Attachment 3:

Fish Passage Design Report to Inform SEPA

Chehalis River Basin Flood Control Zone District

February 4, 2026

Fish Passage Design Report to Inform SEPA

Chehalis River Basin Flood Damage Reduction Project

Lewis County, Washington

February 4, 2026

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Appendix A. In-Water Work Steps During Construction TM

Appendix B. Juvenile Fish Sounding TM

Appendix C. Fishway Lighting TM

Appendix D. Backwater Analysis Pool Frequency with Conduit Gates Open (Draft) TM

Acronyms

AWS	auxiliary water supply
cfs	cubic feet per second
Ecology	Washington state Department of Ecology
FFPF	Flood Fish Passage Facility
ft/s	feet per second
FRE	Flood Retention Expandable
FRFA	Flood Retention Flow Augmentation
ft-lbs/sec/ft3	foot-pounds per second per cubic foot
gpm	gallons per minute
HDR	HDR Engineering, Inc.
NOAA	National Oceanic and Atmospheric Administration
RDEIS	Revised Draft Environmental Impact Statement
RPDR	Revised Project Description Report
SEPA	State Environmental Policy Act
Subcommittee	Fish Passage Subcommittee
TM	Technical Memo
TWG	Technical Working Group
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geologic Survey
WDFW	Washington Department of Fish and Wildlife

1 Background

The Proposed Chehalis River Basin Flood Damage Reduction project (Proposed Project) objective is to implement a series of measures aimed at reducing damage to the communities of the Chehalis River Basin from Pe Ell to Cosmopolis during major flood events. Among these measures is a proposed Flood Retention Expandable (FRE) structure on the Chehalis River, south of Pe Ell, Washington.

Following submittal of the Revised Project Description Report (HDR Engineering, Inc. [HDR] 2024), a Chehalis River Basin Flood Damage Reduction draft Preliminary Design Report (PDR) was initiated to document ongoing draft design refinements, as the design process iterates toward a future 30 percent design that will be documented in a completed PDR. The draft PDR records ongoing draft design decisions, assumptions, and methods related to the development of the design of the FRE structure and related elements and collects technical details of the main features of the Proposed Project elements as they continue to develop.

A SEPA Revised Draft Environmental Impact Statement (RDEIS) for the Proposed Project was issued on November 20, 2025 with comments due February 4, 2026. To support the submission of comments on the SEPA RDEIS, some draft design elements are being formalized in reports and memoranda to describe the current state of the project design. While still not at a full 30 percent preliminary design level, these elements are at a point at which they can reasonably inform tribal governments, state and federal agencies, partners, stakeholders, and the public about the nature of the project.

2 Introduction

The proposed FRE structure includes the following fish passage components, designed to provide passage for a range of species and life stages:

- Flood Fish Passage Facility (FFPF)
- Fishways
- Fish passage conduits
- Temporary channels
- Permanent channels

The fish passage design documented herein focuses on the design updates to the outlet works, which includes the fishways and fish passage conduits. Design updates to these features include updates to the design criteria to comply with current standards and updates to previous concept-level design development. This document also includes a performance and survival assessment for fish passage during normal flow-through operation, flood retention operation, and construction. Finally, the document provides a brief description of a plan and timeline to advance the fish passage design to inform the final Biological Assessment. These activities were performed in collaboration with

Washington Department of Fish and Wildlife (WDFW) and National Oceanic and Atmospheric Administration (NOAA) Fisheries and in conjunction with other physical, biological, and engineering studies and analyses to refine the FRE Proposed Project design, evaluate potential flood damage reduction, and minimize and avoid environmental impact. The Fish Passage Technical Working Group (TWG) also provided input through design update meetings.

3 Purpose and Intent

The integration of fish passage systems is a central component of the flood damage reduction structure design. Washington State's regulatory authority defined in Revised Code of Washington 77.57.030, (Fishways required in dams, obstructions – Penalties, remedies for failure) requires that dam owners provide safe and timely fish passage for all fish species and fish life stages present in an affected area. No aquatic species are federally listed as endangered or threatened on this part of the Chehalis River. However, spring and fall Chinook salmon are prey items for the endangered Southern Resident Killer Whale.

Fish passage facility design has occurred simultaneously with facility design efforts throughout the development of the Revised Project Description Report (RPDR). This report summarizes the results and conclusions for select, critical elements of fish passage concept development performed in previous documents, including the RPDR and identifies a roadmap for fish passage design development. The information provided in and appended to this document is intended to be used by the Washington Department of Ecology (Ecology) in development of the final State Environmental Policy Act Environmental Impact Statement.

4 Design Criteria

This section describes the criteria used for the preliminary design of fish passage components for the Proposed Project. Previous development identified design criteria based on contemporary design guidance, collaboration with regulatory agencies and nonregulatory entities, and contemporary science. The previously developed design criteria have been updated to reflect current design guidance, science, and collaboration. Future design development will use contemporary guidelines, and the design will be updated accordingly. Refer to Section 7 for additional information regarding potential design criteria revision.

This section notes design criteria that have been confirmed, added to, removed from, or revised from previously published documents.

4.1 Collaboration with Technical Committees

From 2016 to 2017, the fish passage design team and members of the Chehalis Basin Strategy Flood Damage Reduction Technical Committee held nine Fish Passage Subcommittee (Subcommittee) meetings. During development of the RPDR in 2023 and

2024, the Fish Passage TWG was formed to continue coordination with members of the Subcommittee. Two TWG meetings were held during development of this study.

The TWG meetings were forums for information transfer, detailed discussion, and making recommendations to the District about the biological and technical aspects of the fish passage facility alternative development. Of primary importance were the discussion, interpretation, and formulation of design criteria.

Participants attending the Subcommittee and TWG meetings included representatives from the following organizations:

- WDFW (Subcommittee and TWG participant)
- U.S. Fish and Wildlife Service (USFWS) (Subcommittee and TWG participant)
- USACE (Subcommittee and TWG participant)
- NOAA Fisheries (Subcommittee and TWG participant)
- Washington Department of Ecology (Subcommittee and TWG participant)
- Quinault Indian Nation (Subcommittee participant; invited to participate in TWG)
- Cowlitz Indian Tribe (invited to participate in TWG)
- State of Washington Consultant Study Team (Subcommittee and TWG participant)

The Quinault Indian Nation and Confederated Tribes of the Chehalis Reservation have been invited to participate in the TWG; but at the time this document was written, neither has attended or participated in these meetings.

In addition to the Subcommittee and TWG meetings, the District's design team met separately with WDFW and NOAA Fisheries to discuss specific design aspects. From 2023 through 2025 the District's design team met with NOAA Fisheries 16 times to gather input from NOAA Fisheries on the proposed design refinements. Topics discussed in the meetings included implementation of the NOAA Fisheries climate change design guidance (NOAA Fisheries 2023a); one, two, and three-dimensional hydraulic modeling results of the proposed conduits, fishways, modifications to the permanent river channel, construction bypass channels, and existing river reaches; dual dedicated fishways; and fish sounding (Appendix B) and lighting (Appendix C). NOAA Fisheries input is reflected in the fish passage design documented in this report.

