lower Columbia River coho salmon	Threatened 6/28/05	NMFS 2013	NWFSC 2015	Of the 24 populations that make up this ESU, 21 populations are at very high risk, 1 population is at high risk, and 2 populations are at moderate risk. Recent recovery efforts may have contributed to the observed natural production, but in the absence of longer term data sets it is not possible to parse out these effects. Populations with longer term data sets exhibit stable or slightly positive abundance trends. Some trap and haul programs appear to be operating at or near replacement, although other programs still are far from that threshold and require supplementation with additional hatchery-origin spawners .Initiation of or improvement in the downstream juvenile facilities at Cowlitz Falls, Merwin, and North Fork Dam are likely to further improve the status of the associated upstream populations. While these and other recovery efforts have likely improved the status of a number of coho salmon populations, abundances are still at low levels and the majority of the populations remain at moderate or high risk. For the Lower Columbia River region land development and increasing human population pressures will likely continue to degrade habitat, especially in lowland areas. Although populations in this ESU have generally improved, especially in the 2013/14 and 2014/15 return years, recent poor ocean conditions suggest that population declines might occur in the upcoming return years	• Degraded estuarine and near-shore marine habitat • Fish passage barriers • Degraded freshwater habitat: Hatchery-related effects • Harvest-related effects • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Snake River sockeye salmon	Endangered 6/28/05	NMFS 2015b	NWFSC 2015	This single population ESU is at very high risk dues to small population size. There is high risk across all four basic risk measures. Although the captive brood program has been successful in providing substantial numbers of hatchery produced fish for use in supplementation efforts, substantial increases in survival rates across all life history stages must occur to re-establish sustainable natural production In terms of natural production, the Snake River Sockeye ESU remains at extremely high risk although there has been substantial progress on the first phase of the proposed recovery approach – developing a hatchery based program to amplify and conserve the stock to facilitate reintroductions.	• Effects related to the hydropower system in the mainstem Columbia River • Reduced water quality and elevated temperatures in the Salmon River • Water quantity • Predation
Upper Columbia River steelhead	Threatened 1/5/06	Upper Columbia Salmon Recovery Board 2007	NWFSC 2015	This DPS comprises four independent populations. Three populations are at high risk of extinction while 1 population is at moderate risk. Upper Columbia River steelhead populations have increased relative to the low levels observed in the 1990s, but natural origin abundance and productivity remain well below viability thresholds for three out of the four populations. The status of the Wenatchee River steelhead population continued to improve based on the additional year's information available for the most recent review. The abundance and productivity viability rating for the Wenatchee River exceeds the minimum threshold for 5% extinction risk. However, the overall DPS status remains unchanged from the prior review, remaining at high risk driven by low abundance and productivity relative to viability objectives and diversity concerns.	• Adverse effects related to the mainstem Columbia River hydropower system • Impaired tributary fish passage • Degraded floodplain connectivity and function, channel structure and complexity, riparian areas, large woody debris recruitment, stream flow, and water quality • Hatchery-related effects • Predation and competition • Harvest-related effects

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Lower Columbia River steelhead	Threatened 1/5/06	NMFS 2013	NWFSC 2015	This DPS comprises 23 historical populations, 17 winter-run populations and six summer-run populations. Nine populations are at very high risk, 7 populations are at high risk, 6 populations are at moderate risk, and 1 population is at low risk. The majority of winter-run steelhead populations in this DPS continue to persist at low abundances. Hatchery interactions remain a concern in select basins, but the overall situation is somewhat improved compared to prior reviews. Summer-run steelhead populations were similarly stable, but at low abundance levels. The decline in the Wind River summer-run population is a source of concern, given that this population has been considered one of the healthiest of the summer-runs, however, the most recent abundance estimates suggest that the decline was a single year aberration. Passage programs in the Cowlitz and Lewis basins have the potential to provide considerable improvements in abundance and spatial structure, but have not produced self-sustaining populations to date. Even with modest improvements in the status of several winter-run DIPs, none of the populations appear to be at fully viable status, and similarly none of the MPGs meet the criteria for viability.	• Degraded estuarine and nearshore marine habitat • Degraded freshwater habitat • Reduced access to spawning and rearing habitat • Avian and marine mammal predation • Hatchery-related effects • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Upper Willamette River steelhead	Threatened 1/5/06	NMFS 2011	NWFSC 2015	This DPS has four demographically independent populations. Three populations are at low risk and one population is at moderate risk. Declines in abundance noted in the last status review continued through the period from 2010-2015. While rates of decline appear moderate, the DPS continues to demonstrate the overall low abundance pattern that was of concern during the last status review. The causes of these declines are not well understood, although much accessible habitat is degraded and under continued development pressure. The elimination of winter-run hatchery release in the basin reduces hatchery threats, but non-native summer steelhead hatchery releases are still a concern for species diversity and a source of competition for the DPS. While the collective risk to the persistence of the DPS has not changed significantly in recent years, continued declines and potential negative impacts from climate change may cause increased risk in the near future.	• Degraded freshwater habitat • Degraded water quality • Increased disease incidence • Altered stream flows • Reduced access to spawning and rearing habitats due to impaired passage at dams • Altered food web due to changes in inputs of microdetritus • Predation by native and non-native species, including hatchery fish and pinnipeds • Competition related to introduced salmon and steelhead • Altered population traits due to interbreeding with hatchery origin fish
Middle Columbia River steelhead	Threatened 1/5/06	NMFS 2009	NWFSC 2015	This DPS comprises 17 extant populations. The DPS does not currently include steelhead that are designated as part of an experimental population above the Pelton Round Butte Hydroelectric Project. Returns to the Yakima River basin and to the Umatilla and Walla Walla Rivers have been higher over the most recent brood cycle, while natural origin returns to the John Day River have decreased. There have been improvements in the viability ratings for some of the component populations, but the DPS is not currently meeting the viability criteria in the MCR steelhead recovery plan. In general, the majority of population level viability ratings remained unchanged from prior reviews for each major population group within the DPS.	• Degraded freshwater habitat • Mainstem Columbia River hydropower-related impacts • Degraded estuarine and nearshore marine habitat • Hatchery-related effects • Harvest-related effects • Effects of predation, competition, and disease

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Snake River basin steelhead	Threatened 1/5/06	NMFS 2016 (draft)	NWFSC 2015	This DPS comprises 24 populations. Two populations are at high risk, 15 populations are rated as maintained, 3 populations are rated between high risk and maintained, 2 populations are at moderate risk, 1 population is viable, and 1 population is highly viable. Four out of the five MPGs are not meeting the specific objectives in the draft recovery plan based on the updated status information available for this review, and the status of many individual populations remains uncertain A great deal of uncertainty still remains regarding the relative proportion of hatchery fish in natural spawning areas near major hatchery release sites within individual populations.	• Adverse effects related to the mainstem Columbia River hydropower system • Impaired tributary fish passage • Degraded freshwater habitat • Increased water temperature • Harvest-related effects, particularly for B-run steelhead • Predation • Genetic diversity effects from out-of-population hatchery releases
Southern DPS of green sturgeon	Threatened 4/7/06	In development	NMFS 2015c	The Sacramento River contains the only known green sturgeon spawning population in this DPS. The current estimate of spawning adult abundance is between 824-1,872 individuals. Telemetry data and genetic analyses suggest that Southern DPS green sturgeon generally occur from Graves Harbor, Alaska to Monterey Bay, California and, within this range, most frequently occur in coastal waters of Washington, Oregon, and Vancouver Island and near San Francisco and Monterey bays. Within the nearshore marine environment, tagging and fisheries data indicate that Northern and Southern DPS green sturgeon prefer marine waters of less than a depth of 110 meters.	• Reduction of its spawning area to a single known population • Lack of water quantity • Poor water quality • Poaching

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Southern DPS of eulachon	Threatened 3/18/10	NMFS 2017	Gustafson et al. 2016	The Southern DPS of eulachon includes all naturally-spawned populations that occur in rivers south of the Nass River in British Columbia to the Mad River in California. Sub populations for this species include the Fraser River, Columbia River, British Columbia and the Klamath River. In the early 1990s, there was an abrupt decline in the abundance of eulachon returning to the Columbia River. Despite a brief period of improved returns in 2001-2003, the returns and associated commercial landings eventually declined to the low levels observed in the mid-1990s. Although eulachon abundance in monitored rivers has generally improved, especially in the 2013-2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years	• Changes in ocean conditions due to climate change, particularly in the southern portion of the species' range where ocean warming trends may be the most pronounced and may alter prey, spawning, and rearing success. • Climate-induced change to freshwater habitats • Bycatch of eulachon in commercial fisheries • Adverse effects related to dams and water diversions • Water quality, • Shoreline construction • Over harvest • Predation

2.2.2 Status of the Critical Habitat

This section describes the status of designated critical habitat affected by the proposed action by examining the condition and trends of the essential physical and biological features of that habitat throughout the designated areas. These features are essential to the conservation of the ESA-listed species because they support one or more of the species' life stages (*e.g.*, sites with conditions that support spawning, rearing, migration and foraging).

For most salmon and steelhead, NMFS's critical habitat analytical review teams (CHARTs) ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5) in terms of the conservation value they provide to each ESA-listed species that they support (NMFS 2005). The conservation rankings were high, medium, or low. To determine the conservation value of each watershed to species viability, the CHARTs evaluated the quantity and quality of habitat features, the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area. Even if a location had poor habitat quality, it could be ranked with a high conservation value if it were essential due to factors such as limited availability, a unique contribution of the population it served, or is serving another important role.

For southern DPS green sturgeon, a team similar to the CHARTs — a critical habitat review team (CHRT) — identified and analyzed the conservation value of particular areas occupied by southern green sturgeon, and unoccupied areas necessary to ensure the conservation of the species (USDC 2009). The CHRT did not identify those particular areas using HUC nomenclature, but did provide geographic place names for those areas, including the names of freshwater rivers, the bypasses, the Sacramento-San Joaquin Delta, coastal bays and estuaries, and coastal marine areas (within 110 m depth) extending from the California/Mexico border north to Monterey Bay, California, and from the Alaska/Canada border northwest to the Bering Strait, and certain coastal bays and estuaries in California, Oregon, and Washington.

For southern DPS eulachon, critical habitat includes portions of 16 rivers and streams in California, Oregon, and Washington (USDC 2011). We designated all of these areas as migration and spawning habitat for this species.

A summary of the status of critical habitats, considered in this opinion, is provided in Table 3, below.

Table 3. Critical habitat, designation date, federal register citation, and status summary for critical habitat considered in this opinion

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Lower Columbia River Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Oregon and Washington containing 47 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some, or high potential for improvement. We rated conservation value of HUC5 watersheds as high for 30 watersheds, medium for 13 watersheds, and low for four watersheds.
Upper Columbia River spring-run Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses four subbasins in Washington containing 15 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some, or high, potential for improvement. We rated conservation value of HUC5 watersheds as high for 10 watersheds, and medium for five watersheds. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Snake River spring/summer-run Chinook salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers, and all tributaries of the Snake and Salmon rivers (except the Clearwater River) presently or historically accessible to this ESU (except reaches above impassable natural falls and Hells Canyon Dam). Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar et al. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Upper Willamette River Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Oregon containing 56 occupied watersheds, as well as the lower Willamette/Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some, or high, potential for improvement. Watersheds are in good to excellent condition with no potential for improvement only in the upper McKenzie River and its tributaries (NMFS 2005). We rated conservation value of HUC5 watersheds as high for 22 watersheds, medium for 16 watersheds, and low for 18 watersheds.
Snake River fall-run Chinook salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers, and all tributaries of the Snake and Salmon rivers presently or historically accessible to this ESU (except reaches above impassable natural falls, and Dworshak and Hells Canyon dams). Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar et al. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Columbia River chum salmon	9/02/05 70 FR 52630	Critical habitat encompasses six subbasins in Oregon and Washington containing 19 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 16 watersheds, and medium for three watersheds.
Lower Columbia River coho salmon	2/24/16 81 FR 9252	Critical habitat encompasses 10 subbasins in Oregon and Washington containing 55 occupied watersheds, as well as the lower Columbia River and estuary rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 34 watersheds, medium for 18 watersheds, and low for three watersheds.
Snake River sockeye salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers, Alturas Lake Creek, Valley Creek, and Stanley, Redfish, Yellow Belly, Pettit and Alturas lakes (including their inlet and outlet creeks). Water quality in all five lakes generally is adequate for juvenile sockeye salmon, although zooplankton numbers vary considerably. Some reaches of the Salmon River and tributaries exhibit temporary elevated water temperatures and sediment loads that could restrict sockeye salmon production and survival (NMFS 2015b). Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Upper Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Washington containing 31 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 20 watersheds, medium for eight watersheds, and low for three watersheds.
Lower Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses nine subbasins in Oregon and Washington containing 41 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 28 watersheds, medium for 11 watersheds, and low for two watersheds.
Upper Willamette River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses seven subbasins in Oregon containing 34 occupied watersheds, as well as the lower Willamette/Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. Watersheds are in good to excellent condition with no potential for improvement only in the upper McKenzie River and its tributaries (NMFS 2005). We rated conservation value of HUC5 watersheds as high for 25 watersheds, medium for 6 watersheds, and low for 3 watersheds.
Middle Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 15 subbasins in Oregon and Washington containing 111 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of occupied HUC5 watersheds as high for 80 watersheds, medium for 24 watersheds, and low for 9 watersheds.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Snake River basin steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 25 subbasins in Oregon, Washington, and Idaho. Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar et al. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Southern DPS of green sturgeon	10/09/09 74 FR 52300	Critical habitat has been designated in coastal U.S. marine waters within 60 fathoms depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary, the Sacramento River, lower Feather River, and lower Yuba River in California, the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California, tidally influenced areas of the Columbia River estuary from the mouth upstream to river mile 46, and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor), including, but not limited to, areas upstream to the head of tide in various streams that drain into the bays, as listed in Table 1 in USDC (2009). The CHRT identified several activities that threaten the PCEs in coastal bays and estuaries and necessitate the need for special management considerations or protection. The application of pesticides is likely to adversely affect prey resources and water quality within the bays and estuaries, as well as the growth and reproductive health of Southern DPS green sturgeon through bioaccumulation. Other activities of concern include those that disturb bottom substrates, adversely affect prey resources, or degrade water quality through re-suspension of contaminated sediments. Of particular concern are activities that affect prey resources. Prey resources are affected by: commercial shipping and activities generating point source pollution and non-point source pollution that discharge contaminants and result in bioaccumulation of contaminants in green sturgeon, disposal of dredged materials that bury prey resources, and bottom trawl fisheries that disturb the bottom (but result in beneficial or adverse effects on prey resources for green sturgeon).
Southern DPS of eulachon	10/20/11 76 FR 65324	Critical habitat for eulachon includes portions of 16 rivers and streams in California, Oregon, and Washington. All of these areas are designated as migration and spawning habitat for this species. In Oregon, we designated 24.2 miles of the lower Umpqua River, 12.4 miles of the lower Sandy River, and 0.2 miles of Tenmile Creek. We also designated the mainstem Columbia River from the mouth to the base of Bonneville Dam, a distance of 143.2 miles. Dams and water diversions are moderate threats to eulachon in the Columbia and Klamath rivers where hydropower generation and flood control are major activities. Degraded water quality is common in some areas occupied by southern DPS eulachon. In the Columbia and Klamath river basins, large-scale impoundment of water has increased winter water temperatures, potentially altering the water temperature during eulachon spawning periods. Numerous chemical contaminants are also present in spawning rivers, but the exact effect these compounds have on spawning and egg development is unknown. Dredging is a low to moderate threat to eulachon in the Columbia River. Dredging during eulachon spawning would be particularly detrimental.

2.3 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02).

Fifteen ESA-listed species use the action area for adult migration, and juvenile rearing and migration. Critical habitat has been designated for all species. The action area is designated EFH for Chinook salmon and coho salmon (Pacific Fishery Management Council 2014), and is an area where environmental effects of the proposed action may adversely affect EFH of those species. The effects to EFH are analyzed in the MSA portion of the document.

The action area includes all watersheds or partial watersheds where project related effects will occur. For the WWSS, the upper extent of the action area begins 1,650 feet upstream of the raw water facilities, near the City of Wilsonville, where hydroacoustic disturbance will occur from the pile driving, downstream to the point at which the Columbia River enters into the Pacific Ocean, where stormwater effects will occur. The action area also includes the length of the pipeline and the Tualatin River and its tributaries with pipeline crossings. A map depicting the extent of the project across jurisdictions and watersheds can be found at ourreliablewater.org.

2.4 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

The climate change effects on the environmental baseline are described in Section 2.2, above.

Clean Water Services (CWS) manages surface water infrastructure throughout the Tualatin River watershed, through wastewater and stormwater management as well as through regulation of activities that adversely affect the Tualatin River. Through its recently renewed, watershed-based NPDES permit (Permit #s: 101141, 101142, 101143, 101144, and MS4, which expires on May 3, 2021), CWS is authorized to: (1) operate a wastewater collection, treatment, control, and disposal system, and (2) discharge treated wastewater to waters of the state only from the authorized discharge points in conformance with the requirements, limits, and conditions set forth in its NPDES permit. The authorized discharge points for CWS are the existing Durham, Rock Creek, Hillsboro, and Forest Grove Wastewater Treatment Facilities, all of which discharge to the Tualatin River, which then flows into the Willamette River.

CWS's NPDES permit and its related plans address the wasteload allocation requirements of the Tualatin Subbasin total maximum daily load (TMDL) issued in August 2001 and amended in August 2012 (ODEQ 2012). Those TMDLs are based on a variety of factors, including salmonid thermal and water quality requirements, and include monitoring at the treatment plants, watershed-wide in-stream water quality monitoring, including biological and physical monitoring.

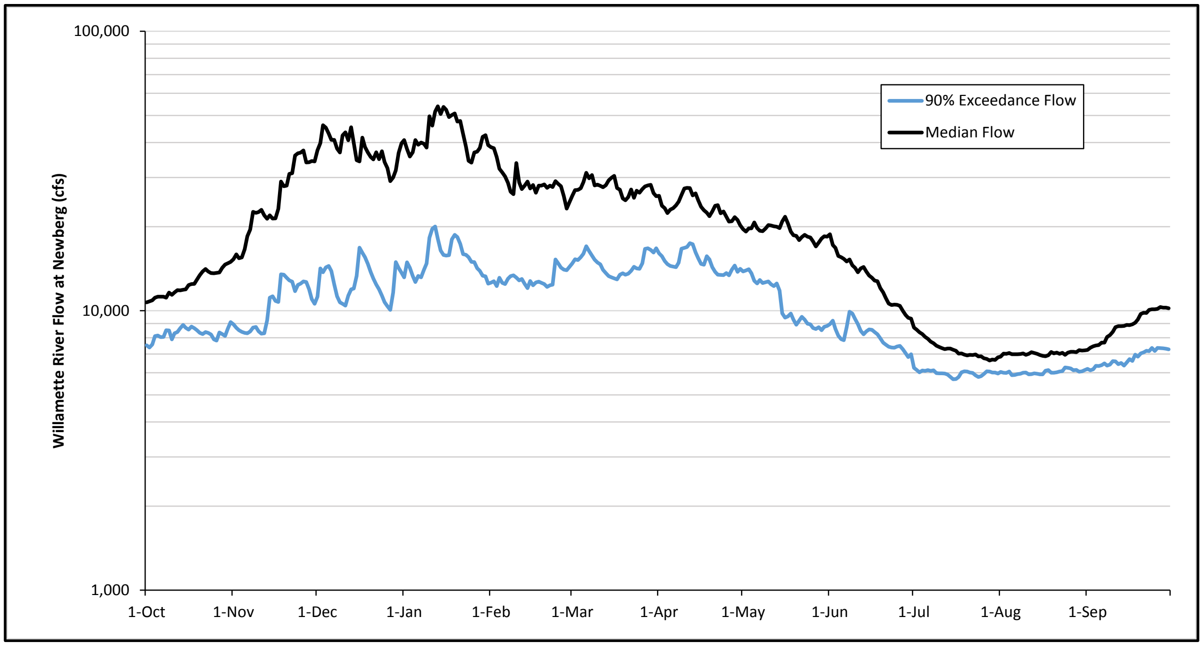
2.4.1 Willamette River

Within the project vicinity, the Willamette River flows eastward through the City of Wilsonville, turns northward near Canby, and continues toward the Willamette Falls at Oregon City. Willamette River tributaries within the RWF action area include the Pudding River, Molalla River, Tualatin River, and a number of smaller streams.

Hydrology.

Since 1900, more than 15 large dams and many smaller ones have been built in the Willamette River drainage basin. The dams on the Willamette River and its major tributaries were built primarily for purposes of flood control, water storage, and power generation. Thirteen of these dams were built by the USACE as the Willamette Valley Project, and serve to regulate flows within the Willamette River Basin. In the Willamette River Basin, approximately 14,000 water rights have been issued for the use of surface water. The majority of these water rights authorize the use of water from points of diversion upstream from the action area. The use of water under these existing water rights reduces the streamflows in the tributaries as well as the Willamette River mainstem (NMFS 2016).

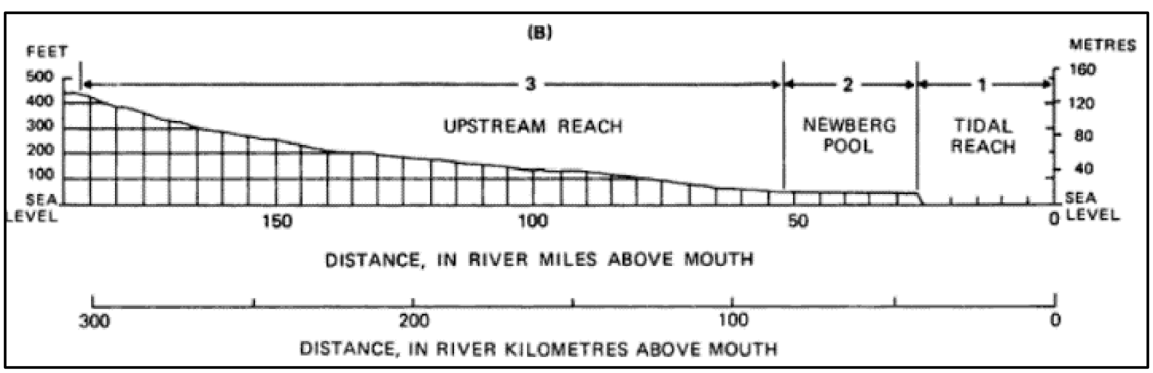
The Newberg gage is 11 miles upstream of the WRWTP intake (USGS 14197900, RM 50) and is used to evaluate flows at the WRWTP intake. The Newberg gage data dates back to 2001, while the Salem gage dates back to 1909, however, the flow relationships between the two gages have been correlated by month, and additional flow data for the Newberg gage has been synthesized to extend the Newberg data to a full 30 years. Figure 1 illustrates the daily flows at Newberg at the 50 percent (median) and 90 percent exceedance values. Low flows at the WRWTP intake are estimated at 5,955 cfs and generally occur in July and August (based on 90 percent exceedance values at the Newberg gage during August from 1985 to 2015). Existing permits currently allow diversion of up to 70 mgd (108.3 cfs) at the WRWTP intake. When this rate of diversion is compared to the 90 percent exceedance flows, the percent of flow that can be diverted is generally less than 2 percent of the streamflow.



Source: Newberg gage data, 1985-2015.

Figure 1. Daily Flows at Newberg Gage – 50 Percent and 90 Percent Exceedance.

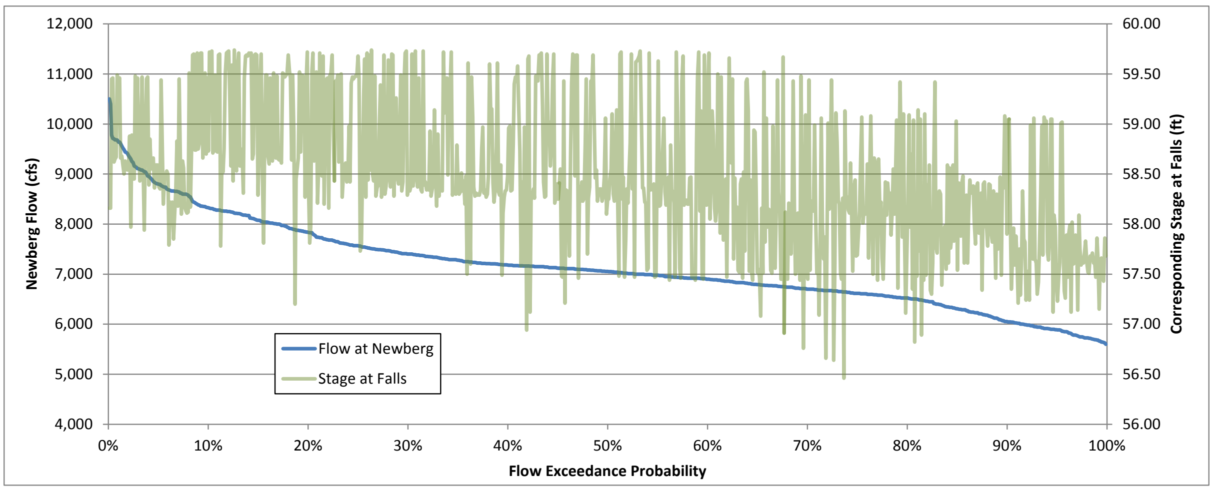
Within the vicinity of the WRWTP intake (RM 38.7), the Willamette River is, hydraulically, a large stilling basin from the Willamette Falls to Newberg (Rickert 1940). The river has a flat profile within the RWF action area, especially compared to the upstream reach, and is referred to as the Newberg Pool (Caldwell and Doyle, 1995). The Newberg Pool extends 30 miles from the Willamette Falls (approximately RM 27) upstream to approximately RM 56 (see Figure 2). The WRWTP intake is approximately 12 miles upstream from the falls.



Source: Rickert, 1940

Figure 2. Extent of Newberg Pool.

Part of the Newberg Pool was formed naturally by the Willamette Falls, and the pool was enlarged with development and operation of the Portland General Electric (PGE) Willamette Falls Hydroelectric Project. The PGE facility includes a 600-foot-wide flow control structure with adjustable weirs, and a 2,300-foot-long concrete dam with seasonal 18-inch-high flashboards installed generally between June and late fall/early winter when high flows cause them to wash out. Water surface elevation at Willamette Falls varies by almost 4 feet (approximate elevation is 56 to 60 feet in vertical datum NAVD 1988) during low-flow periods (MWH 2016). These operations have a significant effect on flows and water surface elevations within the project vicinity. During low-flow conditions, water surface elevation at the WRWTP intake is essentially controlled by operations at the dam, and there is little correlation between flows at the Newberg gage and the stage (i.e., river water surface elevation) at Willamette Falls (Figure 3).



Source: MWH, May 26, 2016. PowerPoint presentation to USACE/NMFS
Note: Stage/elevations shown are in vertical datum NAVD 1988. August is shown because it is representative of low flows.

Figure 3. Willamette River at Newberg Daily Average Flow Exceedance Probability During August and Daily Average Willamette River Stage at Willamette Falls on Corresponding Days.

Fish Habitat Conditions.

The Willamette River is mapped as rearing and migration habitat within the project vicinity. As discussed above, the action area is influenced by PGE's operation of the dam. Fish habitat is predominately a large pool with a uniform-shaped channel with limited off-channel habitat. In general, the Willamette River has a U-shaped channel and is slow-moving within the project vicinity. The river has a relatively uniform cross-sectional shape from the City of Wilsonville until its turn northward.

HEC-RAS modeling of the Willamette River from Newberg to Willamette Falls allowed for an analysis of potential shallow water and complex habitat. Based on cross-sections from the modeling, analysis shows that there is little variation in the river bottom shape between the WRWTP intake site (RM 39) and Canby (RM 34). After the Molalla River joins the Willamette River (RM 36), the first general change in channel morphology is at Willow Island and New Era Bar, where the river turns northward. Rock Island is almost 2 miles downstream of New Era Bar (RM 32), and is a complex of bare rock and riparian vegetated islands. This area near Rock Island appears to have the potential for isolated residual pools as the water elevation recedes.

Water Quality.

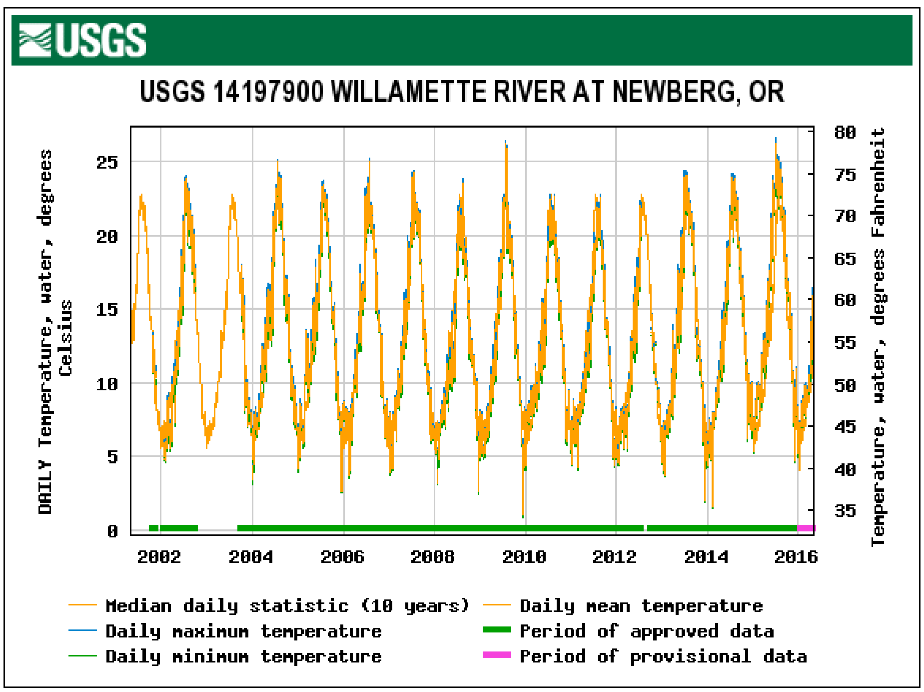
In 2006, the Willamette Basin Total Maximum Daily Load (TMDL) was issued as an order by the Oregon Department of Environmental Quality, providing limits for temperature, fecal bacteria and dioxins. The Willamette River is water quality-limited for temperature, *Escherichia coli* (*E. coli*), and dioxin (ODEQ 2006). These limits, from the TMDL, are summarized below.

Temperature. Temperature within the action area is influenced by the USACE's reservoir management Willamette Valley Project, upstream, and the PGE Willamette Falls Hydroelectric Project, downstream. USACE manages reservoir operations for the purposes of flood control and flow augmentation. The USACE flow augmentation actions substantially modify the temperature of the Willamette River by releasing large volumes of water that are often substantially cooler or warmer than natural water temperatures. Releasing large volumes of water to augment the flow of the river also yields higher flow velocities, and results in shorter travel time through mainstem river reaches, and less exposure to meteorological heating and cooling processes upstream of the pool. In summer, the release of large volumes of water from the USACE's reservoirs can contribute to cooler maximum daily temperatures in many mainstem locations. Data collected in August 2002 shows that the influence of cooler water released from the USACE's reservoirs decreases in a downstream direction. The river maintains relatively warm temperatures around the upper end of the Newberg Pool and in the region of the WRWTP intake (ODEQ 2006).

As part of establishing the Willamette Basin TMDL, PGE and DEQ conducted modeling that examined the effects on river temperatures from the Willamette Falls Hydroelectric Project. The modeling showed that removal of the dam and flashboards would result in lower water elevation and lower volume in the Newberg Pool (the dam and flashboards increase the Newberg Pool volume by 16,300 acre-feet), which would mean that water temperatures would respond more quickly to daily heating and cooling processes, and would be more variable, with the dam removed. From the Newberg gage at RM 50 to about RM 28 at Willamette Falls, the range of changes in temperature were less substantial than the range experienced upstream in Corvallis at RM 138. The Newberg Pool slows down the velocity and the heating/cooling process, which decreases the temperature variability in the RWF aquatic action area. The overall low-flow travel time (residence time) through the pool increases from about three days without the PGE project to about four days with the dam and flashboards in place. It is this increase in pool volume and travel time with the dam and flashboards in place that influences the river temperatures. Based on the modeling, the hydroelectric project has a neutral impact on temperatures in the spring, a cooling influence in the during the summer months, and may result in generally warmer temperatures in the Newberg Pool in the fall (ODEQ 2006).

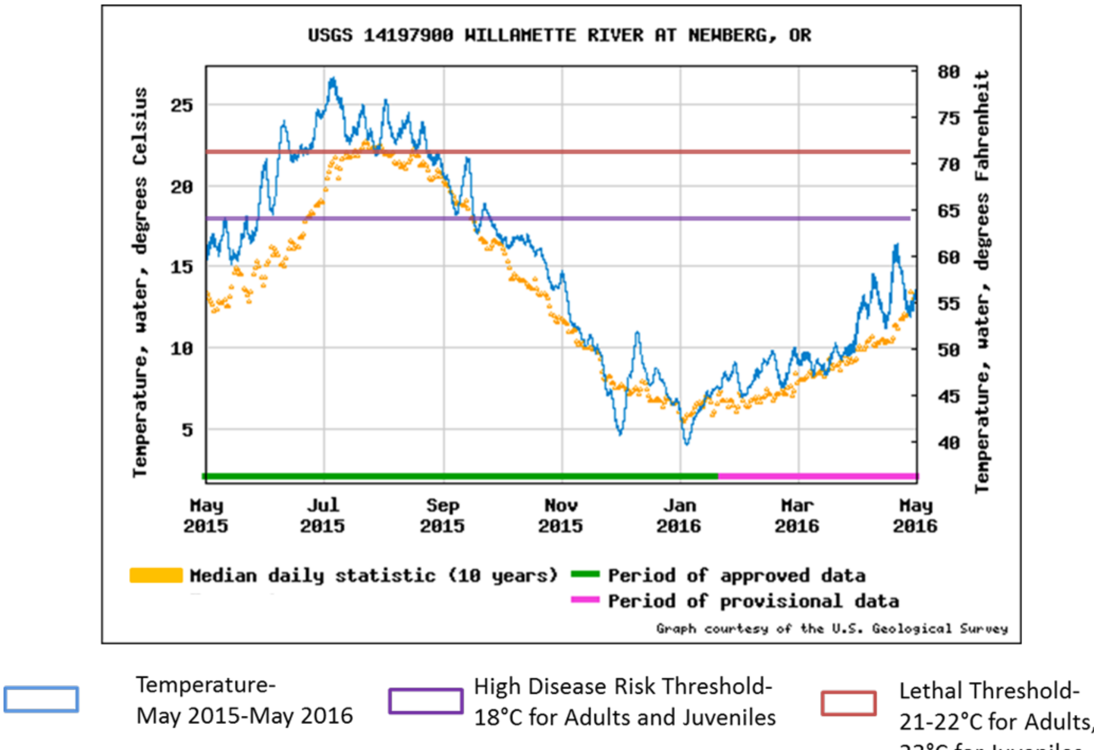
The mainstem Willamette River from its confluence with the Columbia River upstream to approximately the city of Newberg (RM 0-50) has been designated as a salmon and steelhead migration corridor. The numeric temperature criterion for this use is 20 degrees Celsius (°C) (68°F) and applies throughout the year (ODEQ 2006). The risk of contracting diseases and mortality increases among these species when temperatures exceed this threshold. This criterion is expressed as a seven-day rolling average and serves as a water quality standard across Oregon (ODEQ 2006). Gages with temperature measurements in the Willamette River are located at Newberg and at the Morrison Bridge in central Portland.