4.2 Biological Design Criteria

In 2016, the Washington State legislature created the Chehalis Basin Strategy, tasking participants with "designing and implementing on-the-ground projects to restore aquatic habitats and protect residents from flood damage." As part of the Chehalis Basin Strategy, WDFW has led an extensive field sampling program to collect data and better understand the phenology, abundance, habitat requirements, distribution, and migration patterns of fish present within the Chehalis River and, more specifically, in the potentially affected areas of the FRE structure and temporary inundation limits. Using new and historically available data, WDFW assisted the Subcommittee with biological criteria development, including the following three primary types with the most influence on facility type, size, and configuration:

- **Selected Species and Migration Timing:** Informs the selection of species and life stages targeted for fish passage design and their seasonality, anticipated hydrologic conditions, and the timing of when the target fish species may be expected to migrate upstream and/or downstream of the facility location.
- **Species Abundance:** Informs the annual number of fish and peak daily rate of migration that the facility is designed to pass and that influences facility size and operation requirements. For clarity, species abundance numbers used in designing the fishway *do not represent current or predicted future species abundance* in the Proposed Project vicinity. Rather, these numbers were used to provide a conservative passage design that will meet passage needs under a variety of potential future fish abundance conditions.
- **Trapping and Holding Criteria:** Informs the requirements for fish trapping and holding volume, duration, temperature, and water supply.

Biological design criteria, including the above-listed bullet points, are discussed in the following subsections.

4.2.1 General Biological Design Criteria

General biological design criteria apply to all project components where fish passage must be maintained (i.e., dedicated fishways, fish passage conduits, FFPF, permanent Chehalis River and Crim Creek channels, and Chehalis River and Crim Creek construction bypass channels), unless stated otherwise.

4.2.1.1 Selected Species and Migration Timing

The selection of fish species and life stages for fish passage design was derived from field-specific data obtained by WDFW in 2015 and 2016 and readily available historical documentation developed for the Chehalis Basin. In general, Washington State interprets the Revised Code of Washington 77.57.030 to require provisions for passage of all fish and fish life stages believed to be present in the system.

For development of the general upstream and downstream fish passage criteria, anadromous and resident species known to occur in the vicinity of the FRE structure, in the temporary inundation area, and upstream of the temporary inundation area were selected as target species. These target species and their known swimming and leaping abilities were used to develop specific technical design criteria. Of the target species, salmonids, cutthroat trout, and lamprey were identified as priority species due to the greater abundance of biological, swim, and leaping data available for them as well as their importance to federal regulators and indigenous peoples. Other species known to occur downstream of the FRE site were selected for consideration but did not directly influence the development of specific technical design criteria.

The life histories and specific life stages of each target species were also considered relative to their known occurrence, distribution, and movement through the FRE site. Life stages of specific species were selected if they have been observed moving or are believed to move through the FRE site (either upstream or downstream).

Table 1 presents the selected target fish species and their respective life stages.

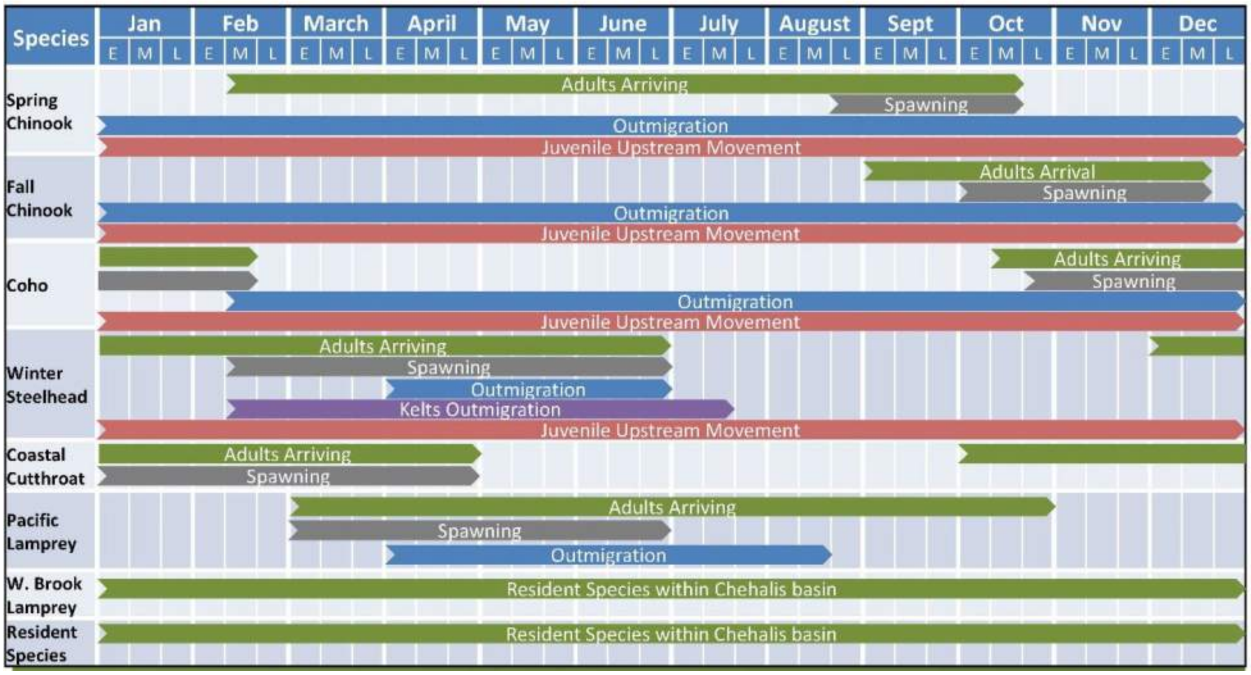
Table 1. Target Fish Species and Life Stages Selected for Design Development

Species	Upstream	Downstream
Spring-run Chinook Salmon	Adult, juvenile	Juvenile
Fall-run Chinook Salmon	Adult, juvenile	Juvenile
Coho Salmon	Adult, juvenile	Juvenile
Winter-run Steelhead	Adult, juvenile	Adult, juvenile
Coastal Cutthroat Trout	Adult, juvenile	Adult, juvenile
Pacific Lamprey	Adult	Ammocoetes, Macropthalmia
Western Brook Lamprey	Adult	Ammocoetes, Macropthalmia
Resident Fish: river lamprey, largescale sucker, Salish sucker, torrent sculpin, reticulate sculpin, riffle sculpin, prickly sculpin, speckled dace, longnose dace, peamouth, northern pikeminnow, redside shiner, rainbow trout, mountain whitefish	Adult	Adult

Passage technologies for lamprey are relatively new, and few facilities exist in the western United States for passage or collection and transport above dams. Where applicable, readily available best practices, lessons learned from experimental facilities on the Columbia River, and interviews with researchers who specialize in understanding lamprey behavior and navigational capabilities were used to inform lamprey passage facility requirements and anticipated performance. In addition to salmonids and the anadromous Pacific lamprey, multiple resident fish species and two species of resident lamprey (Western Brook and River) are believed to inhabit and transit the proposed FRE area (Table 1). Therefore, these resident species are also included as target species.