Water temperatures at the Newberg gage exhibit substantial variations during the year, reaching lows of less than 5°C in the winter months of December through February and highs above 20°C during the summer months of July through August. Temperatures in the Willamette River exceed the 20°C criteria on an annual basis, for varying lengths of time (Figure 4, see also Figure 5, showing temperatures in May 2015 to May 2016 one of the worst drought years on record for the region). Thus, temperatures in the Willamette River at the Newberg gage exceed the lethal limits for salmonids during summer months in most years. There are a variety of chronic and sub-lethal effects that are likely to occur to Pacific Northwest salmonid species exposed to a maximum weekly average of temperature of 18°C. These chronic and sub-lethal effects include reduced juvenile growth, increased incidence of disease, reduced viability of gametes in adults prior to spawning, increased susceptibility to predation and competition, and suppressed or reversed smoltification (EPA, 2003).



Source: USGS, 2016

Figure 4. Willamette River Temperature 2001–2016.



Source: USGS, 2016 and EPA, 2003

Figure 5. Willamette River Temperature May 2015–May 2016

Escherichia coli. Measures of *E. coli* concentration in waters are used as an indicator for the presence of fecal bacteria, and are tracked in order to protect against illness due to recreational contact. Multiple point and nonpoint sources are responsible for contributing *E. coli*. The mainstem Willamette River is considered water quality-limited for recreational uses due to elevated levels of fecal bacteria during fall, winter, and spring throughout the action area (ODEQ 2006).

As land use transitions from heavily agricultural above RM 48 to a mix of forestry, agricultural, and urban/residential from RM 48 to RM 18, there is a corresponding increase in *E. coli* concentrations in the Willamette River. Oregon DEQ attributes the increases in *E. coli* concentration at Salem and Corvallis to sanitary sewer overflows. *E. coli* concentrations increase slightly in the Willamette River due to inflows from the Molalla/Pudding and Tualatin River subbasins, and are relatively unaffected by inflows from the Clackamas River (ODEQ 2006).

2.4.2 Tualatin River

The Tualatin River is a tributary to the Willamette River. Most of the stream crossings by the transmission pipelines lie within the Tualatin River Basin. The reach of the Tualatin River within the project vicinity has a low gradient and a low flow velocity, making it prone to higher temperatures. Water quality improvement and introduction of shade to lower temperatures along the banks have been the focus of restoration efforts in the Tualatin River subbasin for many years (City of West Linn 2014, Tualatin River Watershed Council 2016).

Land use within the Tualatin River subbasin is generally urban east and northwest of the proposed pipeline, and predominantly agricultural west of the proposed pipeline alignment. Significant forested areas are mainly located in the northern and eastern areas of the Tualatin River subbasin.

The transmission pipelines cross the Tualatin River at SW Roy Rogers Road. Land use within this area is largely agricultural, and several intact riparian areas exist. The Tualatin River NWR lies to the southeast and northwest of this crossing. These areas consist of seasonally flooded wetlands, woodland, and riparian habitats (USFWS 2016). Rural residential areas are in the immediate vicinity.

Fish Habitat Conditions.

The Tualatin River is not designated critical habitat for steelhead within the project area, though it drains to steelhead critical habitat in the Willamette River. Steelhead spawning and rearing habitat in the Tualatin River subbasin is concentrated in the Coast Range headwaters rather than the valley bottom. Fish use within the mainstem Tualatin River is mainly limited to migration due to its mud bottom, high temperatures, and overall lack of quality spawning substrate (ODFW 1992). The Tualatin River at the SW Roy Rogers Road transmission pipeline crossing has been designated as cool water habitat (ODFW 1999), and is mapped as steelhead migration habitat and coho salmon rearing habitat (ODFW 2012), although there is no apparent off-channel or otherwise unique refugia in this stretch of the river. Designated cool water habitat is defined as supporting species that are physiologically adapted to cool waters but are not restricted to cold water habitat, such as salmonids and cold-water invertebrates (ODEQ 2012).

Water Quality.

In the project area, the Tualatin River is water quality-limited for aquatic weeds, chlorophyll a, dissolved oxygen, *E. coli*, phosphorus, and temperature.

The mainstem Tualatin River and tributaries have been designated as salmon and steelhead rearing and migration corridors, and the temperature criterion is 18°C (ODEQ 2006). Temperature management is a foremost water quality concern in the Tualatin River, because rises in temperature due to human and natural processes can exacerbate other water quality issues, and are harmful to salmon survival and habitat viability (Rounds and Wood 2001). In summer, high temperatures exacerbate other pollutants such as total phosphorous and bacteria, while reducing total dissolved oxygen. CWS releases water from Hagg Lake to the Upper Tualatin River, and has planted millions of trees and native plants along streambanks to provide shade (CWS 2017). The strategically timed water releases from Hagg Lake during the critical low-flow summer months provide lower temperatures and better overall water quality (ODEQ 2012).

2.4.3 Tualatin River Tributaries

Chicken Creek.

Chicken Creek is a perennial stream that begins near the Chehalem Mountains and flows through the Tualatin River NWR, downstream of the proposed Project, and then to the Tualatin River. Chicken Creek has been historically channelized through agricultural practices prior to the establishment of the Tualatin River NWR, and cut off from its original meandering channel (see Section 1.2.3.1). Native anadromous and resident fish species have access to the creek at the proposed crossing. Chicken Creek is mapped as winter steelhead spawning habitat in its middle reach, with rearing habitat in its lower reach north of the city of Sherwood. It is mapped as primarily rearing habitat for winter steelhead at the SW Roy Rogers Road Transmission Pipeline crossing (ODFW, 2012). Chicken Creek is not designated critical habitat for steelhead within the project area. Areas north of the creek crossing consist of rural agricultural land and the Tualatin River NWR. Areas south of the crossing consist of dense suburban land development associated with the city of Sherwood.

The Chicken Creek mainstem is water quality-limited for dissolved oxygen, lead, iron, and phosphorus. These pollutants are known to negatively impact resident fish, aquatic life, anadromous fish passage, and fish spawning (ODEQ 2012). The Transmission Pipeline crossing is within the water quality-limited section of the creek.

Butternut Creek.

Butternut Creek is mapped as winter steelhead spawning habitat, with some rearing habitat within approximately 100 feet downstream of the transmission pipeline crossing (ODFW 2012). There are no mapped fish passage barriers to prevent steelhead approaching the pipeline crossing, so the area may have the potential for spawning habitat. The creek crossing occurs along the future SW Cornelius Pass Road alignment in South Hillsboro. The creek provides high quality habitat, because it meanders slowly through wetland floodplain and has intact forested riparian corridors.

The Butternut Creek mainstem is water quality-limited for phosphorus, biological criteria, temperature, and dissolved oxygen. These pollutants are known to negatively impact resident fish, aquatic life, anadromous fish passage, and fish spawning (ODEQ 2012). The transmission pipeline crossing is within the water quality-limited section of the creek.

Beaverton Creek.

Beaverton Creek is mapped as winter steelhead rearing habitat with some migration habitat at both of the transmission pipeline crossings at NW Cornelius Pass Road and SW Millikan Way (ODFW 2012). This crossing is situated in a moderately deep drainage within the otherwise highly developed suburban landscape of Hillsboro, Oregon. Beaverton Creek is a perennial creek mostly confined to its banks, but that may overtop during particularly heavy prolonged rain events.

The Beaverton Creek mainstem is water quality-limited for dissolved oxygen, lead, iron, arsenic, phosphorus, biological criteria, and temperature. These pollutants are known to negatively impact resident fish, aquatic life, anadromous fish passage, and fish spawning (ODEQ 2012). The transmission pipeline crossing is within the water quality-limited section of the creek.

Rock Creek.

Rock Creek watershed drains an area of approximately 75 miles from the Tualatin Mountains. This crossing is situated in a small drainage that runs through Orenco Woods Nature Park, which is located within the otherwise highly developed suburban landscape of Hillsboro, Oregon. Rock Creek is mapped as winter steelhead spawning habitat, with some rearing habitat at the NW Cornelius Pass Road transmission pipeline crossing (ODFW 2012). Although mapped as spawning habitat, it was determined during a March 2017 site visit with ODFW that limited rearing and migration habitat occurs at the pipeline crossing. Rock Creek is not designated critical habitat for steelhead within the project area.

The Rock Creek mainstem is water quality-limited for dissolved oxygen, lead, iron, arsenic, phosphorus, biological criteria, and temperature. These pollutants are known to have a negative impact on resident fish, aquatic life, anadromous fish passage, and fish spawning (ODEQ 2012). The transmission pipeline crossing is within the water quality-limited section of the creek.

The environmental baseline includes the anticipated impacts of all Federal actions in the program action area that have already undergone formal consultation. The Corps, Bonneville Power Administration (BPA), and Bureau of Reclamation have consulted on large water management actions, such as operation of the Federal Columbia River Power System and the Willamette Valley Project in the upper Willamette Basin. The Corps and the Federal Emergency Management Agency have consulted on transmission projects, upland development, stormwater management and bank stabilization. Construction actions may have short-term adverse effects, but generally result in long-term improvements to habitat condition and population abundance, productivity, and spatial structure. After going through consultation, many ongoing actions, such as stormwater facilities, roads, culverts, bridges and transmission pipes, have less impact on listed salmon and steelhead.

2.5 Effects of the Action

Under the ESA, “effects of the action” means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

Effects on ESA listed fish and critical habitat analyzed in this opinion will result from construction, operation, and maintenance of the WWSS project components, including effects due to work area isolation and fish salvage, pile driving, suspension of sediments and turbidity, riparian and streambank disturbance, water quantity and quality due to water withdrawal, and stormwater runoff. These effects by each WWSS component are discussed below.

2.5.1 Effects on the Species

Raw Water Facilities.

Construction at the RWF located on the Willamette River in the City of Wilsonville will include modifications to the existing WRWTP intake screens and protection piles, construction of a streambank seismic stabilization drilled shafts below OHW elevation site seismic improvements, and modifications to the existing raw water pump station at the WRWTP. Modification of the intake screens and protection piles, and all construction activities below OHW of the Willamette River will occur during the approved in-water work window of June 1 to October 31, when fish abundance is anticipated to be low.

The replacement of the screens will be accomplished by a contractor working from a barge. No disturbance to the streambed is anticipated with the actual removal of the existing screens and the installation of the new screens. The only anticipated disturbance to the streambed associated with this work is from the spud placement to anchor the barge. No detectable disturbance to the streambed or turbidity is anticipated to result from the barge anchoring. The barge will be anchored to avoid grounding and disturbance to the streambank. The fish screen has been designed to meet all NMFS 2011 criteria and streaming velocities are sufficient to clear fish and debris from the screen. Based on the current design, NMFS does not expect any individual fish to be impinged on the screen during operation.

Of the ESA-listed species considered in this opinion, only the juvenile life history stage of UWR Chinook salmon and steelhead are present in areas with proposed work area isolation during this time that is construction of the open trench crossings and the raw water intake upgrades. Adult salmon and steelhead that may be present when the in-water work area is isolated are likely to leave by their own volition, or can otherwise be easily excluded without capture or direct contact before the isolation is complete.

Most direct, lethal effects of authorizing and carrying out the proposed actions are likely be caused by the isolation of in-water work areas, though lethal and sublethal effects would be greater without isolation. Any individual fish present in the work isolation area will be captured and released. Fish that are transferred to holding tanks can experience trauma if care is not taken in the transfer process, and fish can experience stress and injury from overcrowding in traps, especially if the traps are not emptied on a regular basis. Stress and death from handling occur because of differences in water temperature and dissolved oxygen between the river and transfer buckets, as well as physical trauma and the amount of time that fish are held out of the water. Stress on salmon and steelhead increases rapidly from handling if the water temperature exceeds 64ºF, or if dissolved oxygen is below saturation. Debris buildup and predation within minnow traps can also kill or injure listed fish if they are not monitored and cleared on a regular basis. Design criteria related to the capture and release of fish during work area isolation will avoid most of these consequences, and ensure that most of the resulting stress is short-lived (NMFS 2002).

An estimate of the maximum effect that capture and release operations for in-water work completed under this opinion will have on the abundance of adult salmon and steelhead in the Upper Willamette River recovery domain was obtained as follows: A = n(pct), where:

A = number of adult equivalents killed each year
n = number of WWSS projects that will require in-water work isolation
p = 31, *i.e.*, number of juveniles to be captured per project, based on ODOT's data for site isolation[1]
c = 0.05, *i.e.*, rate of juvenile injury or death caused by electrofishing during capture and release, primarily steelhead and coho salmon. Consistent with observations by Cannon (2008, 2012) and data reported in McMichael *et al*. (1998).
t = 0.02, *i.e.*, an estimated average smolt to adult survival ratio, see Smoker *et al*. (2004) and Scheuerell and Williams (2005). This is very conservative because many juveniles are likely to be captured as fry or parr, life history stages that have a survival rate to adulthood that is exponentially smaller than for smolts.

Thus, the effects of work area isolation on the abundance of juvenile or adult salmon or steelhead in any population is likely to be small, no more than one adult-equivalent per year in any recovery domain (Table 4).

Table 4. Number of salmon and steelhead affected by work area isolation under the proposed action.

	Estimated maximum number of projects requiring in-water work isolation under WWSS (per year) (n)	Estimated maximum number of juveniles captured (n*p)	Estimated maximum number of juveniles injured or killed (n*p*c)	Estimated maximum number of adult equivalents killed (n*p*c*t)
WWSS	5	155	7.75	0.155

The TVWD proposed 5 occasions of in-water work isolation will take place under the WWSS.

Because juvenile-to-adult survival rate for salmon and steelhead is generally very low, the effects of a proposed action would have to kill hundreds or even thousands of juvenile fish in a single population before those effects would be equivalent even to a single adult, and would have to kill many times more than that to affect the abundance or productivity of the entire population over a full life cycle. Thus, the proposed actions will simply kill too few fish, as a function of the size of the affected populations and the habitat carrying capacity after each action is completed, to

[1] In 2007, ODOT completed 36 work area isolation operations involving capture and release using nets and electrofishing, 12 of those operations resulted in capture of 0 Chinook salmon, 345 coho salmon, and 22 steelhead, with an average mortality of 5% Cannon (2008). Cannon (2012) reported a mortality rate of 4.4% for 455 listed salmon and steelhead captures during 30 fish capture and release operations in 2012. No sturgeon or eulachon have been captured as a result of ODOT fish capture and operations.

meaningfully affect the primary VSP attributes of abundance or productivity for any single population.

Acoustic impacts from pile driving

Impact pile driving may be required to install the 10 screen protection H-piles. Vibratory pile driving will be used for initial setting of the piles, with impact driving to set each pile. Based on the nature of the substrate, an impact hammer will probably be needed for the regular piles.

Pile driving often generates intense sound pressure waves that can injure or kill fish (Reyff 2003, Abbott and Bing-Sawyer 2002, Caltrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001). The type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer all influence the sounds produced during pile driving. Fishes with swimbladders (including salmon and steelhead) are sensitive to underwater impulsive sounds, *i.e.*, sounds with a sharp sound pressure peak occurring in a short interval of time, (Caltrans 2001). As the pressure wave passes through a fish, the swimbladder is rapidly squeezed due to the high pressure, and then rapidly expanded as the under pressure component of the wave passes through the fish. The pneumatic pounding may rupture capillaries in the internal organs as indicated by observed blood in the abdominal cavity, and maceration of the kidney tissues (Caltrans 2001). The injuries caused by such pressure waves are known as barotraumas, and include hemorrhage and rupture of internal organs, as described above, and damage to the auditory system. Death can be instantaneous, can occur within minutes after exposure, or can occur several days later.

Vibratory or impact hammers are commonly used to drive piles into the substrate. Sounds produced by impact hammers and those produced by vibratory hammers evoke different responses in fishes due to the differences in the duration and frequency of the sound pressure waves. A vibratory hammer uses a combination of a stationary, heavy weight, and vibration in the plane perpendicular to the long axis of the pile. Vibratory hammers produce sounds of lower intensity, with a rapid repetition rate. When exposed to sounds that are similar to those of a vibratory hammer, fishes consistently displayed an avoidance response (Dolat 1997, Enger *et al.* 1993, Knudsen *et al.* 1997, Sand *et al.* 2000). Acoustic disturbances associated with pile driving can disrupt the foraging behavior of juvenile salmonids, causing them to move away from the shoreline, or to delay their migratory progress.

Peak sound pressure level (SPL) and sound exposure level (SEL) are metrics used to correlate physical injury to fish from underwater sound pressure. “SPL” is defined as the maximum absolute value of the instantaneous pressure and “SEL” is a measurement of the accumulated noise energy from a single event, such as pile driving. According to Popper (2005), the use of the SEL metric is a more appropriate metric to use to correlate physical injury to fish from underwater sound pressure produced during installation of piles than SPL. Sound pressure levels (SPLs) greater than 150 decibels (dB)[2] root mean square (RMS) produced when using an impact hammer to drive a pile are thought to affect fish behavior. A multi-agency work group determined that to protect listed species, sound pressure waves should be within a single strike threshold of 206 decibels (dB), and for cumulative strikes either 187 dB sound exposure level (SEL) where fish are larger than 2 grams or 183 dB SEL where fish are smaller than 2 grams.

[2] All decibels have a reference pressure of one micro Pascal

Computations used to develop the action area and the impact zone from pile driving were developed based on the worst case scenario of 6,000 pile strikes (Table 5). Based on these calculations, NMFS expects injury or death of ESA-listed fish to occur within 243 feet of the piles and significant alteration of normal behaviors within 2070 feet, for steel H-piles piles driven with an impact hammer.

Table 5. Computations used to develop the action area and the impact zone from pile driving.

	Acoustic Metric			
	Peak	SEL	RMS	Effective Quiet
Measured single strike level (dB)	**194**	**163**	**177**	**150**
Distance (m)	**10**	**10**	**10**	

Estimated number of strikes	**6000**

Cumulative SEL at measured distance
200.78

	Distance (m) to threshold			
	Onset of Physical Injury			Behavior
	Peak	Cumulative SEL dB**		RMS
	dB	Fish ≥ 2 g	Fish < 2 g	dB
Transmission loss constant (15 if unknown)	206	187	183	150
15	**2**	**74**	**74**	**631**

The calculation for the cumulative SEL assumes a 10 dB sound reduction from the use of a confined bubble curtain when used with an impact hammer. The proposed number of strikes per day exceeds a cumulative SEL of 187 dB (threshold for onset of injury). Fish in the action area are assumed to be ≥ 2 g. For H steel piles, the model calculates that the onset of injury occurs within a distance of 74 meters (243 feet) from pile driving activity and behavioral response occurs within a distance of 631 meters (2070 feet) from pile driving activity.

As with the work area exclusion, the number of fish killed or injured or disrupted during rearing and migration by pile driving is expected to be very low due to the low density of fish (juveniles and adults) present during the in-water work period of July to October. As indicated above, only small numbers of juvenile fish are expected because fish are likely to avoid the areas due to elevated temperatures. Due to run timing, it is also not expected that many adults will be present. Construction-related noise will also occur early in the IWWW and thus before spawning is expected to occur. In addition, the impacts are for short periods of time. The number of fish killed or injured will be too small to have any impact on the long-term abundance trends of any population affected by the proposed action.

Increased total suspended solids, turbidity, and sedimentation
Temporary increases of suspended solids and turbidity are likely to occur from the proposed disturbance to uplands and riparian vegetation at the RWF. Potential effects from project-related increases in suspended sediment on ESA-listed species include, but are not limited to: (1) Reduction in feeding rates and growth, (2) physical injury, (3) physiological stress, (4) behavioral avoidance, and (5) reduction in macroinvertebrate populations.

At moderate levels, turbidity has the potential to reduce primary and secondary productivity, at higher levels, turbidity may interfere with feeding and may injure and even kill both juvenile and adult fish (Berg and Northcote 1985, Spence *et al.* 1996). However, Bjornn and Reiser (1991) found that adult and larger juvenile salmonids appear to be little affected by the high concentrations of suspended sediments that may be experienced during storm and snowmelt runoff episodes.

Behavioral avoidance of turbid waters by juvenile salmonids may be one of the most important effects of suspended sediments (Birtwell *et al.* 1984, Scannell 1988). Salmonids have been observed to move laterally and downstream to avoid turbid plumes (Lloyd *et al.* 1987, McLeay *et al.* 1984, McLeay *et al.* 1987, Scannell 1988, Servizi and Martens 1991). If the turbidity is severe enough to affect a significant cross-section of the river, the behavioral avoidance of turbid waters may impede or delay downstream or upstream migrations of adult and juvenile ESA-listed species. Salmon rearing in the action area during construction may also be exposed to other stress factors which may impose a cumulative burden in combination with increases in turbidity.

It is likely that construction activities and adjacent mobilization of equipment are likely to produce a short term (hours to days), temporary increase in turbidity in the Willamette River. Behavioral avoidance of areas with increased sediment is likely only to last as long as increased sediment is introduced into the area. Any ESA-listed fish in the area are likely to be disturbed by the increase in suspended sediment, however, as noted earlier few fish are likely to be in the work area between June 1 - October 31. No population-level effects will result from the exposure of a small number fish to a temporary exposure to increased turbidity.

Riparian Vegetation and Streambank.
In the Willamette River portion of the action area, 0.5 acres of riparian vegetation will be removed. Any other vegetation cleared for construction will also be replanted with native plants and bank protection measures will be monitored during the first few years of operation to ensure that vegetation growth occurs. The minor amount of riparian disturbance caused by the proposed action will not result in any long-term adverse effects to ESA-listed species.

Stormwater.
Construction of the RWF will result in 1.4 acres of new impervious surface. Stormwater from these surfaces will be treated in two biorention ponds before draining to the Willamette River.

Stormwater runoff delivers a wide variety of pollutants to aquatic ecosystems, such as nutrients, metals, petroleum-related compounds, sediment washed off the road surface, and agricultural chemicals used in highway maintenance (Buckler and Granato 1999, Colman *et al.* 2001, Driscoll *et al.* 1990, Kayhanian *et al.* 2003). These ubiquitous pollutants are a source of potent adverse effects to salmon and steelhead, even at ambient levels (Hecht *et al.* 2007, Johnson *et al.* 2007, Loge *et al.* 2006, Sandahl *et al.* 2007, Spromberg and Meador 2006), and are among the identified threats to sturgeon. Aquatic contaminants often travel long distances in solution or attached to suspended sediments, or gather in sediments until they are mobilized and transported by the next high flow (Alpers *et al.* 2000b, Alpers *et al.* 2000a, Anderson *et al.* 1996). These contaminants also accumulate in the prey and tissues of juvenile salmon where, depending on the level of exposure, they cause a variety of lethal and sublethal effects on salmon and steelhead, including disrupted behavior, reduced olfactory function, immune suppression, reduced growth, disrupted smoltification, hormone disruption, disrupted reproduction, cellular damage, and physical and developmental abnormalities (Fresh *et al.* 2005, Hecht *et al.* 2007, Lower Columbia River Estuary Partnership 2007). The proposed design for stormwater management will treat stormwater flows associated with more than 95% of the annual average rainfall. Runoff from impervious surfaces within the RWF project area will be treated using bioretention, which has been identified to reduce or eliminate contaminants for stormwater runoff (Barrett *et al.* 1993, Center for Watershed Protection and Maryland Department of the Environment 2000 (revised 2009), Herrera Environmental Consultants 2006, Hirschman *et al.* 2008, National Cooperative Highway Research Program 2006).

Because stormwater run-off moves downstream into the Lower Willamette, then Columbia River it is considered to adversely affect LCR Chinook, CR spring-run Chinook, SR fall Chinook, SR spring/summer Chinook, CR chum, LCR coho, SR sockeye, LCR steelhead, Middle CR steelhead, Upper CR steelhead, SRB steelhead, Southern green sturgeon and Southern eulachon considered in this opinion. This is the only impact from the proposed action on these species.

<u>Indirect effects from water withdrawals.</u>
The proposed project is designed to allow the Willamette Water Supply System to withdraw an additional 80 mgd (148.7 cfs) from the Willamette River. There are three municipal water rights that currently have points of diversion at the WRWTP: Permit S-49240, Permit S-46319, and Permit S-54940.

Permit S-49240. Permit S-49240 is held by the Willamette River Water Coalition (WRWC) which includes the Cities of Tigard, Tualatin, Sherwood and the Tualatin Valley Water District (TVWD). The permit authorizes the use of up to 202 cfs of water from the Willamette River for municipal and industrial use.

Some of the conditions on Permit S-49240 directly affect the amount of water that will be available under the water right. First, before a municipal water provider can use water under the permit, it must obtain authorization to use the water through a request for a ‘green light water’ in an approved water management and conservation plan (WMCP). A WMCP is a planning document that is reviewed and approved by Oregon Water Resources Department (OWRD) and includes a water provider’s existing and projected future water demands, its current water management and conservation efforts and 5-year benchmarks, and its plan for how it will curtail water use during water shortages.

To date, municipal water providers have authorization to use a total of 103.3 cfs under Permit S-49240 through approved WMCPs. The City of Sherwood has requested ‘green light water’ through an approved WMCP and it now has access to 23.2 cfs. Similarly, TVWD has an approved updated WMCP that granted access to 80.1 cfs. In addition, through the permit extension process, "fish persistence conditions" were incorporated into the permit. Fish persistence is defined by the OWRD as "the long-term ability of a species to survive in a stream or river," and fish persistence conditions are restrictions in the form of flow targets based on ODFW recommendations that OWRD applies to the undeveloped portion of a municipal water permit as a conservation measure intended to "maintain the persistence" of listed fish (OWRD 2017).

The fish persistence conditions for Permit S-49240 establish flow targets at USGS' Salem gage (Table 6). When flows in the Willamette River at the Salem gage do not meet the applicable flow target, the fish persistence conditions require the amount of water that can be diverted under the permit must be reduced in proportion to the amount by which target flows are met.

Table 6. Willamette River fish flow targets measured at Salem in cubic feet per second (cfs) by Permit #.

Month	Permit S-49240	Permit S-54940	Permit S-45565
Jul-Oct	5,630	5,630	5,630
Nov-Mar	6,200	6,000	6,000
Apr 1-15	15,000	15,000	15,000
Apri 16-30	15,000	17,000	17,000
May 1-31	15,000	15,000	15,000
Jun 1-15	12,600	12,600	12,600
Jun 16-30	8,500	8,500	8,500

The fish persistence conditions are based on the 7-day rolling average of mean daily flows at the Salem gage. Calculating the required curtailment is based on the streamflow, target flow, and amount of water to which the permit holders have access. The reduction in the amount of water that can be diverted is capped at 20% during April, May and June. The cap in the fish persistence conditions was included in recognition that the main influence on flows in the Willamette River is the Corps' management of the dams in the Willamette Basin Project. There is no cap on the required curtailment percentage in other months.

Permit S-46319. Permit S-46319 is held by the City of Wilsonville and authorizes the use of up to 30 cfs of water from the Willamette River for municipal use. This right pre-dates the legislation requiring fish persistence conditions, so none are included that limit the use of water under Permit S-46319.

Permit S-54940. Permit S-54940 is held by the City of Beaverton and authorizes the use of up to 33.7 cfs from the Willamette River for municipal services. Permit S-54940 includes fish flow targets relatively similar to those described for Permit S-49240 (Table 6). The conditions in

Permit S-54940 prohibit (rather than reduce) diversion of water under the permit if the identified flow targets at Salem are not met.
Permit S-45565. Permit S-45565 is co-held by the City of Salem (144 cfs) and the City of Hillsboro (56 cfs), and includes fish persistence conditions (Table 6).

Similar to Permit S-49240, water use must be reduced (rather than terminated) when the flow targets are not met. The conditions cap curtailment at 20 percent year-round.

Comparison of diversions and streamflow. The use of water under the existing water rights associated with the WRWTP necessarily causes some reduction in flows in the Willamette River.

Representative mean daily streamflows for the Willamette River at Newberg were developed by reviewing 31 years of stream gage records (water years 1985 to 2015). The cumulative flow of the Willamette River from April through September was used to classify each water year into one of three categories. The 10 years with the lowest flow during that period were characterized as being dry years, and the 10 years with the highest flows were considered wet years. The remaining 11 years were characterized as being average years. The flow data for the dry and average years were used to develop 90 percent exceedance flows (flows met or exceeded 90 percent of the time) for each month (or half month) for both types of years, as shown in column (a) in Tables 7 and 8**.** These 90 percent exceedance flows form the basis for the following comparisons to current and future diversions.

Through a previous consultation with the Corps, the NMFS analyzed the effects of a proposed action that currently limits diversion at the WRWTP to 70 mgd (108.3 cfs)[3]. When this rate of diversion is compared to the 90 percent exceedance flows, the percent of flow that can be diverted is generally less than 2 percent of the streamflow in both dry and average years. (The exception is the month of July during dry years, when the maximum diversion is calculated to equate to 2.02 percent of streamflow.) These percentages are in column (b).

The TVWD is seeking additional federal authorizations from the Corps under the Clean Water Act, through consultation with NMFS, to upgrade the intake with a maximum rate of diversion of 150 mgd (232.1 cfs). The percent of streamflow diverted at a rate of 150 mgd would be up to 3.70 percent of streamflow in average years and up to 4.33 percent in dry years. See column c in Tables 8 and 9.

However, even though Federal authorization for the WRWTP may allow an intake capable of pumping 150 mgd (232.1 cfs), some of the existing water rights associated with the WRWTP have further limitations, as described in the previous section. These water right conditions will reduce access to water when the above-described fish flow targets are not met. To estimate the authorized diversions during dry and average years, the fish flow targets were compared to the 90 percent exceedance flows for each month (or half month) and the required curtailment, if any, were calculated. The resulting authorized rates of diversion are provided in column (e) in Tables 8 and 9. These conditions reduce the percent of flow that can be diverted from April 16

[3] 2008 Consultation with the Corps and NMFS for Wilsonville Water Intake and Treatment Facility, Willamette River, Clackamas County (NMFS# NWR-2000-960). Signed 08-10-2000.

through June in average years and April 1 through August in dry years (Tables 7 and 8, column C).

Table 7. Average Year – Streamflows and Percent of Flow Diverted.

Month	90% Exceedance at Newberg (cfs)*	Percent of Flow Diverted (%)			Authorized Diversion with Curtailment (cfs)
		Currently Permitted 108.3 cfs (70 mgd)	Proposed 232.1 cfs (150 mgd) without curtailment	Proposed 232.1 cfs (150 mgd) with curtailment	
	(a)	(b)	(c)	(d)	(e)
Jan	15,486	0.70	1.50	1.50	232.08
Feb	12,400	0.87	1.87	1.87	232.08
Mar	14,540	0.74	1.60	1.60	232.08
Apr 1-15	18,197	0.60	1.28	1.28	232.08
Apr 16-30	17,460	0.62	1.33	1.14	198.38
May	14,600	0.74	1.59	1.27	185.65
Jun 1-15	11,400	0.95	2.04	1.58	180.01
Jun 16-30	8,761	1.24	2.65	2.21	193.62
Jul	6,458	1.68	3.59	3.59	232.08
Aug	6,270	1.73	3.70	3.70	232.08
Sep	7,310	1.48	3.17	3.17	232.08
Oct	8,870	1.22	2.62	2.62	232.08
Nov	13,015	0.83	1.78	1.78	232.08
Dec	14,300	0.76	1.62	1.62	232.08

*The Oregon Water Resources Department calculates curtailment based on flow at the Salem gage (14191000). Percent of flow is calculated on the basis of the Newberg gage (14197900).

Table 8. Dry Year – Streamflows and Percent of Flow Diverted.

Month	90% Exceedance at Newberg (cfs)*	Percent of Flow Diverted (%)			Authorized Diversion with Curtailment (cfs)
		Currently Permitted 108.3 cfs (70 mgd)	Proposed 232.1 cfs (150 mgd) without curtailment	Proposed 232.1 cfs (150 mgd) with curtailment	
	(a)	(b)	(c)	(d)	(e)
Jan	13,529	0.80	1.72	1.72	232.08
Feb	11,778	0.92	1.97	1.97	232.08
Mar	12,138	0.89	1.91	1.91	232.08
Apr 1-15	13,510	0.80	1.72	1.30	175.91
Apr 16-30	12,100	0.90	1.92	1.45	175.91
May	8,341	1.30	2.78	2.11	175.91
Jun 1-15	6,484	1.67	3.58	2.71	175.91
Jun 16-30	6,262	1.73	3.71	2.81	175.91
Jul	5,364	2.02	4.33	3.66	196.57
Aug	5,567	1.95	4.17	3.52	196.19
Sep	6,005	1.80	3.86	3.86	232.08
Oct	8,953	1.21	2.59	2.59	232.08
Nov	9,555	1.13	2.43	2.43	232.08
Dec	13,132	0.82	1.77	1.77	232.08

*The Oregon Water Resources Department calculates curtailment based on flow at the Salem gage (14191000).

The existing water rights associated with the WRWTP (Permits S-46319, S-49240, and S-54940) authorize the use of up to 276.7 cfs for municipal purposes. In addition, the City of Hillsboro has acquired 56 cfs of additional water supply from the Willamette River under Permit S-45565.

The City of Wilsonville has access to the full rate of 30 cfs under Permit S-46319 and the City of Beaverton has access to the 33.7 cfs rate under Permit S-54940, but access to water under Permit S-49240 currently is limited to 103.3 cfs (for TVWD and the City of Sherwood). OWRD will need to approve "green light water" as part of an approved WMCP to increase access to water under Permit S-49240. Similarly, the City of Hillsboro will need OWRD to approve "green light water" as part of an approved updated WMCP to obtain access to water under Permit S-45565. For purposes of calculating the percent of streamflow that could be diverted, GSI has assumed that OWRD has approved access to the entire 56 cfs under Permit S-45565 and has approved access to a total of 112.4 cfs under Permit S-49240 (an increase of 9.1 cfs).

Most of the water rights that have a point of diversion at the WRWTP have conditions intended to protect listed fish. The water rights with such conditions will authorize 91 percent of the combined maximum authorized rate of diversion at the WRWTP. Permits S-49240, S-54940, and S-45565 all have "fish persistence" conditions, which were recommended by ODFW, and reduce or (in the case of Beaverton's permit) prohibit access to water when streamflow at Salem is below the fish flow targets.

The currently authorized diversion capacity of 70 mgd at the WRWTP is calculated to equate to diversion of less than 2 percent of streamflow in average years and every month except July in dry years. When authorizations are obtained to allow a diversion capacity of up to 150 mgd, the percent of streamflow diverted will not increase by the same percentage throughout the year. During periods when the fish flow targets are not met (generally spring and summer), access to water under the water rights associated with the WRWTP will be reduced, and the resulting percent of streamflow diverted will range from 1.14 to 3.70 percent of streamflow in average years and from 1.30 to 3.86 percent of streamflow in dry years. During those periods, the proposed water withdrawal operations are likely to have a very small adverse effect on rearing and migration conditions for UWR Chinook salmon and UWR within the Newberg Pool, when very few individuals are likely to be present.

Effect of water withdrawal on stream temperature.