Many of the target species have unique migration behaviors and are believed to pass upstream or downstream through the FRE site at specific times of the year. Fish species migration timing and duration influence the design and operation of proposed fish passage facilities by defining the physical, operational, and environmental conditions expected to occur while passage is required. The migration timing and duration for each selected fish species and life stage were discussed at Subcommittee/TWG meetings as new information was collected in the field and from literature sources. The resulting conclusions were used in fish passage design development (Figure 1). The selected values in Figure 1 summarize upstream migration, spawning, and outmigration periods suitable to inform robust fish passage designs. The periods shown in Figure 1 incorporate anecdotal data of species presence at the extreme ends of known movement periods and thereby are anticipated to be broader than what may actually be found in the river. Aquatic target species' actual migration and spawning periods are far more complicated and nuanced.

Figure 1. Anticipated Migration Periods of the Targeted Species and Life Stages (Periodicity)



4.2.1.2 Species Abundance

Fish abundance numbers for use in designing the Proposed Project's fish passage were evaluated by WDFW and discussed during Subcommittee meetings. As previously noted, species abundance numbers used in designing the fishway *do not represent current or predicted future species abundance* in the Proposed Project vicinity. Rather, these numbers were used to provide a conservative passage design that will meet passage needs under a variety of potential future fish abundance conditions. Specifically, abundance was described for the design in terms of peak annual and peak daily rates of migration. The peak daily rate of migration for upstream and downstream migrating fish influences the size of many fish passage components. Documents and information provided by WDFW (2016a and 2016b) during Subcommittee meetings were used in the design development of FFPF component sizes and capacities. The species abundance used in design are summarized in the subsections below.

Upstream Migration

Upstream migration rates developed for fish passage design are based on two factors: 1) historic data relative to adult spawner survey results and escapement records, and 2) proposed annual peak goals after project implementation and potential habitat restoration. Table 2 provides the design peak rate for annual migration of adult salmonids moving upstream.

Table 2. Peak Annual Upstream Migration Numbers Used to Inform FFPF Design

Species	Peak Annual Migration Numbers Informing FFPF Design
Spring-run Chinook Salmon	1,350
Fall-run Chinook Salmon	3,900
Coho Salmon	12,900
Winter-run Steelhead	5,630

The numbers for adult upstream-migrating Pacific lamprey, cutthroat trout, resident fish, and juvenile salmonids were not developed for fish passage design. Although these species are an important influence on the overall design of each fish passage alternative, their peak rate of migration is currently unknown and not anticipated to materially influence facility size, which is based on adult salmonids.

The peak daily counts of salmon and Steelhead migrating upstream were estimated as 10 percent of the maximum annual run (WDFW 1993), and peak hourly counts were estimated as 20 percent of the peak daily count based on Bell (1991) and as cited in NOAA Fisheries (2011). When both criteria results are applied, the peak hourly count is 2 percent of the annual run for each species. Using this methodology and based on the run timing information in Figure 1, a combined peak daily count of roughly 2,000 adult salmonids and a peak hourly count of 400 adult salmonids were used for design purposes.

Downstream Migration

Table 3 summarizes the total juvenile abundance numbers recommended by the TWG for use in the design of downstream fish passage for juvenile salmon and Steelhead, representing sub-adult fish produced upstream of the location selected for the FRE.

Table 3. Abundance[1] of Juvenile Salmon and Steelhead Downstream Migrants from Freshwater Habitat above River Mile 108 of the Chehalis River used to inform FFPF Design

Species	Life Stage	Migration Period	Maximum Abundance Number for FFPF Design
Coho Salmon	Fall parr	September–December	340,000
	Spring smolt	March–June	17,000

[1] Species abundance numbers used in designing the fishway *do not represent current or predicted future species abundance* in the Project vicinity. Rather, these numbers were used to provide a conservative passage design that will meet passage needs under a variety of potential future fish abundance conditions

Species	Life Stage	Migration Period	Maximum Abundance Number for FFPF Design
Steelhead Trout	Fall parr	September–December	97,000
	Spring smolt	March–June	14,500
Chinook Salmon	Subyearling (fry)	January–April	229,000
	Subyearling (parr/smolt)	May–August	114,500
	Yearling	March–June	11,000
Other Species	Data unavailable to support conclusions regarding downstream migration.		

For spring smolts, freshwater capacity and migration timing were used to predict total daily arrivals between January and August using two example migration curves originating from other river systems. Timing curve 1 represented a free-flowing river (Coweeman River), whereas timing curve 2 represented a dammed river where smolts rear in cooler stream temperatures and navigate a reservoir during their downstream migration (Cowlitz River). The daily numbers (mean and maximum values) of downstream migrants used for fish passage design were similar between the two migration timing curves when the considered species were included. However, when only Coho salmon and Steelhead trout were included, mean and maximum values were higher under timing curve 1 than timing curve 2. The difference between the two scenarios results from the smolts of Coho salmon and Steelhead trout having a more protracted migration timing under timing curve 2 than timing curve 1.

For fall migrants, timing curves were not available, and daily numbers were approximated for the design based on available information (WDFW 2016a and 2016b). Daily numbers of fall migrants used for fish passage design were based on the maximum daily values derived for spring smolts of Coho salmon and Steelhead trout increased by a multiplier of 17.0. The resulting maximum daily abundance selected for design purposes is 55,505 smolts as indicated in Table 4. As noted above, these numbers do not represent current or predicted smolt daily abundance numbers and were used to inform FFPF design features only.

Table 4. Daily Numbers of Downstream Migrant Fish Species Used to Inform FFPF Design[2]

Data include: juvenile salmon and steelhead from freshwater habitat upstream of river mile 108 in the Chehalis River.

Daily Metric	Spring Smolts (Jan–Aug)		Spring Smolts (Jan–Aug) Coho and Steelhead Only		Fall Smolts (Sep–Dec) Coho and Steelhead Only	
	Daily Abundance to Inform FFPF Design					
	Timing 1	Timing 2	Timing 1	Timing 2	Timing 1	Timing 2
Mean	1,919	1,882	203	82	3,451	1,394
Maximum	11,013	10,935	3,265	668	55,505	11,356

4.2.1.3 Resident Fish

NOAA Fisheries (2023a) and WDFW (2000a, 2000b) have established guidelines for salmonid passage facility design, but little data exists regarding the passage of lamprey and resident fish species through fish passage facilities. The Subcommittee, with support from the team's USFWS representative, assembled relevant biological data for the target resident species, lamprey, and salmonids but was unable to find data about all target resident species. A summary of the data compiled for each species is provided in Table 5. Through continued collaboration with the TWG, fish passage is being designed to accommodate the resident species listed in Table 5 to the extent possible, without adversely affecting facility performance for priority species (salmonids, cutthroat trout, and lamprey).