The applicant commissioned Geosyntec Consultants to study the impacts of the proposed water withdrawal on the river temperature. In a memorandum to the applicant and ODEQ dated 23 May 2018, Geosyntec shares their analysis conducted using CE-QUAL-W2 models developed for the Willamette River TMDL for temperature (Annear et. al 2004). The maximum daily withdrawal scenario was considered: 150 mgd withdrawal throughout the year, except where the withdrawals are curtailed. A scaled scenario was also considered, taking historical demand into account and applying a scaling factor to the maximum 150 mgd.

Calendar Year 2001 was a very dry year in the Willamette River system, and flows were below the 7Q10 (lowest 7-day average flow that occurs (on average) once every 10 years) for much of the summer. Comparing the WWSS withdrawals to calendar year 2001 therefore provides a conservative representation of the impacts of the withdrawal at 7Q10 conditions.

Figure 6 shows the maximum increase in the flow-weighted 7-Day Average of the Daily Maximum (7DADM) water temperature above the baseline. Flow-weighted temperatures were determined by multiplying the flow in each layer within the water column by its temperature and then dividing by the total flow. The increase above the baseline, per model segment, is shown for both the scaled and maximum scenarios for the Middle Willamette River for calendar year 2001. Every other model segment is shown. The location of the WWSP withdrawal is also indicated. The figure demonstrates the impacts on the 7DADM water temperatures are much less than the 0.3-degree C Human Use Allowance for ODEQ Section 401 certification. The maximum 7DADM water temperature increase above baseline for the maximum withdrawal scenario (i.e. maximum of the difference in 7DADM between the maximum and baseline scenarios) is 0.078 degrees C at model segment 394, which is located at RM 27.1, approximately 0.6 miles above Willamette Falls. The maximum increase above the baseline for the scaled withdrawal scenario is 0.069 degrees at Segment 393, approximately 0.8 miles above Willamette Falls.

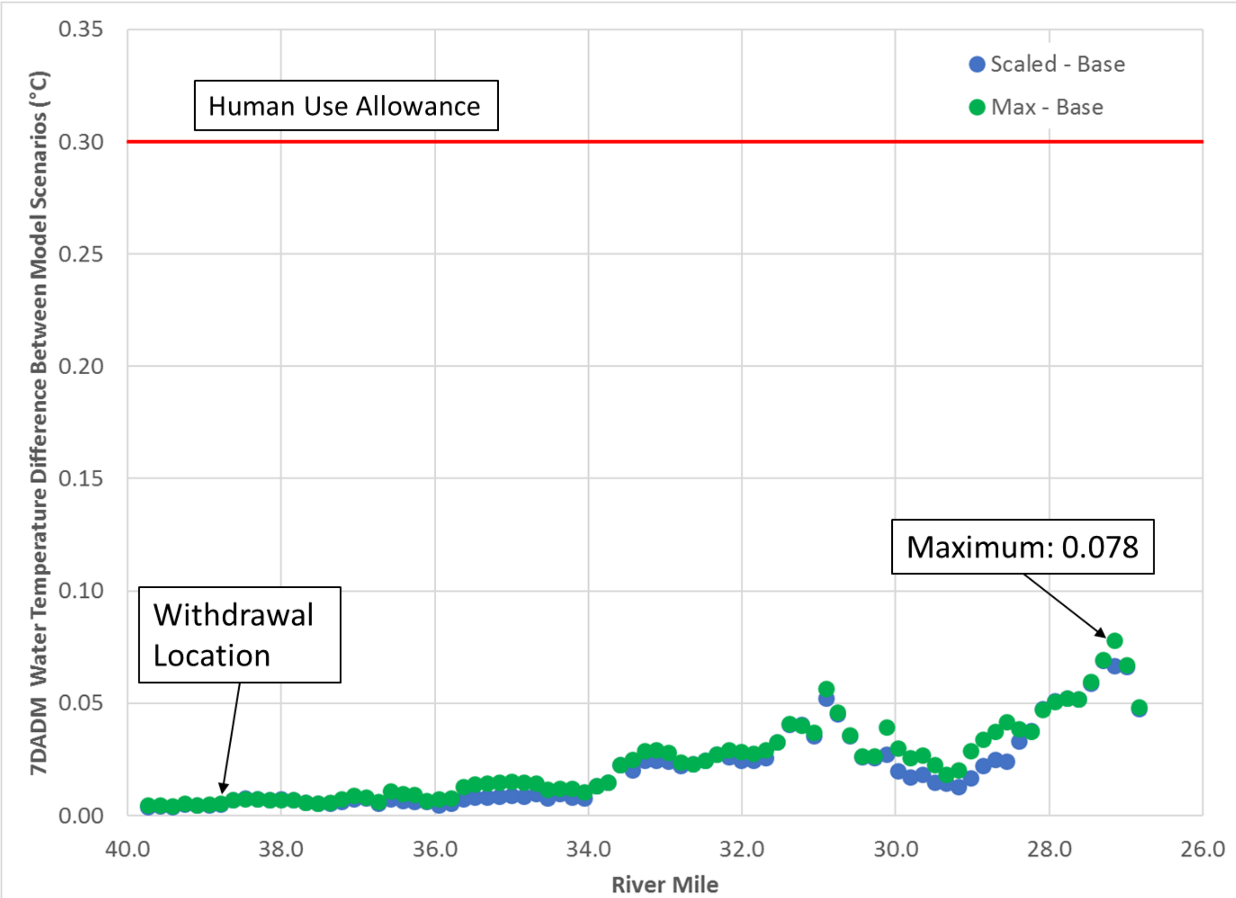


Figure 6. Maximum increase in the flow-weighted 7DADM above the baseline, throughout the full year, for each model segment for Calendar Year 2001 in the Middle Willamette River. The withdrawal location and the 0.3 degree C Human Use Allowance are indicated.

The top panel of Figure 7 shows a time series of the flow-weighted 7DADM water temperatures for the baseline, maximum and scaled model scenarios. The figure indicates that the flow-weighted water temperature differences are very small—indistinguishable at the scale of the figure. The bottom panel of Figure 7 shows a time series of the differences in flow-weighted 7DADM water temperature between the baseline and the maximum (Max – Base) and between the baseline and the scaled (Scaled – Base). The figure demonstrates that even for the location where the maximum increase in water temperature occurs, the increase in the flow-weighted 7DADM is not constant. Instead, the increase in 7DADM water temperature above the Baseline is usualy much less than the maximum water temperature increase. For some parts of the year, the flow-weighted 7DADM water temperature is slightly lower with the withdrawal than under baseline conditions.

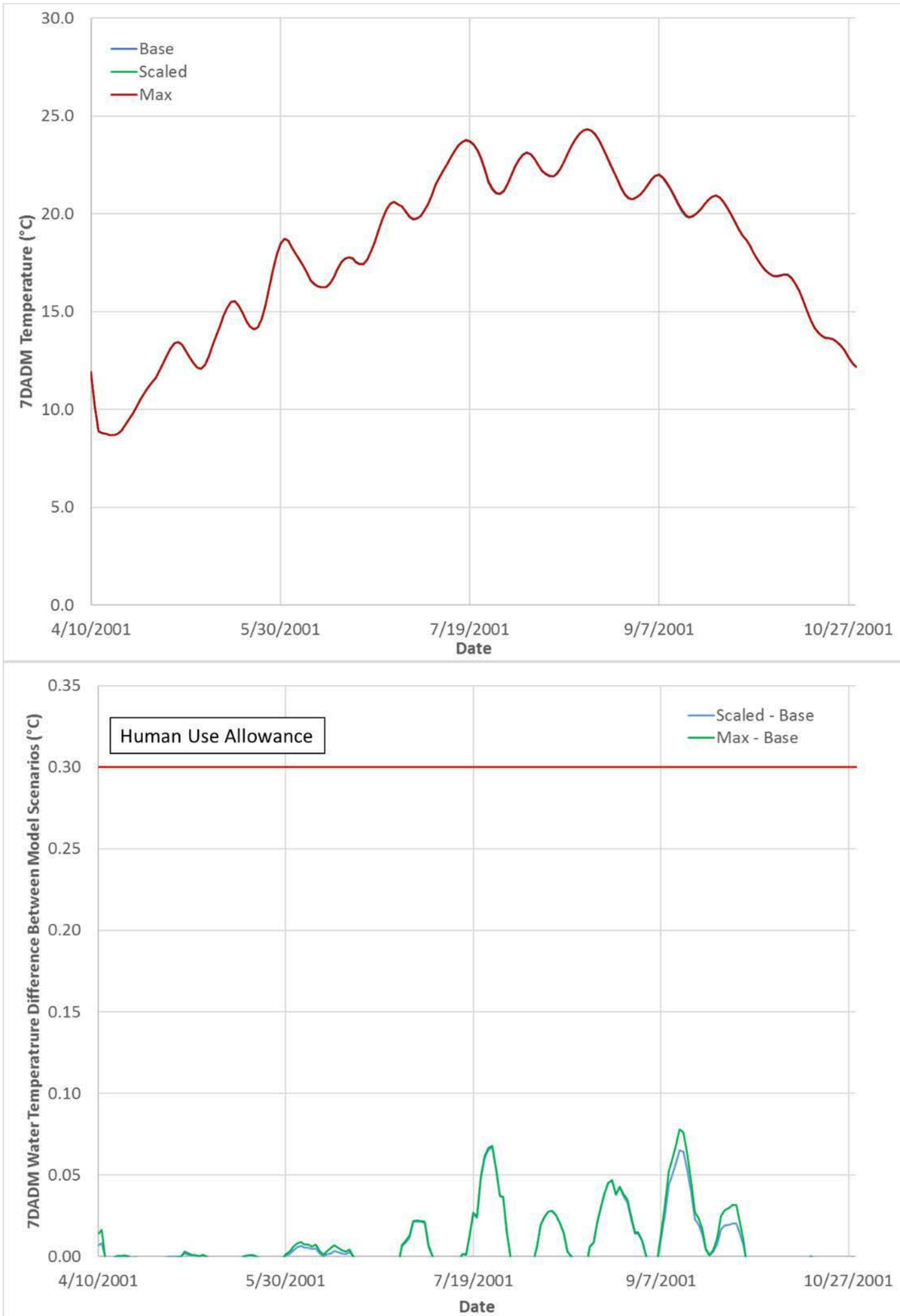


Figure 7. 7-Day Average of the Daily Maximum (7DADM) Temperature for the baseline, maximum and scaled scenarios at Segment 385 (top) and maximum difference (throughout water column) at Segment 385 for Max-Baseline and Scaled-Baseline (bottom). The 0.3-degree C impact threshold is indicated in the bottom panel.

The available information indicates that the proposed action could delay salmon migration behavior by causing a slight increase in temperature. Temperature is an important factor that influences salmon migration timing (Keefer 2008). There are various studies that address the optimal temperatures for salmonid migration, and there is some variation in their results.

For example, Goniea et al found that flexibility in migration timing generally appears to be limited for salmonids and fish may seek thermal refugia when temperatures reach 20° C or more (Goniea *et al* 2006). McCullough (1999) reported migration blockages become important when temperatures exceed 21° C. Richter and Kolmes (2005) reviewed results of numerous studies investigating the maximum lethal temperatures for different life stages of four species of salmon in the Pacific Northwest. The authors note that migration blockages for salmon consistently occur in the temperature range of 19° C to 23° C. The authors cite several studies showing that salmon migration is blocked by temperatures in this range in streams in Oregon, Washington, Idaho, and California. They also report the maximum lethal temperature for Chinook and coho salmon to be approximately 25° C although actual lethal limits for individual fish depend on many factors including temperature acclimation regimes. Richter and Kolmes (2005) further report that preferred migration temperatures for fall Chinook salmon are 10.6-19.4° C and preferred migration temperatures for coho salmon are 7.2-15.6° C.

A recent study of Chinook salmon migration in the Klamath River found initiation of upriver migration by adults after a period of thermally induced migration inhibition ranged from 21.88C to 24.08C (mean = 22.98C) (Strange 2010). Strange (2010) reported the upper thermal limits to adult Chinook salmon migration as indicated this study are substantially higher than previously reported in the literature and approached or exceeded the highest ultimate upper incipient lethal values determined for any life stage of this species. It is uncertain if this behavior is specific to Chinook salmon in the Klamath Basin or other stream systems within southern portion of this species range. Taken together, we believe these studies indicate that 19-20° C is a concerning temperature threshold in the present context.

While fish naturally adapt to changing conditions (Keefer *et al*. 2004) the stress of delayed migration, when added to other environmental stressors, can lead to reduced fitness. Prolonged delays that prevent salmon from reaching suitable resting or spawning areas may reduce their reproductive success (Thorstad *et al.* 2008).

Based on run timing, and temperature trends, the period of greatest concern for temperature impacts to UWR Chinook salmon and steelhead is May through September. Adult Chinook will begin their migration upstream in the April, with juvenile rearing and peak outmigration in May and June though with presence year round. In addition, temperatures drop considerably in mid-September and through October. Specifically, from September 15^{th,} temperatures begin to decrease as a result of shorter days and lower ambient air temperatures.

The proposed volume of the WWSS's withdrawals (up to 150 mgd at full capacity) would likely cause a slight increase in temperature, particularly during late August and September, and so will have a very small adverse effect on rearing and migration conditions for UWR Chinook salmon and UWR within the Newberg Pool during a period when very few individuals are likely to be present.

Willamette Water Supply System Water Treatment Plant.

The construction of the WWSS WTP facilities, access roads, and parking will result in approximately 10 acres of new impervious surface. Section 2.5.1.1 provides effects of stormwater runoff on listed fish species. The design of the WWSS WTP includes a dual-purpose stormwater retention and overflow basin. The proposed design for stormwater management at WWSS WTP facilities will treat stormwater flows associated with more than 95% of the annual average rainfall.

Reservoir Facilities.

The reservoir facilities site will include 3.6 acres of new impervious surface as a result of a new storage tanks, gravel access road, and parking lot. Stormwater runoff has potential adverse effects on listed fish species by altering water quality and stream hydrology as described in Section 2.5.1.1. Low impact development will be used to treat stormwater before it discharges into McKernan Creek, 4 miles upstream of the Tualatin River, the closest ESA-listed fish habitat. The proposed design for stormwater management at reservoir facilities will treat stormwater flows associated with more than 95% of the annual average rainfall.

Transmission Pipelines.

Trenchless and Roadway Crossings. Trenchless and roadway (i.e., over the culvert) crossings will be installed without in-water work and would therefore avoid direct impacts to adjacent riparian habitat. Rock Creek at SW Tualatin-Sherwood Road is the only roadway crossing with ESA-listed fish present. All construction will remain within the roadway at this crossing, the pipeline will be placed over the top of the culvert. Of the approximately six anticipated trenchless crossings, UWR steelhead are known to occur at the following locations: Tualatin River at SW Roy Rogers Road, Butternut Creek at South Hillsboro development, and Beaverton Creek at SW Millikan Way.

Although using a trenchless construction method avoids in-stream excavation, it does not completely eliminate the possibility of impacts on aquatic resources. Microtunneling and HDD construction methods require the use of drill fluid or mud that is under pressure. Since the drill fluid is under pressure, there is a risk of an inadvertent return (also referred to as a hydrofracture or frac-out). Drill fluids primarily consist of water mixed with bentonite, which is a naturally occurring clay material. Similar to other fine-grained particulates, bentonite is more likely to remain in suspension longer in flowing water than in standing water. Consequently, effects to listed salmonids by a release of bentonite into a waterbody would ultimately depend on the volume of the release, the volume of water present, and the current. If an inadvertent return were to occur, drilling fluid would enter the waterway, causing short-term, temporary water quality impacts, including sedimentation and turbidity, downstream of the project area. The behavioral avoidance response is presumed to be triggered within the immediate vicinity of the release, and the fish are expected to return and utilize the affected area shortly after the inadvertent return has been halted.

Microtunneling is the preferred trenchless method because it reduces the potential of an inadvertent return of drilling fluids. A minimum vertical cover beneath resource crossings would be two pipeline diameters or below scour depth, in part to reduce the potential of inadvertent returns. The possibility of inadvertent returns occurring is in part related to the contractor's operating pressure at the MTBM or, for HDD, while excavating. As a conservation measure, the contractor will submit its anticipated slurry operating pressures for review by the Owners' Representative, according to technical specifications, before construction begins. Drill fluid is not required with jack and bore, pipe ramming, or shielded tunneling construction methods.

Open-Trench Crossings. In-water work isolation will be implemented at all open-trench waterway crossings. Of the 11 anticipated open-trench waterway crossings, UWR steelhead are known to occur at Chicken Creek at SW Roy Rogers Road, Beaverton Creek at NW Cornelius Pass Road, and Rock Creek at NW Cornelius Pass Road.

All construction activities below OHW will occur during the approved in-water work window, when fish abundance is anticipated to be low. The transmission pipeline work area will be isolated from the wetted channel using work area isolation measures approved by the Owners' Representative, such as a sheetpile cofferdam or culverts. A pump, outfitted with a fish screen conforming to NMFS standards, will be installed and used to dewater the interior of the isolation area until the water is at a depth that allows effective fish salvage. The water will be discharged to a settlement basin or through other appropriate treatment measures to meet water quality conditions before being released back into the stream. The work area isolation measures will be installed, maintained, and removed in a manner that allows downstream flows to remain at levels necessary to prevent dewatering outside of the isolated work area.

Fish salvage will be conducted by a qualified biologist under an Oregon Scientific Collection Permit immediately following isolation. Although fish salvage will be conducted by a qualified biologist, juvenile salmonids can become stressed during capture, handling, and release, which can result in immediate or delayed death or injury. Depending on conditions during isolation, it may not be possible to capture, remove, and relocate all of the individual fish within the isolated in-water work area. Any individual juvenile salmonids remaining within the isolated work area after fish salvage would not be expected to survive.

The in-water work area for open-trench crossings will remain inaccessible to fish for the duration of construction, which will vary for each crossing. Fish passage requirements will be determined for each crossing through the ODFW Fish Passage Permit application process. In general, upstream and downstream fish movement will be required in locations where blocking upstream movement, even for short durations, would unduly stress salmonids using the area. Downstream fish movement is generally required unless water quality conditions preclude the likely use of the area by salmonids, in which case the ability to completely block fish movement will be limited to no more than ten days and must be approved by ODFW.

Increased Turbidity and Contaminant Release. There are seven crossing methods (remain in the roadway, open cut, and five trenchless options) that could be used where listed salmon occur along the pipeline route. In general, during pipeline construction, there is a risk of increased turbidity, sediment, and contaminant-laden surface water runoff, and contaminant release entering the waterway. See Section 2.5.1 for the effects of increased turbidity UWR Chinook and steelhead.

In-water construction activities are likely to temporarily increase concentrations of sediment and turbidity. Short-term pulses of sediment are likely to occur during installation of the work area isolation, and again during and after removal of the isolation, when flows will increase and inundate the work areas. Minor, localized increases in suspended sediments (resuspension lasting a few hours to a few days) may continue to occur until all disturbed materials in the construction area have been flushed out. In the absence of conservation measures, dewatering of the work area isolation could also lead to increased turbidity. However, implementation of erosion and sediment control measures and in-water work conservation measures will greatly reduce the duration and intensity of sediment and turbidity in the waterways.

Although BMPs will be implemented, suspended sediment is likely to occur in waterways with listed fish. The exposure of listed fish to increased suspended sediment will likely result in a behavioral response to move to locations with lower concentrations of fine sediment. If fish failed to avoid increased suspended sediment, such exposure could result in gill irritation or abrasion, which can reduce respiratory efficiency or lead to infection and a reduction in juvenile feeding efficiency due to reduced visibility. In some circumstances, individuals may find increased feeding opportunities along the sediment plume fringe as suspended fauna are transported downstream with the sediment. While fish sometimes have been observed to seek refuge from predators in turbid water, the forced dispersal or avoidance of the sediment plume will result in the denial of refuge to most juvenile salmonids present in the affected area, and could therefore increase losses of these salmonids to predation.

Fish habitat could be adversely affected if petroleum-based products were accidentally released into aquatic environments. Products likely to be present during construction of the transmission pipelines include diesel fuel, lubricants, hydraulic fluid, and other contaminants contained in construction equipment. Inadvertent spills in and near waterways could potentially result in negative impacts to fish and critical habitat. In addition, long-term effects could also result if a spill is not properly remediated. The effects of any contaminant release from construction equipment to listed fishes are anticipated to be negligible, because spills would most likely be small and be cleaned up quickly. To minimize the potential for spills, conservation measures, such as an erosion control plan including spill containment, storing hazardous materials and refueling at least 150 feet from the permitted work area will be implemented.

Riparian Vegetation Removal and Modification. Aquatic resources could be affected as a result of removal of vegetation and habitat at the open-trench waterway crossings. At the trenchless crossings, the drill shafts and bore pits are set back from the streambanks and are located to minimize vegetation impacts to the extent possible. The disturbed areas will be revegetated after construction of the crossings is complete. The site plan restricts the low-growth vegetation area to a small portion of the total permanent easement, which would allow much of the ecological function of the riparian conditions to remain. This measure would limit the overall long-term impacts from loss of riparian habitat to a small portion of each stream crossing. Some limited, intermediate-term adverse effects to salmon habitat function could be associated with the potential reduction of large woody debris.

Aquatic Habitat. Open-trench construction will directly impact an 8-foot-wide to 12-foot-wide section of the streambank and channel substrate during excavation of the trench. Work area isolation measures, fish passage measures, and dewatering could occur in the temporary construction area (up to 75 feet wide at the channel crossing where listed fish are present). Following construction, the stream channel substrate and streambank will be restored to conditions that are equivalent to or better than pre-construction conditions. The streambed material will be stockpiled, or equivalent material will be used, to restore the channel. The streambanks will be stabilized following bio-engineered designs and with native vegetation.

There are potential indirect effects to aquatic habitat from increased suspended sediment resulting from the construction of stream crossings for the Transmission Pipelines. The most likely effect of increased suspended sediment would be increased embeddedness of spawning gravels. Although mapped as spawning habitat, it was determined during a March 2017 site visit with ODFW and NMFS that limited rearing and migration habitat occurs at the Rock Creek crossing. At all other open trench crossings, there is no spawning habitat downstream of the transmission pipeline crossings. A change in habitat preference may occur as a result of temporary increases in suspended sediment, however, considering the short duration of likely increased suspended sediment levels, it is not anticipated to measurably degrade spawning gravels.

Return Flows

The proposed project is designed to allow the WWSS to withdraw up to 150 mgd at full capacity, but that does not account for how much of the water diverted will actually be consumptively used, or how much will eventually be returned to the environment through discharge of treated wastewater or other return flows (see OWRD 2015). The specific timing, volume, location, and quality of those return flows will vary as follows:

- Peak M&I withdrawal and use is likely to occur between June and September (USACE 2017).
- The volume of return flow compared to the volume of water that is diverted for M&I use, delivered to customers, used, treated, and then returned to streams or to groundwater is not known, but is assumed to be large (OWRD 2015).
- All return flows from wastewater treatment plants will be discharged by CWS at four authorized points (Durham at Tualatin RM 9.2, Rock Creek at Tualatin RM 37.7, Hillsboro at Tualatin RM 42.9 and Tualatin 43.3, and Forest Grove at Tualatin RM 53.8), which then flow into the Willamette River at Willamette RM 28.5, a distance of 10.2 miles downstream from the WRWTP (RM 38.7).
- The quality of those wastewater discharges is regulated by the Tualatin Subbasin total maximum daily load (TMDL) issued in August 2001 and amended in August 2012 (ODEQ 2012) based on a variety of factors, including salmonid thermal and water quality requirements. In addition to wastewater treatment plant monitoring, the applicable permits include conditions for watershed-wide in-stream water quality monitoring as well as biological and physical monitoring to ensure that state water quality standards are maintained.

2.5.2 Effects on Critical Habitat

Designated critical habitat within the action area for ESA-listed salmon and steelhead considered in this opinion consists of freshwater rearing sites and freshwater migration corridors and their essential physical and biological features (PBFs) as listed below. The effects of the proposed action on these features are summarized as a subset of the habitat-related effects of the action that were discussed more fully above. Due to the similar life histories and biology of the species considered in the opinion, the effects on critical habitat are generally described collectively.

Freshwater rearing sites

Water quantity – The proposed action will reduce water quantity, particularly between WRWTP and the confluence of the Tualatin River, where the primary source of return flows will re-enter the Willamette River. The greatest effect will be between June and September, and during low flow years. Small numbers of ESA-listed juveniles are likely to be in the Willamette River, but due to increased temperatures most juveniles have moved to habitats with cooler water temperatures.

Floodplain connectivity – The proposed action will have no effect on floodplain connectivity.

Water quality – In the short term, the proposed action may slightly decrease water quality due to increased sedimentation from construction. Over the long term, sedimentation will decrease as disturbed areas are revegetated. Although the proposed action is likely to slightly exacerbate the water temperature problem in the Willamette River downstream of the intake, state water quality standards will be maintained.

Forage – The proposed action is not likely to have an effect on forage due to limited substrate in the construction area at the new intake. Substrate in this area is largely bedrock and lacks the interstitial spaces to host significant number of invertebrate prey items. Any ESA-listed fish in the action area will have ample opportunities to forage outside the immediate construction areas.

Natural cover – Natural cover will be reduced from removal of trees for construction. Cover will be increased over the long term due to replanting of riparian areas.

Freshwater migration corridors

Water quantity – The proposed action will reduce water quantity, particularly between WRWTP and the confluence of the Tualatin River, where the primary source of return flows will re-enter the Willamette River. The greatest effect will be between June and September, and during low flow years. This reduction in water quantity is likely to adversely affect this PCE. Due to decreased flows from water withdrawals, adult migration in the Willamette River is likely to be delayed as described above.

Free passage – The proposed action will not obstruct fish passage. However, reductions in flow may delay passage for adult fish holding in the action area as discussed above.

Water quality – In the short term, the proposed action may slightly decrease water quality due to increased sedimentation from construction. Over the long term, sedimentation will decrease as disturbed areas are revegetated. Increased levels of suspended sediment are not likely to constitute a barrier to adult or juvenile migration. Increased water withdrawals will slightly increase water temperatures in the Willamette River downstream of the intake, likely delaying migration of UWR Chinook and steelhead. Although the proposed action is likely to slightly exacerbate the water temperature problem in the Willamette River downstream of the intake, state water quality standards will be maintained.

Natural cover – Natural cover will be temporarily reduced from removal of a few trees for construction. Cover will be increased over the long term due to replanting of riparian areas.

2.6 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline (Section 2.4).

A large variety of land uses and development activities occurs in the project action areas, such as agriculture, forestry activities, commercial and residential development, and transportation and utility infrastructure development, maintenance, and upgrading. Additional development projects are expected to occur in the future in accordance with anticipated population growth and land use planning (this water supply project is planned to respond to the growth anticipated by Metro—the regional government—as a result of recent urban growth boundary expansions and urban reserve land use designations). These activities will contribute to cumulative effects predominately as a result of their impacts on stormwater quality and quantity. Future development projects would be subject to local design and construction standards and would, therefore, need to meet environmental standards.

Gradual habitat and water quality improvements may also occur over time within the action areas, such as conservation measures, riparian plantings, and habitat enhancement. Such improvements would likewise contribute to cumulative effects through their beneficial impacts on ESA-listed salmonid habitat.

Future private or municipal water diversions affecting the action area surrounding the RWF would result in cumulative effects, because increased water withdrawals could have the potential to lower streamflows in ESA-listed salmonid habitat below current levels. Streamflows in the action area are already affected, in part, by water supply and water withdrawal projects that appropriate water from the Willamette River and its tributaries above or within the vicinity of the existing WRWTP intake, as described in Section 2.4.

In addition to the proposed project, the applicants have identified 52 existing water use permits for municipal purposes with authorized points of diversion above Willamette Falls. These permits represent authorizations to use water that are generally not fully developed (construction is not complete and/or the full amount of water authorized is not being used). The portions of these municipal use permits that could reasonably be expected to be developed, and therefore would have a reasonably foreseeable impact on future streamflow, were determined through review of publicly available state and local government documents. These documents included water system master plans and water management and conservation plans, which typically have a 20-year planning period.

If all of the reasonably foreseeable portions of the permits discussed above were developed, it would result in the diversion of approximately 99.4 cfs to 104.9 cfs, depending on the month. The rate varies by month, because two of the permits identified do not authorize water use year-round. These rates of diversion would not correspond to combined flow reductions at the Newberg gage, however, because after water is used for municipal purposes, the water is typically treated and returned to the stream.

The amount of overall reduction in streamflow is the portion of the diverted water that is consumptively used (i.e., lost to evapotranspiration, evaporation). According to the Oregon Water Resources Department, the typical consumptive use for municipal water suppliers in the Willamette River Basin is considered to be 45 percent during the summer months (June through September) and 15 percent the remainder of the year. As a result, the combined reduction in streamflow that would result from reasonably foreseeable municipal water diversions (not associated with this proposed action) would range from 15.58 cfs in February to 47.2 cfs in June. These reasonably foreseeable diversions result in a maximum reduction in streamflow of 0.76 percent. When these reasonably foreseeable diversions are combined with the estimated streamflow reduction during a dry year from the project's 150 mgd intake capacity, the maximum overall reduction in streamflow is estimated to be 4.62 percent (0.76 percent + 3.86 percent in the month of September).

2.7 Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution, or (2) appreciably diminishes the value of designated or proposed critical habitat for the conservation of the species.

UWR Chinook salmon and UWR steelhead are at a moderate risk of extinction. The UWR steelhead DPS has several viable populations while the UWR Chinook has one viable population and several populations at very high risk. As explained in our effects analysis, construction activities as part of the proposed action will affect only a small number of the fish from populations of these two species because: (1) UWR steelhead are found only in the Willamette River portion of the action are, (2) a very small number of UWR Chinook salmon would be in the action area to experience the short term construction-related effects of the action, and, (3) the action area is marginal rearing habitat at best and the reduction of stream flow resulting from the proposed action is not likely to impact more than a tiny portion of the UWR Chinook salmon and UWR steelhead juveniles rearing within the Willamette River basin. Impacts from water withdrawals should not affect these two species due to their migration timing not occurring during low flow periods. Therefore, the effects of the action on UWR Chinook salmon and UWR steelhead will be minor and cause no appreciable impact on population abundance or productivity.

In our analysis above, we determined that the construction related effects, including from driving piles with an impact hammer, increased turbidity and salvaging fish from the work area will directly or indirectly harass, injure or kill a small number of juvenile UWR Chinook and steelhead. The few adults and juveniles that are likely to be injured or killed due to the action are too few to cause a measurable effect on the long-term abundance, productivity, genetic diversity, or spatial diversity of any affected population. This is primarily because the number of fish within the action area during construction activities will be extremely small when compared to the total abundance of individuals within each the populations affected by this action. Therefore, the effects of the proposed action will not reduce the productivity or survival of the affected populations of UWR Chinook salmon and UWR steelhead, even when combined with a degraded environmental baseline and additional pressure from cumulative effects and climate change.

Future increases in water withdrawals are likely to impact temperature and flow in the Willamette River as explained in our effects analysis. Temperature and flow are already impacted by activities analyzed in the baseline section of this opinion, including the system's current water withdrawals of up to 130 cfs.

Increasing the RWF intake capacity from 70 mgd to 150 mgd will result in a minor reduction in flows in the Willamette River. Most of the water rights with points of diversion at the existing WRWTP intake have fish persistence conditions recommended by ODFW. These conditions are developed to maintain the persistence of fish species that are listed as sensitive, threatened, or endangered under state or federal law. Permits S-49240, S-54940, and S-45565 all have fish persistence conditions that reduce or, in the case of Beaverton's permit (Permit S-54940), prohibit access to water when streamflow at Salem is below the fish flow targets. Fish persistence conditions govern 91 percent of the combined maximum authorized rate of diversion at the existing intake. These water rights and their fish persistence conditions were described in detail above.

Because of the fish persistence conditions associated with the water rights at the existing intake, access to water is reduced when fish flow targets are not met, which generally occurs in spring and summer, and the resulting percent of streamflow diverted will range from 1.14 percent (April

16 through April 30) to 3.70 percent (August) of streamflow in average years and from 1.30 percent (April 1 through April 15) to 3.86 percent (September) of streamflow in dry years. Because the action area is not high quality rearing habitat for these species during these time periods, most UWR Chinook and steelhead juveniles are expected to stay in or move to better quality rearing habitats so that adverse impacts due to water withdrawals would have no measurable effect on the VSP parameters for these species.

Temperature within the intake action area is influenced primarily by the existing operation of the PGE Willamette Falls Hydroelectric Project and formation of the Newberg Pool. The Newberg Pool slows down the velocity and heating/cooling process, which decreases the temperature variability in the reach of the WRWTP intake. The model scenario demonstrated that the impact of 150 mgd withdrawal is below the 0.3-degree threshold for 7DADM water temperature in the Willamette River. The largest difference in 7DADM water temperatures across the Middle and Lower Willamette Rivers at any time was 0.078 degrees C. Thus, additional withdrawals by the proposed action, taken together with cumulative withdrawals, could make temperatures higher. However, these temperature effects are expected to be slight when measured against the baseline.

The environmental baseline is such that ESA-listed species considered in this opinion in the action area are exposed to reduced water quality, lack of suitable riparian and aquatic habitat, and restricted movement due to developed urban areas and land use practices. These stressors, as well as those from climate change, already exist and the effects of the action are in addition to these significant limiting factors in the baseline, which for both UWR Chinook and steelhead include lack of functioning riparian conditions, large wood, and habitat diversity.

Cumulative effects in the action area include some additional habitat degradation caused by human development as well as localized habitat improved resulting from improved industry practices or restoration projects. On balance, we expect these cumulative effects to have a relatively neutral effect on population abundance trends and the quality and function of critical habitat PCEs. Cumulative effects from water withdrawals are also expected and are discussed below.

The value of critical habitat for these species in the UWR is limited by poor water quality, altered hydrology, lack of floodplain connectivity and shallow-water habitat, and lack of complex habitat to provide forage and cover. The action area is in an urban area where the habitat has been degraded due to past land use practices including stormwater runoff and industrial and urban development. Despite this, the critical habitat in the action area has a high conservation value for UWR Chinook salmon and UWR steelhead due to its critical role for rearing and migration.

The same effects of the proposed action that will have an effect on ESA-listed salmon and steelhead will also have an effect on critical habitat PBFs for salmon and steelhead critical habitat. The proposed action is likely to result in the short-term reduction in the quality and function of critical habitat PBFs in the action area during construction due to water quality, free passage, and forage effects. Trees and riparian vegetation removed for the intake area and driveway will reduce water quality and forage. Riparian plantings proposed for site revegetation may provide some benefits, but these will not be realized until future decades, so we do not consider the beneficial effects in this analysis.

The effects of this action will not lower the quality and function of the necessary habitat attributes in the action area over the long term. At the watershed scale, the proposed action will not increase the extent of degraded habitat within the basin, add to the degradation of water quality, or further decrease limited rearing areas or limit access to rearing habitat. Even when cumulative effects and climate change are included, the proposed action will not negatively influence the function or conservation role of critical habitat at the watershed scale. Critical habitat for UWR Chinook salmon and UWR steelhead will remain functional, or retain the current ability for the PBFs to become functionally established, to serve the intended conservation role for the species, in this case, to provide freshwater rearing sites and migration corridors.

For all the reasons described in the preceding paragraphs of this section, the proposed action will not appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction or distribution nor will the proposed action reduce the value of designated critical habitat for the conservation of the species.