Table 5. Locomotive and Biological Data Availability

Species		Data Collected*	
Life Stage	Common Name	Swim Speed	Jump Height
Adult	Spring-run Chinook Salmon	●	●
Adult	Fall-run Chinook Salmon	●	●
Adult	Coho Salmon	●	●
Adult	Winter-run Steelhead	●	●
Juvenile	Spring-run Chinook Salmon	●	●
Juvenile	Fall-run Chinook Salmon	●	●
Juvenile	Coho Salmon	●	●
Juvenile	Winter-run Steelhead	●	●

[2] Species abundance numbers used in designing the fishway *do not represent current or predicted future species abundance* in the Project vicinity. Rather, these numbers were used to provide a conservative passage design that will meet passage needs under a variety of potential future fish abundance conditions

Species		Data Collected*	
Life Stage	**Common Name**	**Swim Speed**	**Jump Height**
Adult	Coastal Cutthroat Trout	●	●
Adult	Pacific Lamprey	●	Not applicable
Adult	Western Brook Lamprey	●	Not applicable
Adult	River Lamprey	●	Not applicable
Adult	Largescale Sucker	●	No data found
Adult	Salish Sucker	●	No data found
Adult	Torrent Sculpin	Not applicable	No data found
Adult	Reticulate Sculpin	Not applicable	No data found
Adult	Riffle Sculpin	Not applicable	No data found
Adult	Prickly Sculpin	Not applicable	No data found
Adult	Speckled Dace	●	No data found
Adult	Longnose Dace	●	No data found
Adult	Peamouth	●	No data found
Adult	Northern Pikeminnow	●	No data found
Adult	Redside Shiner	●	No data found
Adult	Rainbow Trout	●	No data found
Adult	Mountain Whitefish	●	No data found

● = Indicates a data source was identified

4.3 Technical Design Criteria

This section identifies technical design criteria, sources, and guidance for the development of fish passage designs. Technical fish facility design criteria typically fall into two categories: criteria and guidelines. Criteria are specific standards for fish passage design that require an approved variance from the governing state or federal agency before a design can deviate from the established criteria. Deviating from an agency-established criterion requires establishing a site-specific, biological- or physical-based rationale for the deviation.

In contrast, guidelines provide a range of values or specific values the designer should seek to achieve but that can be adjusted for project-specific conditions to achieve the overall fish passage objectives by supporting better performance or solving site-specific issues. Governing agencies may request adjustments to a design during development.

The technical design criteria used in the RPDR were primarily developed in previous design phases and documented in previous design documents. The NOAA Fisheries fish passage design guidance has been updated since the previous design documents. The design criteria in this report and appendices reflects design criteria from the current NOAA Fisheries guidance (2023a). If two or more agencies provide differing guidance on a design criterion, the most conservative guidance for fish passage and protection will be followed. The following documents provide the guidelines used during the previous conceptual design and the current design:

- NOAA Fisheries WCR Anadromous Salmonid Design Manual. (NOAA Fisheries 2023a)
- NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change (NOAA Fisheries 2023c)
- Anadromous Salmonid Passage Facility Design (NOAA Fisheries 2011)
- Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (USFWS 2010)
- Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual (WDFW 2009)
- Fishway Guidelines for Washington State (WDFW 2000a)
- Fish Protection Screen Guidelines for Washington State (WDFW 2000b)
- Water Crossing Design Guidelines (WDFW 2013)

4.3.1 General Technical Design Criteria

Technical design criteria for each fish passage component of the Proposed Project are discussed in the following subsections. General fish passage criteria apply to project components where fish passage must be maintained (i.e., conduits, fishways, FFPF, and construction bypass), unless shown otherwise.

4.3.1.1 Fish Passage Design Flows

Fish passage design flow criteria influence several factors associated with fish passage facility size and complexity. NOAA Fisheries and WDFW provide guidelines for the selection of high and low flows to be used in the design of fish passage facilities. These guidelines are based on exceedance calculations of mean daily flows but can be modified to accommodate site-specific requirements. The exceedance flows statistically represent the flow equaled or exceeded during certain percentages of the time when migrating fish may be present. The established guidelines are used to set instream flow depths, flow velocities, debris and bedload conditions, fish attraction requirements, tailwater fluctuations, and numerous other factors that a facility may experience while target fish species are migrating.

NOAA Fisheries (2023a) requires the high fish passage design flow to be the mean daily stream flow that is exceeded 5 percent of the time during periods when target fish species are migrating using the 90th percentile t-distribution of the late-century ensemble climate change projection. WDFW (2000b) suggests a 10 percent exceedance flow be used as a high design flow using hydrologic analysis of the historic period of record. NOAA Fisheries (2023a) requires a low fish passage design flow equal to the mean daily stream flow that is exceeded 95 percent of the time during periods when migrating fish are typically present using the 90th percentile t-distribution of the late-century ensemble climate change projection. Because using the 90th percentile t-distribution for the 95 percent exceedance resulted in increased, not decreased flows, NOAA Fisheries agreed that the 95 percent exceedance should be based on the late-century ensemble mean. WDFW recommends that a low flow be established based on site-specific conditions using hydrologic analysis of the historic period of record. A flow range between the 95 and 5 percent exceedance flows based on the late-century ensemble of climate change models provides the widest range of flows for which facilities should be capable of passing fish. Therefore, this flow range is set as the design criterion for the proposed facilities.

Per *NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change* (NOAA Fisheries 2023c), the effects of climate change need to be considered when establishing fish passage design flows. As the fish passage conduits have a life expectancy of more than 10 years, the Proposed Project must follow the process for long-term projects defined in Section 2.3 of the guidance. This nine-step process is underway and collaboration with NOAA Fisheries is ongoing at document publication. The current process ends with final design. A NOAA Long-Term Project Climate Change TM (HDR 2026) documents the first seven steps and is available to Ecology upon request. On September 26, 2025, NOAA Fisheries established the fish passage design flows based on this process. The high and low fish passage design flows are 3,200 and 11 cfs, respectively.

4.3.1.2 Sediment Continuity Design Flow

The Chehalis River Basin Flood Control Zone District has committed to maintaining the continuity of movement for spawning gravels passing downstream through the FRE structure. This commitment includes passing river flow at levels capable of mobilizing and transporting spawning gravel in an open channel(s) through the FRE structure. The river flow "capable of fully mobilizing the surface armor layer of spawning substrates…" is identified as the current climate 2-year flood event (Kleinschmidt 2024). Kleinschmidt states the river flow mobilizing spawning gravel is about 6,976 cfs, which corresponds to about a 2-year flood event according to the hydrologic analysis they cite. Recent hydrologic analysis by HDR has identified the Chehalis River flow for the current climate 2-year flood as 9,500 cfs (HDR 2025). The conduits are designed to pass 13,700 cfs, well above 9,500 cfs, in an open channel condition, more than is needed to pass the sediment mobilizing river flow identified by Kleinschmidt.

4.3.1.3 Fish Passage Conduits

At the time of Subcommittee consultations, the fish passage conduits were intended to provide primary, year-round, safe, volitional upstream and downstream passage for migrating adult salmon and Steelhead, resident fish, and lamprey for the full range of fish passage flow conditions as required by NOAA Fisheries criteria. During a 2014 study by

HDR, criteria used to assess the fish passage conduits was based on the 2013 *Water Crossing Design Guidelines* document, which suggests that a minimum hydraulic design target of 0.8 feet of water depth and maximum flow velocity of 2 feet per second (ft/s) be used for water crossing structures with lengths of approximately 200 feet. However, in consultation with members of the Subcommittee in 2015 and 2016, it was determined that the natural flow characteristics in this reach of the river were more restrictive to passage than WDFW's guidelines. It was agreed that the hydraulic conditions in the natural channel upstream and downstream of the passage tunnels (fish passage conduits) would negate the passage benefit of designing the tunnels to WDFW's guidelines. Therefore, the Subcommittee concluded that the proposed flow velocity and depth through the conduits mimic the flow velocity and depth occurring naturally through the existing river reach at the FRE. This premise influenced the overall approach for designing and evaluating performance of upstream and downstream passage through the conduits. As such, the proposed approach cannot be categorized as the hydraulic design method or the stream simulation method but rather a site-specific approach that incorporates elements of both.

This design approach was revisited and presented to WDFW, NOAA Fisheries, and the TWG during the course of this study, who raised no objections. The location of the existing rock-incised channel was shared with the TWG on January 17, 2024.

4.3.1.4 Swimming Capability

Swimming and leaping capabilities for target species were used in developing the draft hydraulic fish passage criteria. The Subcommittee decided fish passage through the FRE during run-of-river conditions must mimic the hydraulic conditions of the existing rock canyon located immediately downstream of the proposed FRE. Specific, measurable criteria to this effect were defined during an April 4, 2025 meeting with NOAA Fisheries. The specific hydraulic design criteria were based on the swim speed of the target species. A table of species' swim speeds was shared and discussed with NOAA Fisheries in a meeting with NOAA Fisheries on March 4, 2025. Discussion in this meeting led to establishing the hydraulic criteria. The hydraulic criteria are grouped into three ranges of river velocity based on the swim capabilities of the target species and life stages:

- 0 to < 1.5 feet per second (ft/s) resident/juvenile salmonid prolonged
- 1.5 to < 3.5 ft/s adult salmonid sustained
- 3.5 to 7 ft/s adult salmonid prolonged

These river velocity ranges and the specific fish passage requirements associated with them have not been finalized with NOAA Fisheries. For this evaluation, the following **draft passage criteria** were used where the river flow was within the fish passage design flow range:

- 0 to < 1.5 ft/s resident/juvenile salmonid prolonged and 1.5 to < 3.5 ft/s adult salmonid sustained.
- A continuous flow pathway **must be provided** through the proposed FRE structure with flow velocities within these ranges where three-dimensional computational fluid

dynamic modeling indicates a continuous pathway exists for this velocity range through the existing rock canyon 3.5 to 7 ft/s adult salmonid prolonged.

- A continuous flow pathway is **preferred but not required** through the proposed FRE structure with flow velocities within these ranges where three-dimensional computational fluid dynamic modeling indicates a continuous pathway exists for this velocity range through the existing rock canyon.

4.3.1.5 Juvenile Fish Sounding

Appendix B (Juvenile Fish Sounding TM) summarizes the research and findings related to the potential risk of juvenile entrainment in the unscreened, high velocity evacuation conduits at this location on the Chehalis River. The research and findings in this Technical Memo (TM) were discussed with NOAA Fisheries in 2025. The TM concludes that most juvenile salmonids likely would not sound deeper than 30 feet in a temporary inundation pool at the FRE structure and would have limited exposure to potential entrainment and flood operation conditions at the FRE. A hydraulic outlet that does not exclude fish or provide safe downstream passage through hydraulically favorable conditions must only discharge flow during flood retention operation when the water surface is 30 feet or more above the top of the same hydraulic outlet. Hydraulic outlets that discharge when the water depth is less than 30 feet must have a smooth inlet transition, such as curved entrances and radial gates. Accordingly, evacuation conduits will remain unscreened and the 30-foot depth threshold be used to govern evacuation operations.

4.3.1.6 Fishways

The original concept of fish passage conduits relied on multiple conduits, arrayed at staggered invert elevations, with different sizing and roughness features to support passage hydraulics across the range of fish passage design discharge. Additionally, these conduits are subject to evaluation criteria related to temporary inundation area evacuation and passage of the 2-year event, which conflict with attempts to optimize for fish passage. To meet design criteria and deconflict competing requirements, a revised conduit and stilling basin configuration is proposed to support fish passage and provide more reliable sediment throughput. This design revision includes dual outboard technical fish ladders as fishways (Figure 3; Section 5.1).

4.3.1.7 Lamprey Passage

As requested by participating resource agencies and Indian Tribes, the best available science for lamprey passage was considered throughout the design. Lessons learned from experimental facilities on the Columbia River, and interviews with researchers who specialize in understanding lamprey behavior and navigational capabilities were used to inform lamprey passage facility requirements, which are summarized in Table 6.

The following resources outline several best practices that were used to form a basis of design for lamprey passage technologies and measures:

- Technical White Paper: Practical Guidelines for Incorporating Adult Pacific Lamprey Passage at Fishways, Version 2.0 (Lamprey Technical Workgroup 2022)
- Use of Adult Pacific Lamprey Passage Structures at Bonneville and John Day Dams (USACE 2019)
- Passage Guidelines for Select Native Pacific Northwest Fish, USFW Region 1, Version 2.0 (USFW 2025)
- Technical Report 2015-5: Design Guidelines for Pacific Lamprey Passage Structures, Portland District (USACE 2015)
- Barriers to Adult Pacific Lamprey at Road Crossings: Guidelines for Evaluating and Providing Passage, Version 1.0 (Lamprey Technical Workgroup 2020)

Table 6. Lamprey Upstream Passage Criteria

Criteria	Value	Reference
Free swimming flow velocity	<2.95-3.9 ft/s	Lamprey Technical Workgroup 2022
Max burst free swimming flow velocity	<8.2-9.8 ft/s	Lamprey Technical Workgroup 2022
Ramp width	1.0 ft, min 2.0 ft, min	Lamprey Technical Workgroup 2022, USACE 2015
Resting area velocity	2.95 ft/s, max	Lamprey Technical Workgroup 2022
Water depth in ramp	1 foot, min	Lamprey Technical Workgroup 2020, USFWS 2025
Wetted Surface Finish	Smooth, 1.2 inch gap, max	USFWS 2025
Diffuser Grating	0.5 inches or less	Lamprey Technical Workgroup 2022

4.3.1.8 Trashracks

Trashracks are commonly used at fishway exits and entrances to prevent large debris from entering fish passage facilities. They are also used at fish passage conduits. Table 7 lists the design criteria for trashracks.