2.8 Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of LCR Chinook, UWR Chinook, UCR spring-run Chinook, SR fall run Chinook, SR spring/summer Chinook salmon, CR chum, LCR coho, SR sockeye, LCR steelhead, UWR steelhead, MCR steelhead, UCR steelhead, SRB steelhead, Southern green sturgeon, or Southern eulachon, or destroy or adversely modify their designated critical habitats.

2.9 Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the reasonable and prudent measures and terms and conditions of this ITS.

2.9.1 Amount or Extent of Take

In the biological opinion, NMFS determined that incidental take is reasonably certain to occur as follows:

- Capture and relocation of juvenile fish of all ESA-listed species considered in this opinion during construction of the WWSS during in-water work area isolation.
- Harm to juvenile fish of all ESA-listed species considered in this opinion during construction of the WWSS due to the hydroacoustic impacts from vibratory pile driving, and temporary increases in suspended sediment and associated contaminants during pile installation and removal.
- Harm to juvenile fish of all ESA-listed species considered in this opinion due to continued operation of the WWSS, including the water quantity and quality effects of continued water withdrawals.

Capture of juvenile fish during work area isolation

The proposed action calls for the isolation of five in-water work areas, one for the raw water intake and one at each of the four open trench crossings. NMFS expects that each work area isolation is likely to result in the capture and relocation of juvenile fish, and the immediate or delayed injury or death of up to 31 individual juvenile salmon or steelhead, for a total of 155 individual juvenile salmon or steelhead.

Harm from impairing habitat

Take caused by the habitat-related effects of this program cannot be accurately quantified as a number of fish because the distribution and abundance of fish that occur within the action area are affected by habitat quality, competition, predation, amongst others. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, the distribution and abundance of fish within the action area cannot be attributed entirely to habitat conditions, nor can we precisely predict the number of fish that are reasonably certain to be injured or killed if their habitat is modified or degraded. Additionally, there is no practical way to count the number of fish affected without causing additional stress and injury. To estimate the extent of these forms of take, NMFS uses the take surrogates identified below.

Here, the best available indicator for the extent of incidental take are:

- For harm associated with hydroacoustic impacts from vibratory and impact pile driving, the take surrogate is the total number of impact strikes that will be necessary to construct the intake. Assuming that 10 piles will be driven, and that each will require 600 hammer impacts to install, the anticipated take will be exceeded if impact hammer use exceeds 6000 strikes.
- For harm associated with an increase in suspended sediments, the take surrogate is the extent of suspended sediment plumes. Specifically, the anticipated take will be exceeded if increased suspended sediment from pile installation and removal causes suspended sediment plumes 300 feet from the boundary of the new intake, or any other point of in-water work, construction activities to exceed 5 NTU over the background level for two consecutive monitoring intervals.
- For harm associated with continued operation of the WWSS, including the water quantity and quality effects of continued water withdrawals, the take surrogate is the

maximum withdrawal analyzed. Specifically, the anticipated take will be exceeded if water withdrawals at the raw water intake exceed 150 mgd, or a maximum withdrawal rate of 232 cfs.

These features best integrate the likely take pathways associated with this action, are proportional to the anticipated amount of take, and are the most practical and feasible indicators to measure. In particular, the number of impact hammer strikes is directly correlated to the potential for harm due to hydroacoustic impacts, and thus the number of individuals harmed due to pile installation. The extent of suspended sediment plumes rationally reflects the amount of take from suspended sediment and associated contaminants caused by disturbance of sediment that is in the riparian area, streambank, or active channel because larger sediment plumes are correlated with greater exposure to a larger number of individual fish. The extent of water withdrawal, expressed as daily volume or rate of withdrawal, is related to harm that water withdrawal for the WWSS will cause due to reduced flow and increased temperature or other water quality impacts associated with return flows.

2.9.2 Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.9.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02). The Corps or the applicant shall implement the following Reasonable and Prudent Measures that are necessary and appropriate to minimize the impact of incidental take of listed species from the proposed action:

1. Minimize incidental take from project construction by applying conditions to the proposed action that avoid or minimize construction impacts.
2. Minimize incidental take from project operation by applying conditions to the proposed action that avoid or minimize impacts due to the effects of water withdrawal.
3. Ensure completion of a monitoring and reporting program to confirm that the take exemption for the proposed action is not exceeded, and that the terms and conditions in this incidental take statement are effective in minimizing incidental take.

2.9.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and the Corps or any applicant must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). The Corps or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this incidental take statement (50 CFR 402.14). If the following terms and conditions are not complied with, the protective coverage of section 7(o)(2) will likely lapse.

1. To implement reasonable and prudent measure #1 (construction), the Corps shall ensure that the applicant will:
    a. Work Window. Perform all construction activities below OHW during the designated in-water work windows as follows:
        i. Willamette River: June 1–October 31
        ii. Willamette River tributaries: July 15–October 15
        iii. Tualatin River tributaries: July 15–September 30
    b. Notice to Contractors. Before beginning work, provide all contractors working on site with a complete list of Corps permit special conditions, reasonable and prudent measures, and terms and conditions intended to minimize the amount and extent of take resulting from in-water work.
    c. Minimize Impact Area. Confine construction impacts to the minimum area necessary to complete the project.
    d. Conservation Measures. Carry out all relevant conservation measures from the proposed action section of this opinion and avoidance and minimization measures as described in the biological assessment.
    e. Fish Capture. The following measures shall be taken during salvage of any ESA-listed fish:
        i. All fish shall be captured and released from the isolated area using trapping, seining, electrofishing, or other methods as are prudent to minimize risk of injury, then released at a safe release site before excavation work commences.
        ii. A fishery biologist experienced with work area isolation and competent to ensure the safe handling of all ESA-listed fish must conduct or supervise the entire capture and release operation.
        iii. If electrofishing equipment is used to capture fish, the capture team must comply with NMFS' electrofishing guidelines.
        iv. The capture team must handle ESA-listed fish with extreme care, keeping fish in water to the maximum extent possible during seining and transfer procedures to prevent the added stress of out-of-water handling.
        v. Captured fish must be released as near as possible to capture sites.
        vi. ESA-listed fish may not be transferred to anyone except NMFS personnel, unless otherwise approved in writing by NMFS.
        vii. The NMFS or its designated representative must be allowed to accompany the capture team during the capture and release activity, and must be allowed to inspect the team's capture and release records and facilities.
    f. Pile Driving Sound Attenuation: Use one of the following sound attenuation methods when using an impact pile driver, or other methods that have been demonstrated to have the same or better sound attenuation, as approved by NMFS:
        i. Completely isolate the pile from flowing water by dewatering the area around the pile.
        ii. If water velocity is less than 1 knot (1.7 feet per second), surround the piling being driven by a confined or unconfined bubble curtain (see NMFS and USFWS 2006, Würsig *et al*. 2000, and Longmuir and Lively 2001)

that will distribute small air bubbles around 100% of the piling perimeter for the full depth of the water column.

iii. If water velocity is 1 knot (1.7 feet per second) or greater, surround the piling being driven by a confined bubble curtain (*e.g.*, a bubble ring surrounded by a fabric or non-metallic sleeve) that will distribute air bubbles around 100% of the piling perimeter for the full depth of the water column.

2. To implement reasonable and prudent measure #2 (project operations), the applicant shall ensure that maximum water withdrawals at the raw water intake do not exceed 150 mgd or a maximum withdrawal rate of 232 cfs.

3. To implement reasonable and prudent measure #3 (monitoring and reporting), the Corps shall ensure that the applicant completes the following monitoring and reporting:
    a. <u>Annual monitoring and reporting</u>. To be carried out each year until project completion, including the following information
        i. Fish capture
            1. Name and contact information for supervisory fish biologist
            2. Fish capture location
            3. Site description
            4. Fish salvage methods
            5. Fish captured, by species, age, and condition, including any incidence of observed fish injury or death
        ii. Pile driving
            1. Name and contact information for pile driving foreman
            2. Project area and pile removal or installation locations
            3. Dates of initiation and completion of pile driving
            4. Number, size, and type of pile removed or installed
            5. Impact pile installation
                a. Type of sound attenuation used
                b. Total number of impacts per pile
            6. Vibratory pile removal or installation
                a. Total number of minutes of vibration per pile removed
                b. Total number of minutes of vibration per pile installed
        iii. Turbidity
            1. Name and contact information for monitoring technician
            2. Type of equipment used
            3. Observational data for baseline and compliance sites
            4. Description of any corrective action taken
        iv. Water withdrawals
            1. Daily flow volume and withdrawal rate at the raw water intake
            2. Daily temperature, and 7-day average of the daily maximum (7DADM) at the raw water intake
        v. Any other data or analyses the applicant deems necessary or helpful to assess habitat trends as a result of actions authorized under this opinion.

b. Water withdrawals monitoring. To be carried out for an additional ten years following project completion.
c. Reporting. Submit annual monitoring and water withdrawal reports for each calendar year no later than March 15 of the following calendar year, to the following address:

> Oregon/Washington Coast Area Office
> National Marine Fisheries Service
> Attn: WCR-2017-7795
> 1201 NE Lloyd Blvd., Ste. 1100
> Portland, Oregon 97232-1274

2.10 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). The following recommendation is a discretionary measure that is consistent with this obligation and therefore should be carried out by the Corps:

> The Corps should conduct an analysis to determine the relationship between streamflow in tributaries of the Willamette River and the essential behavioral patterns of ESA-listed salmon and steelhead, including breeding, spawning, rearing, migrating, feeding, or sheltering. Establishment of those flows will help determine the amount of water available in the Willamette River for appropriation to new out-of-stream consumptive uses without impairing streamflows necessary to ensure the survival and recovery of ESA-listed salmon and steelhead.

Please notify NMFS if the Corps carries out this recommendation so that we will be kept informed of actions that are intended to improve the conservation of listed species or their designated critical habitats.

2.11 Reinitiation of Consultation

This concludes formal consultation for the Willamette Water Supply System.

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

3. MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the Corps and descriptions of EFH for Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The proposed action and action area for this consultation are described in the Introduction to this document. The action area includes areas designated as EFH for various life-history stages of coho and Chinook salmon (PFMC 1999).

3.2 Adverse Effects on Essential Fish Habitat

Based on information provided by the action agency and the analysis of effects presented in the ESA portion of this document, NMFS concludes that proposed action will have the following adverse effects on EFH designated for Pacific Coast salmon:

1. Short-term increase in underwater noise from proofing of steel pipe piles using an impact hammer.
2. Short-term increase in turbidity from in-water work.
3. Long-term decrease in flow, increase in water temperature, and decrease in other water quality conditions due to continuing water withdrawals.

3.3 Essential Fish Habitat Conservation Recommendations

The following conservation measures are necessary to avoid and minimize the impact of the proposed action on EFH. These recommendations include measures previously provided in the ESA portion of this document.

We recommend the Corps and applicant implement:

1. Term and Condition #1 in the ESA portion of this document to minimize adverse effects of construction on EFH.

2. Term and Condition #2 in the ESA portion of this document to minimize the adverse effects of continuing water withdrawals on EFH.

3. Term and Condition #3 in the ESA portion of this document to monitor the impacts of construction and water withdrawals on EFH.

NMFS expects that fully implementing these EFH conservation recommendations would protect, by avoiding or minimizing the adverse effects described in Section 3.2 above, to designated EFH for Pacific coast salmon.

3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Corps must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations unless NMFS and the Federal agency have agreed to use alternative time frames for the Federal agency response. The response must include a description of measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5 Supplemental Consultation

The Corps must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH Conservation Recommendations (50 CFR 600.920(l)).

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion is the Corps. Other interested users could include permit applicants, citizens of affected areas, or others interested in the conservation of the affected species. Individual copies of this opinion were provided to the Corps. The format and naming adheres to conventional standards for style.

4.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130, the Computer Security Act, and the Government Information Security Reform Act.

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased, and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. REFERENCES

Abatzoglou, J.T., Rupp, D.E. and Mote, P.W. 2014. Seasonal climate variability and change in the Pacific Northwest of the United States. Journal of Climate 27(5): 2125-2142.

Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10.

Alpers, C.N., R.C. Antweiler, H.E. Taylor, P.D. Dileanis, and J.L. Domagalski (editors). 2000a. Volume 2: Interpretation of metal loads.*In:* Metals transport in the Sacramento River, California, 1996-1997, Water-Resources Investigations Report 00-4002. U.S. Geological Survey. Sacramento, California.

Alpers, C.N., R.C. Antweiler, H.E. Taylor, P.D. Dileanis, and J.L. Domagalski (editors). 2000b. Volume 1: Methods and Data.*In:* Metals transport in the Sacramento River, California, 1996-1997, Water-Resources Investigations Report 99-4286. U.S. Geological Survey. Sacramento, California.

Anderson, C.R., and J.A. Reyff. 2006. Port of Oakland Berth 23 – Underwater sound measurement data for the driving of sheet steel piles and square concrete piles: November 17 and December 3, 2005. Illingsworth and Rodkin, Inc. Petaluma, California.

Anderson, J.J. 1990. Assessment of the risk of pile driving to juvenile fish. Fisheries Research Institute, University of Washington. Presented to the Deep Foundations Institute, Seattle, WA.

Barrett, M.E., R.D. Zuber, E.R. Collins, J.F. Malina, R.J. Charbeneau, and G.H. Ward (editors). 1993. A review and evaluation of literature pertaining to the quantity and control of pollution from highway runoff and construction. 2nd edition. Center for Research in Water Resources, Bureau of Engineering Research, University of Texas at Austin. Austin, Texas.

Berg, L., and T.G. Northcote. 1985. Changes In Territorial, Gill-Flaring, and Feeding Behavior in Juvenile Coho Salmon (Oncorhynchus kisutch) Following Short-Term Pulses of Suspended Sediment. Canadian Journal of Fisheries and Aquatic Sciences 42:1410-1417.

Birtwell I.K., G. F. Hartman, B. Anderson, 0, J. McLeay, and J. G.Malick. 1984. A Brief Investigation of Arctic Grayling (Thymallus arcticus) and Aquatic Invertebrates In the Minto Creek Drainage, Mayo, Yukon Territory: An Area Subjected to Placer Mining Department of Fisheries and Oceans, Fisheries Research Branch, West Vancouver Laboratory. Canadian Technical Report Fisheries and Aquatic Sciences. No. 1287

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 in: W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

Buckler, D.R., and G.E. Granato. 1999. Assessing biological effects from highway-runoff constituents. U.S. Geological Survey, Open File Report 99-240. Northborough, Massachusetts. 45 p.

Caldwell, J. M., and Doyle, M. C. 1995. Sediment Oxygen Demand in the Lower Willamette River, Oregon, 1994. U.S. Geological Survey (USGS) Water Resources Investigations Report 95-4196. Portland, OR.

Caltrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August. 9 p.

Cannon, K. 2008. Email from Ken Cannon, Oregon Department of Transportation transmitting ODOT 2007 Fish Salvage Report. Personal Communication to Marc Liverman, National Marine Fisheries Service. July 29, 2008.

Cannon, K. 2012. Email from Ken Cannon, Oregon Department of Transportation transmitting ODOT 2012 Fish Salvage Report. Personal Communication to Marc Liverman, National Marine Fisheries Service. February 4, 2012.

Center for Watershed Protection, and Maryland Department of the Environment. 2000 (revised 2009). 2000 Maryland stormwater design manual: Volumes I and II. Maryland Department of the Environment. Baltimore, Maryland. http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx.

City of West Linn. 2014. Tualatin River TMDL Implementation Plan 2014-2019. Revised June 2014.

Clean Water Services (CWS). 2017. Annual Report, 2015-2016.

Colman, J.A., K.C. Rice, and T.C. Willoughby. 2001. Methodology and significance of studies of atmospheric deposition in highway runoff. U.S.G. Survey, Open-File Report 01-259. Northborough, Massachusetts. 63 p.

Cramer, Michelle L. (managing editor). 2003. Integrated Streambank Protection Guidelines. Washington Department of Fish and Wildlife. Published by Washington State Aquatic Habitat Guidelines Program 2002. Available online at: http://wdfw.wa.gov/publications/pub.php?id=00046.

Cramer, Michelle L. (managing editor). 2012. Stream Habitat Restoration Guidelines. Co-published by the Washington Departments of Fish and Wildlife, Natural Resources, Transportation, and Ecology, Washington State Recreation and Conservation Office, Puget Sound Partnership, and the U.S. Fish and Wildlife Service. Olympia, WA. Available online at: http://wdfw.wa.gov/publications/01374/wdfw01374.pdf.

Crozier, L.G., Hendry, A.P., Lawson, P.W., Quinn, T.P., Mantua, N.J., Battin, J., Shaw, R.G. and Huey, R.B., 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. *Evolutionary Applications* 1(2): 252-270.

Crozier, L. G., M. D. Scheuerell, and E. W. Zabel. 2011. Using Time Series Analysis to Characterize Evolutionary and Plastic Responses to Environmental Change: A Case Study of a Shift Toward Earlier Migration Date in Sockeye Salmon. *The American Naturalist* 178 (6): 755-773.

Dominguez, F., E. Rivera, D. P. Lettenmaier, and C. L. Castro. 2012. Changes in Winter Precipitation Extremes for the Western United States under a Warmer Climate as Simulated by Regional Climate Models. *Geophysical Research Letters* 39(5).

Dolat, S.W. 1997. Acoustic measurements during the Baldwin Bridge demolition. Prepared for White Oak Construction by Sonalysts, Inc, Waterford, CT.. 34 p. plus appendices. March 14.

Doney, S. C., M. Ruckelshaus, J. E. Duffy, J. P. Barry, F. Chan, C. A. English, H. M. Galindo, J. M. Grebmeier, A. B. Hollowed, N. Knowlton, J. Polovina, N. N. Rabalais, W. J. Sydeman, and L. D. Talley. 2012. Climate Change Impacts on Marine Ecosystems. *Annual Review of Marine Science* 4: 11-37.