Table 7. Trashrack Criteria

Criteria	Value	Reference
Velocity	1.5 ft/s, maximum	NOAA Fisheries 2023a
Water depth	Equal to fish ladder exit pool depth	

Criteria	Value	Reference
Bar spacing	10 inches, minimum	
Support bar spacing	24 inches, minimum	
Slope	1 horizontal 5 vertical	

4.3.1.9 Constructed Channels

A reference reach design approach to be used for the permanent Chehalis River approach and discharge channels, for Crim Creek confluence, and for the construction phase Chehalis River and Crim Creek bypass channels (WDFW 2013, NOAA Fisheries 2023b). This approach was presented to WDFW, NOAA Fisheries, and the TWG during the course of this study, who raised no objections. The locations of the reference reaches were shown in slides at the January 17, 2024 TWG meeting.

4.3.2 General Operating Criteria

Operational trigger, rules, and frequency for impoundment events is described in the Environmental Impact Reduction Due to Refinement of Proposed Reservoir Operations and Debris Management During Retention Operations TM which is appended to the District's comments on the SEPA RDEIS. "Impoundment events" refer to flood operations triggered by high flows at Grand Mound but do not include backwater events. Backwater events are infrequent events where the river flow exceeds the open-channel capacity of the conduits, and some water is retained upstream of the FRE structure. The number and duration of backwater events that would have occurred during the historic period of record is described in Appendix D - Backwater Analysis Pool Frequency with Conduit Gates Open (Draft) TM.

During impoundment events that coincide with flood retention activities, downstream passage of outmigrating fish will be delayed. During Flood Retention Operations, the conduit gates will be operated to control flow release and retain water upstream of the facility. Outmigrating fish entering the temporary inundation area at this time will also be temporarily delayed until the pool drains and open channel river flow resumes. When the inundation pool depth is lower than the juvenile fish sounding depth, either early as the inundation pool begins filling or when it is almost fully drained, flow must be released through gates designed for fish passage or through outlets that exclude fish passage in accordance with federal and state criteria. When the inundation pool is below sounding depth, some fish may choose to pass downstream via gates designed for fish passage. Downstream passage through conduits with fully open gates will resume when normal operation resumes.

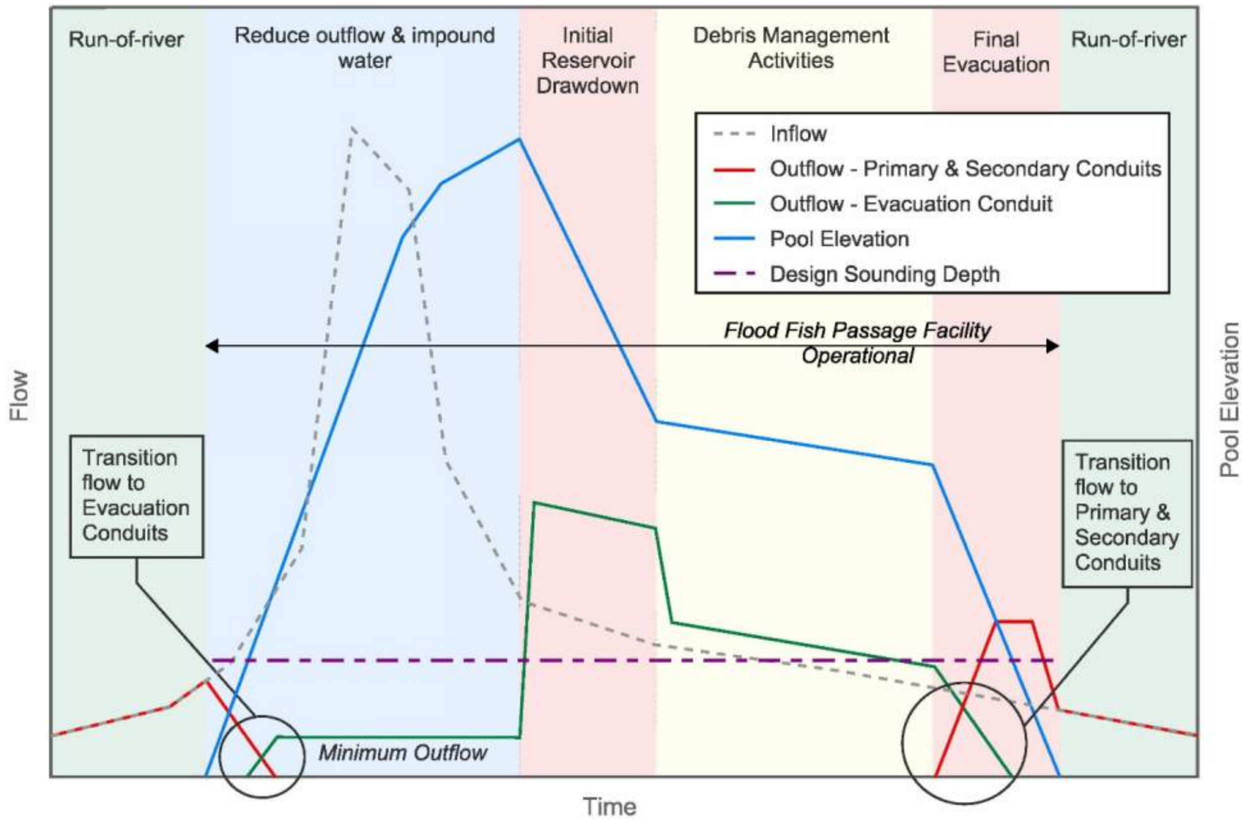
Note that backwater is expected to occur when the river's natural flow is greater than the capacity of the fish passage conduits but not enough at Grand Mound to trigger an impoundment event. Backwater is expected to occur once river flow reaches 13,700 cfs. River flow data was analyzed for the historic period 1982–2022. For this historic period, backwater events are estimated to have occurred on average once every 3.3 years and last an average of 3.6 hours, with the maximum duration being 6.5 hours (Appendix D). Backwater is expected to occur for flows well above the range of flows during which the project must provide fish passage (11 to 3,200 cfs; Section 4.3.1.1). During these temporary pooling (backwater) events, the fish passage conduit gates will not be operated and will remain fully open, and operation of the FFPF will not be required. Fish are anticipated to reside or shelter below the facility during such events (which are short in duration) and continue passage once conditions improve.

4.3.2.1 Water Supply

Water supply for the AWS and FFPF can be provided by pump station or via gravity. The Subcommittee agreed AWS may be provided solely via gravity from the impoundment pool when the impoundment pool depth exceeds the juvenile fish sounding depth. A literature review of juvenile sounding depth was conducted and discussed with NOAA Fisheries. The sounding depth used in the current design, as agreed upon with NOAA Fisheries, is discussed in Section 4.3.1.5, and documented in Appendix B. When the water depth in the inundation pool is less than the design sounding depth, water from the inundation pool must either be screened to exclude fish in accordance with NOAA Fisheries (2023a) and WDFW (2000b) guidance or provided from another source meeting the same screening requirements, such as from a pump station. Figure 2 is a graphed impoundment event example showing unscreened discharge (evacuation conduits) only being used when the impoundment pool depth exceeds the design sounding depth.

The amount of attraction flow required varies with changes in river flow. During FFPF operation all river flow at the FFPF location comes from inundation pool discharge. When the inundation pool discharge is greater than the high fish passage design river flow (refer to Section 4.3.1.1), the FFPF will continue to operate and attraction flow is not required to exceed 300 cfs. Attraction flow must be greater than 5 percent of the river flow for flows below the high fish passage design flow. AWS may not be necessary to meet this requirement at lower river flows as operational flows from the fish ladder may be sufficient to meet attraction flow requirements.

Figure 2. Attraction Water and Auxiliary Water Supply Durations During a Sample Impoundment Event



5 Fish Passage Outlet Works Design

This section summarizes the fish passage outlet works design.

FRE facility operation occurs in two main operational states:

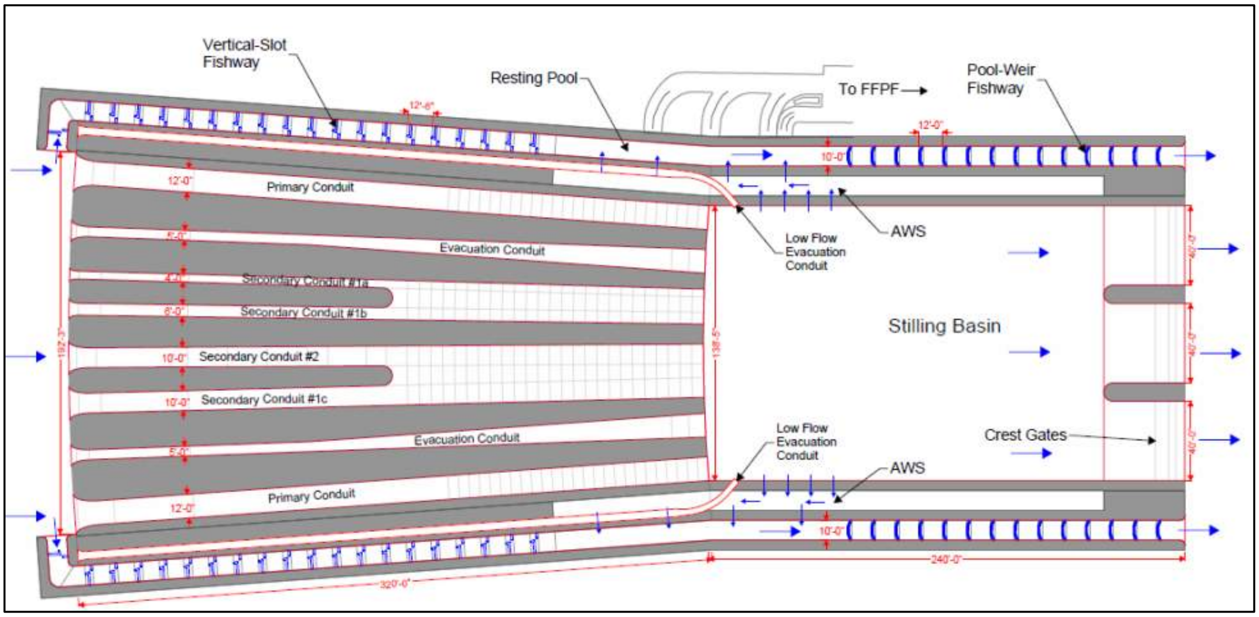
- **Normal Operation:** When the fish passage and hydraulic outlet gates are open and the Chehalis River flows through the FRE unimpeded.
- **Flood Retention Operation:** When the fish passage gates are closed and openings on the hydraulic outlets are reduced to impound incoming floodwaters behind the FRE.

Upstream fish passage during Normal Operation is primarily provided by dual fishways located adjacent to the FRE outlet works. Passage conduits serve as secondary upstream passage pathways and the primary downstream pathway.

5.1 Fishways and Conduits

During Normal Operation, dual fishways serve as the primary feature facilitating upstream fish passage (Figure 3). The entrances to the fishways are located adjacent to the stilling basin endsill crest gates. Following input from NMFS during consultation, these gates are raised for flows within the fish passage design discharge range to serve as a vertical passage barrier. The passage conduits remain open, except under low flow conditions, but function primarily to provide downstream passage to the stilling basin and beyond. Within the range of fish passage flows, the passage conduits will be able to support upstream escape for fish in the stilling basin due to fallback.