Driscoll, E.D., P.E. Shelley, and E.W. Strecher. 1990. Pollutant loadings and impacts from highway runoff, Volume III: Analytical investigation and research report. Federal Highway Administration, Office of Engineering and Highway Operations Research and Devlepment. FHWD-RD-88-008. McLean, Virginia.

Enger, P.S., H.E. Karlsen, F.R. Knudsen, and O. Sand. 1993. Detection and reaction of fish to infrasound. Fish behavior in relation to fishing operations. ICES Marine Science Symposia 196:108-112.

EPA (Environmental Protection Agency). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA.

FISRWG (Federal Interagency Stream Restoration Working Group). 1998. Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 federal agencies of the US gov't). GPO Item No. 0120-A, SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3. October 1998.

Feely, R.A., T. Klinger, J.A. Newton, and M. Chadsey (editors). 2012. Scientific summary of ocean acidification in Washington state marine waters. NOAA Office of Oceanic and Atmospheric Research Special Report.

Fresh, K.L., E. Casillas, L.L. Johnson, and D.L. Bottom. 2005. Role of the estuary in the recovery of Columbia River Basin salmon and steelhead: An evaluation of the effects of selected factors on salmonid population viability. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-69. 105 p.

Glick, P., J. Clough, and B. Nunley. 2007. Sea-Level Rise and Coastal Habitats in the Pacific Northwest: An analysis for Puget Sound, southwestern Washington, and northwestern Oregon. National Wildlife Federation, Seattle, WA.

Goniea, T.M., Keefer, M.L., Bjornn, T.C., Peery, C.A., Bennett, D.H. and L. C. Stuehrenberg 2006. Behavioral Thermoregulation and Slowed Migration by Adult Fall Chinook Salmon in Response to High Columbia River Water Temperatures, Transactions of the American Fisheries Society, 135:2, 408-419

Goode, J.R., Buffington, J.M., Tonina, D., Isaak, D.J., Thurow, R.F., Wenger, S., Nagel, D., Luce, C., Tetzlaff, D. and Soulsby, C., 2013. Potential effects of climate change on streambed scour and risks to salmonid survival in snow-dominated mountain basins. *Hydrological Processes* 27(5): 750-765.

Gustafson, R. G., L. Weitkamp, YW. Lee, E. Ward, K. Somers. V. Tuttle, and J. Jannot. 2016. Status Review Update of Eulachon (*Thaleichthys pacificus*) Listed under the Endangered Species Act: Southern Distinct Population Segment. US Department of Commerce, NOAA, Online at: http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/other_species/eulachon/eulachon_2016_status_review_update.pdf

Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity. U.S. Department of Commerce, NOAA Fisheries, NOAA Technical Memorandum NMFS-NWFSC-83. 39 p.

Hirschman, D., K. Collins, and T. Schueler. 2008. Technical Memorandum: The Runoff Reduction Method. Center for Watershed Protection. Ellicott City, Maryland. April 18. http://www.region9wv.com/Bay/Calculators/RRTechMemo.pdf.

Isaak, D.J., Wollrab, S., Horan, D. and Chandler, G., 2012. Climate change effects on stream and river temperatures across the northwest US from 1980–2009 and implications for salmonid fishes. *Climatic Change* 113(2): 499-524.

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

ISAB (Independent Scientific Advisory Board) (editor). 2007. Climate change impacts on Columbia River Basin fish and wildlife. *In:* Climate Change Report, ISAB 2007-2. Independent Scientific Advisory Board, Northwest Power and Conservation Council. Portland, Oregon.

Johnson, L.L., G.M. Ylitalo, M.R. Arkoosh, A.N. Kagley, C.L. Stafford, J.L. Bolton, J. Buzitis, B.F. Anulacion, and T.K. Collier. 2007. Contaminant exposure in outmigrant juvenile salmon from Pacific Northwest estuaries. Environmental Monitoring and Assessment 124:167-194

Kayhanian, M., A. Singh, C. Suverkropp, and S. Borroum. 2003. Impact of annual average daily traffic on highway runoff pollutant concentrations. Journal of Environmental Engineering 129:975-990.

Keefer, M.L , Peery, C.A., Jepson, M.A., Tolotti, K.R., Bjornn, T.C. and L. C. Stuehrenberg. 2004. Stock-Specific Migration Timing of Adult Spring–Summer Chinook Salmon in the Columbia River Basin, North American Journal of Fisheries Management, 24:4, 1145-1162

Keefer, M.L., Peery, C.A. and C. C. Caudill. 2008. Migration Timing of Columbia River Spring Chinook Salmon: Effects of Temperature, River Discharge, and Ocean Environment, Transactions of the American Fisheries Society, 137:4, 1120-1133

Knudsen, F.R., C.B. Schreck, S.M. Knapp, P.S. Enger, and O. Sand. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. Journal of Fish Biology, 51:824-829.

Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K. T. Redmond, and J. G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 6. *Climate of the Northwest U.S. NOAA Technical Report NESDIS 142-6*. 83 pp. National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington, D.C.

Lawson, P. W., Logerwell, E. A., Mantua, N. J., Francis, R. C., & Agostini, V. N. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences* 61(3): 360-373

Lloyd, D.S., J.P. Koenings, and J.D. LaPerriere. 1987. Effects of Turbidity in Fresh Waters of Alaska. North American Journal of Fisheries Management 7: 18-33.

Loge, F., M.R. Arkoosh, T.R. Ginn, L.L. Johnson, and T.K. Collier. 2006. Impact of environmental stressors on the dynamics of disease transmission. Environmental Science & Technology 39(18):7329-7336.

Longmuir, C., and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 p.

Lower Columbia River Estuary Partnership. 2007. Lower Columbia River and estuary ecosystem monitoring: Water quality and salmon sampling report. Portland, Oregon. http://www.estuarypartnership.org/sites/default/files/resource_files/WaterSalmonReport.pdf

Mantua, N., I. Tohver, and A. Hamlet. 2009. Impacts of Climate Change on Key Aspects of Freshwater Salmon Habitat in Washington State. *In* The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, edited by M. M. Elsner,J. Littell, L. Whitely Binder, 217-253. The Climate Impacts Group, University of Washington, Seattle, Washington.

Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change* 102(1): 187-223.

McCullough, D.A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. EPA 910-R-99-010.

McLeay, D.J., G.L. Ennis, I.K. Birtwell, and G.F. Hartman. 1984. Effects On Arctic Grayling (*Thymallus arcticus*) of Prolonged Exposure to Yukon Placer Mining Sediment: A Laboratory Study. Canadian Technical Report of Fisheries and Aquatic Sciences 1241.

McLeay, D.J., I.K. Birtwell, G.F. Hartman, and G.L. Ennis. 1987. Responses of Arctic Grayling (*Thymallus arcticus*) To Acute and Prolonged Exposure to Yukon Placer Mining Sediment. Canadian Journal of Fisheries and Aquatic Sciences 44: 658-673.

McMahon, T.E., and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 46: 1551–1557.

McMichael, G.A., A.L. Fritts, and T.N. Pearsons. 1998. Electrofishing injury to stream salmonids, injury assessment at the sample, reach, and stream scales. North American Journal of Fisheries Management 18:894-904.

Meyer, J.L., M.J. Sale, P.J. Mulholland, and N.L. Poff. 1999. Impacts of climate change on aquatic ecosystem functioning and health. *JAWRA Journal of the American Water Resources Association* 35(6): 1373-1386.

MWH (Montgomery, Watson, Harza). 2016. HEC-RAS modeling for May 2016 presentation to USACE, NMFS, and ODFW.

Mote, P.W, A. K. Snover, S. Capalbo, S.D. Eigenbrode, P. Glick, J. Littell, R.R. Raymondi, and W.S. Reeder. 2014. Ch. 21: Northwest. In Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, T.C. Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 487-513.

Mote, P.W., D.E. Rupp, S. Li, D.J. Sharp, F. Otto, P.F. Uhe, M. Xiao, D.P. Lettenmaier, H. Cullen, and M. R. Allen. 2016. Perspectives on the cause of exceptionally low 2015 snowpack in the western United States, Geophysical Research Letters, 43, doi:10.1002/2016GLO69665

National Cooperative Highway Research Program. 2006. Evaluation of Best Management Practices for Highway Runoff Control. Transportation Research Board. NCHRP Report 565. Washington, D.C. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_565.pdf.

NMFS (National Marine Fisheries Service). 2005. Assessment of NOAA Fisheries' critical habitat analytical review teams for 12 evolutionarily significant units of West Coast salmon and steelhead. NMFS, Protected Resources Division, Portland, Oregon.

NMFS (National Marine Fisheries Service). 2009b. Middle Columbia River steelhead distinct population segment ESA recovery plan. National Marine Fisheries Service, Northwest Region. Seattle.

NMFS (National Marine Fisheries Service). 2011a. Anadromous Salmonid Passage Facility Design. Available at: http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_passage_design_criteria.pdf

NMFS (National Marine Fisheries Service). 2011b. Upper Willamette River conservation and recovery plan for Chinook salmon and steelhead. Oregon Department of Fish and Wildlife and National Marine Fisheries Service, Northwest Region.

NMFS (National Marine Fisheries Service). 2013. ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead. National Marine Fisheries Service, Northwest Region. June

NMFS (National Marine Fisheries Service). 2015a. Proposed ESA Recovery for Snake River Fall Chinook Salmon. West Coast Region, Protected Resources Division, Portland, OR, 97232.

NMFS (National Marine Fisheries Service). 2015b. ESA Recovery Plan for Snake River Sockeye Salmon. West Coast Region, Protected Resources Division, Portland, OR.

NMFS (National Marine Fisheries Service). 2015c. Southern Distinct Population Segment of the North American Green Sturgeon (*Acipenser medirostris*) 5-Year Review: Summary and Evaluation. West Coast Region, Long Beach, California. 42 p.

NMFS (National Marine Fisheries Service). 2016. 2016 5-Year Review: Summary & Evaluation of Upper Willamette River Steelhead, Upper Willamette River Chinook. West Coast Region, Portland, Oregon.

NMFS (National Marine Fisheries Service). 2016a. Proposed ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon and Snake River Steelhead. West Coast Region, Protected Resources Division, Portland, OR.

NMFS (National Marine Fisheries Service). 2017. Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, OR, 97232. September.

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2006. Impact pile driving sound attenuation specification. Revised October 31, 2006. National Marine Fisheries Service and U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office. Lacey, Washington.

NWFSC (Northwest Fisheries Science Center). 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest.

ODEQ (Oregon Department of Environmental Quality). 2006. Willamette Basin TMDL.

ODEQ (Oregon Department of Environmental Quality). 2012. Tualatin Subbasin TMDL.

ODFW (Oregon Department of Fish and Wildlife). 1992. Tualatin River Subbasin Fish Management Plan. Available online at: http://www.trwc.org/water/docs/efiles.pdf.

ODFW (Oregon Department of Fish and Wildlife). 1999. Geographic Information System (GIS) fish distribution overlays.

ODFW (Oregon Department of Fish and Wildlife). 2012. Fish Distribution Maps. Natural Resources Information Management Program.

OWRD (Oregon Water Resources Department). Background Information on Municipal Extensions and Fish Persistence. Updated March 8, 2017. https://olis.leg.state.or.us/liz/2017R1/Downloads/CommitteeMeetingDocument/105362. Accessed July 26, 2018.

PFMC (Pacific Fish Management Council). 1999. Description and identification of essential fish habitat, adverse impacts and recommended conservation measures for salmon. Appendix A to Amendment 14 to the Pacific Coast Salmon Plan. Pacific Fishery Management Council. Portland, Oregon. http://www.pcouncil.org/salmon/fishery-management-plan/adoptedapproved-amendments/amendment-14-to-the-pacific-coast-salmon-plan-1997/.

PFMC (Pacific Fish Management Council). 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon.

Popper, A. N., Carlson, T. J., Hawkins, A. D., Southall, B. L. and Gentry, R. L. 2006 Interim criteria for injury of fish exposed to pile driving operations: a white paper.

Raymondi, R.R., J.E. Cuhaciyan, P. Glick, S.M. Capalbo, L.L. Houston, S.L. Shafer, and O. Grah. 2013. Water Resources: Implications of Changes in Temperature and Precipitation. *In* Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, edited by M.M. Dalton, P.W. Mote, and A.K. Snover, 41-58. Island Press, Washington, DC.

Reeder, W.S., P.R. Ruggiero, S.L. Shafer, A.K. Snover, L.L Houston, P. Glick, J.A. Newton, and S.M Capalbo. 2013. Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines. *In* Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, edited by M.M. Dalton, P.W. Mote, and A.K. Snover, 41-58. Island Press, Washington, DC

Reyff, J.A. 2007. Underwater sound from marine pile driving. Effects of noise on aquatic life, Session 6: Anthropogenic sources. Nyborg, 13-17 August.

Richter, A. and S.A. Kolmes. 2005. Maximum Temperature Limits for Chinook, Coho and Chum Salmon and Steelhead Trout in the Pacific Northwest. Reviews in Fisheries Science 13:23-49.

Rickert, D. A. 1940. A Synoptic survey of trace metals in bottom sediments of the Willamette River, Oregon. (River quality assessment of the Willamette River Basin, Oregon.)

Rounds, S. A., and Wood, T. M. 2001. Modeling Water Quality in the Tualatin River, Oregon, 1991–97: U.S. Geological Survey Water-Resources Investigations Report 01–4041, 53 pp.

Sand, O., P.S. Enger, H.E. Karlsen, F. Knudsen, and T. Kvernstuen. 2000. Avoidance responses to infrasound in downstream migrating European silver eels, Anguilla anguilla. Environmental Biology of Fishes, 57:327-336.

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science & Technology 41(8):2998-3004.

Scannell, P.O. 1988. Effects of Elevated Sediment Levels from Placer Mining on Survival and Behavior of Immature Arctic Grayling. Alaska Cooperative Fishery Unit, University of Alaska. Unit Contribution 27.

Scheuerell, M.D., and J.G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (Oncorhynchus tshawytscha). Fisheries Oceanography 14:448-457.Shared Strategy for Puget Sound. 2007. Puget Sound salmon recovery plan. Volume 1, recovery plan. Shared Strategy for Puget Sound. Seattle.

Servizi, J.A., and D.W. Martens. 1991. Effects of temperature, season, and fish size on acute lethality of suspended sediments to coho salmon. Canadian Journal of Fisheries and Aquatic Sciences 49:1389-1395.

Smoker, W.W., I.A. Wang, A.J. Gharrett, and J.J. Hard. 2004. Embryo survival and smolt to adult survival in second-generation outbred coho salmon. Journal of Fish Biology 65 (Supplement A):254-262.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approachto salmonid conservation. ManTech Environmental Research Services, Inc., Corvallis, Oregon, to National Marine Fisheries Service, Habitat Conservation Division, Portland, Oregon (Project TR-4501-96-6057).

Spromberg, J.A., and J.P. Meador. 2006. Relating chronic toxicity responses to population-level effects: A comparison of population-level parameters for three salmon species as a function of low-level toxicity. Ecological Modeling 199:240-252.

Spromberg, J.A. and N.L. Scholz. 2011. Estimating future decline of wild coho salmon populations resulting from early spawning die-offs in urbanizing watersheds of the Pacific Northwest. Integrated Environmentalal Assessment and Management 7:648-656.

Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 p. plus appendices.

Strange, J.S. 2010. Upper Thermal Limits to Migration in Adult Chinook Salmon: Evidence from the Klamath River Basin. Transactions of the American Fisheries Society. 139:1091–1108.

Sunda, W. G., and W. J. Cai. 2012. Eutrophication induced CO2-acidification of subsurface coastal waters: interactive effects of temperature, salinity, and atmospheric p CO2. *Environmental Science & Technology*, 46(19): 10651-10659

Tague, C. L., Choate, J. S., & Grant, G. 2013. Parameterizing sub-surface drainage with geology to improve modeling streamflow responses to climate in data limited environments. Hydrology and Earth System Sciences 17(1): 341-354

Tillmann, P., and D. Siemann. 2011. Climate Change Effects and Adaptation Approaches in Marine and Coastal Ecosystems of the North Pacific Landscape Conservation Cooperative Region. National Wildlife Federation.

Thorstad, E.B., Økland, F. Aarestrup, K and T. G. Heggberget. 2008. Factors affecting the within-river spawning migration of Atlantic salmon, with emphasis on human impacts. Rev Fish Biol Fisheries. 18:345–371

Tualatin River Watershed Council. 2016. Annual Report, 2014-2015.

USACE (U.S. Army Corps of Engineers). Willamette Basin Review Feasibility Study, Appendix A: Municipal & Industrial Demand and Supply Analyses. Portland District, Portland, Oregon. (November 2017).

USDC (United States Department of Commerce). 2009. Endangered and threatened wildlife and plants: final rulemaking to designate critical habitat for the threatened southern distinct population segment of North American green sturgeon. U.S. Department of Commerce, National Marine Fisheries Service. Federal Register 74(195):52300-52351.

USDC (United States Department of Commerce). 2011. Endangered and threatened species: designation of critical habitat for the southern distinct population segment of eulachon. U.S. Department of Commerce, National Marine Fisheries Service. Federal Register 76(203):65324-65352.

Upper Columbia Salmon Recovery Board. 2007. Upper Columbia spring Chinook salmon and steelhead recovery plan.

USFWS (U.S. Fish and Wildlife Service). 2016. Tualatin River National Refuge Website. Updated September 10, 2016. Available online at: https://www.fws.gov/refuge/tualatin_river/.

Wainwright, T. C., and L. A. Weitkamp. 2013. Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. *Northwest Science* 87(3): 219-242.

Winder, M. and D. E. Schindler. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. Ecology 85: 2100–2106

Würsig, B., C.R. Greene Jr., and T.A. Jefferson. 2000. Development of an air bubble curtain to reduce underwater noise from percussive piling. Marine Environmental Research 49:19-93.

Zabel, R.W., M.D. Scheuerell, M.M. McClure, and J.G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology 20(1):190-200