Figure 3. Fishway and Passage Conduit Layout

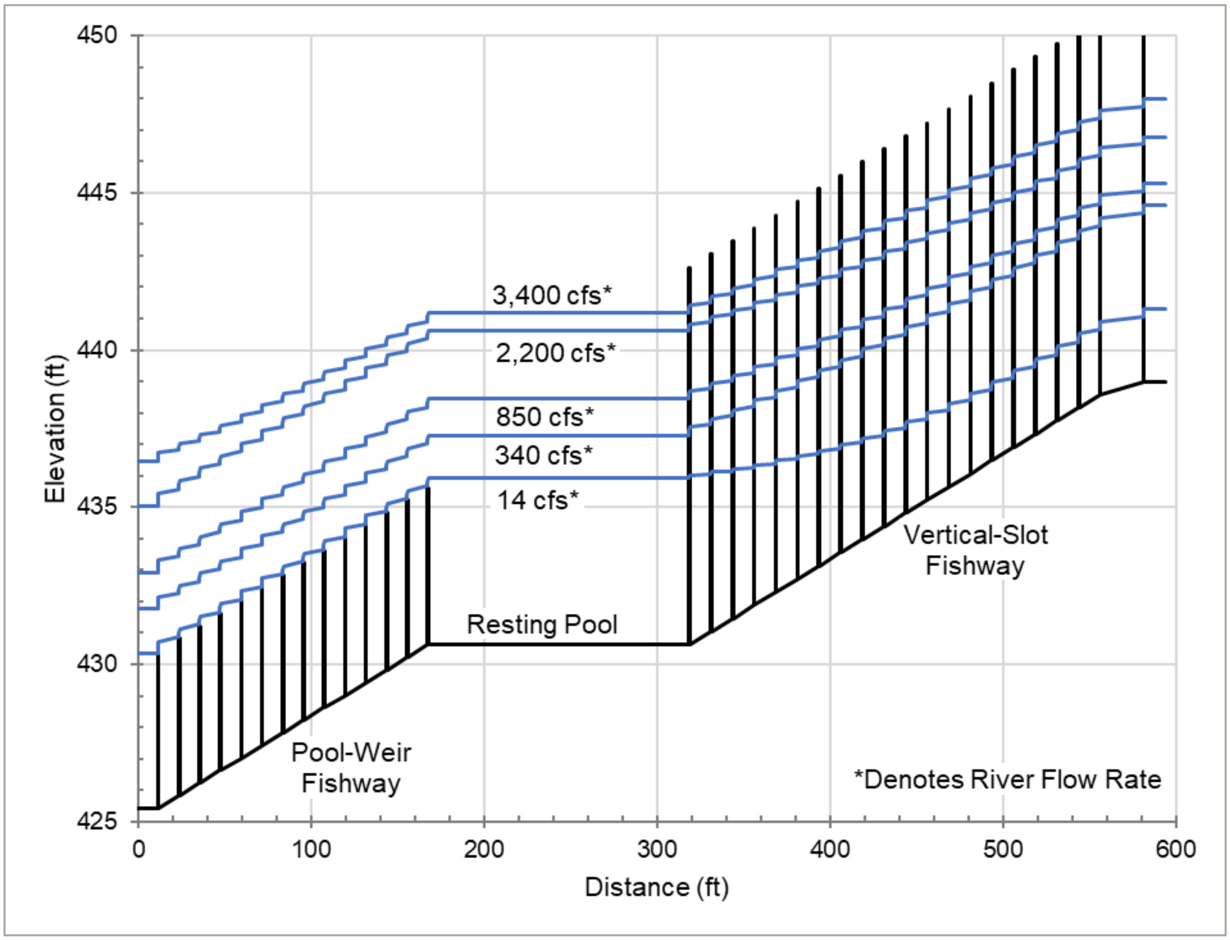


5.1.1 Fishways

Technical fish ladders consist of a concrete fish ladder passing through the FRE structure. The design target hydraulic differential between baffles in the ladder will follow standard agency design guidelines for the upstream passage of juvenile salmonids. Pool geometry will be established using NOAA Fisheries (2023a) guidelines and consider the specific baffle type selected for the ladder. A fish ladder will be composed of typical pools which may include resting pools, turning pools, and potentially multiple exit pools to account for temporary inundation area stage fluctuations. This technology requires consideration of guidance, attraction, and collection strategies for the fish ladder entrance as well as debris, temperature, and flow control provisions.

There will be two fishways on either side of the conduits to provide reliable fish passage upstream of the FRE. The fishways will consist of three main components: the pool-weir, resting pool, and vertical-slot sections. The fishway will be 10 feet wide through all the different sections. The pool-weir section will be at the fish entrance and contain a bent weir with a 90-degree V-notch for low flows. The resting pool will contain a vertical screen for additional flow from the AWS, and fish entrances on the left fishway for the FFPF. The vertical-slot section will continue through to the fish exit and have a slot width of 1.25 feet. Figure 4 shows the water surface elevations through the fishway.

Figure 4. Fishway Water Surface Profiles



5.1.2 Conduits

The fish passage primary and secondary conduits will operate with gates open for downstream fish passage and sediment transport but be closed for Flood Retention Operation. There are some instances where gates are closed to facilitate fish passage at lower flows, when only the fishways are in operation. During initial phases of flood retention, the passage conduit gates will be used to regulate the flow until flow control is transferred to the evacuation conduits. After the passage conduit gates are closed, the evacuation conduit will be used for reservoir releases. The secondary conduits will be used for emergency flood releases or reservoir drawdown when the required capacity is insufficient to meet the required flow.

The passage conduit sizing and configuration will support upstream passage for the fish passage design flow range. Under these conditions, the stilling basin endsill is raised to serve as the tailwater control necessary to support the requisite passage depth and velocity criteria.

5.1.2.1 Controlling Flow Design Scenarios

The controlling flow design scenarios were compiled to better understand and evaluate the effectiveness of the primary, secondary, and evacuation conduits to meet the potential flow requirements. During flow-through conditions, all the gates are fully open, except for during very low flow when only the fishways are operating. During flood retention, the gates are throttled or closed. Special considerations are included to ensure downstream fish passage at sounding depths under a throttled gate. The minimum flow during flood retention can occur at any elevation up to the spillway crest elevation. Design provisions include adding a narrower secondary conduit to facilitate minimum releases at lower pool elevations, and a low-flow evacuation conduit to make minimum releases at pool elevations near the spillway crest elevation. The maximum flow during flood retention is accommodated using the two evacuation conduits. If additional flow is required, then the secondary conduits will be used to supplement the maximum flow. Table 8 provides a high level summary of the controlling flow design scenarios.

Table 8. Controlling Flow Design Scenarios

Description		Value (cfs)
Flood Retention Gates Regulate Outflow	Minimum Flow	300
	Maximum Flow	10,000
Flow-Through Gates Fully Open	Fish Passage Flows	14 – 3,400
	Sediment Mobilization Flow	7,000 – 9,500
	Maximum Flow	13,700

cfs = cubic feet per second.

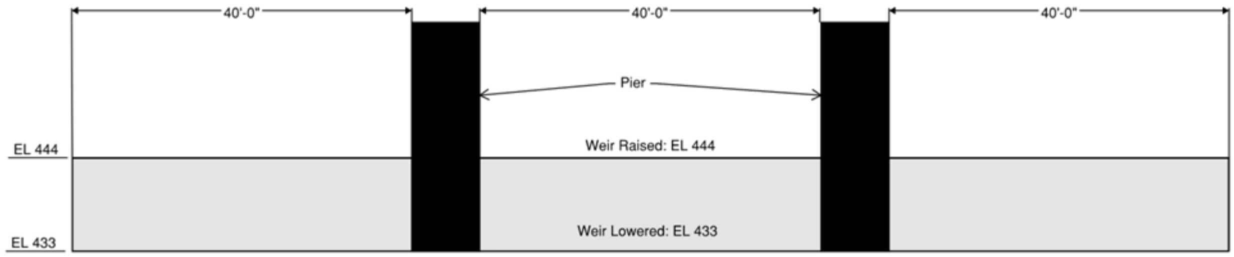
5.1.2.2 Primary and Secondary Conduits

The primary and secondary conduit features, described from downstream to upstream include the end sill, stilling basin, conduit profiles, and conduit entrance.

End Sill Crest Gates

The end sill is intended to provide sufficient backwater to prevent a hydraulic jump from forming within the conduits, thus limiting the velocity in the conduits and providing sufficient depth for fish passage. The end sill will also provide sufficient water depth in the stilling basin to provide the AWS (auxiliary water supply) to the fishways via gravity flow. Lastly, the end sill directs fish toward the fishways providing connectivity to the upstream channel. The end sill will have three 40-foot bays with two piers to house the adjustable crest gates that can be raised or lowered during times of sediment mobilization or fish passage conditions. Figure 5 shows the adjustable end sill crest gates concept.

Figure 5. End Sill Configuration

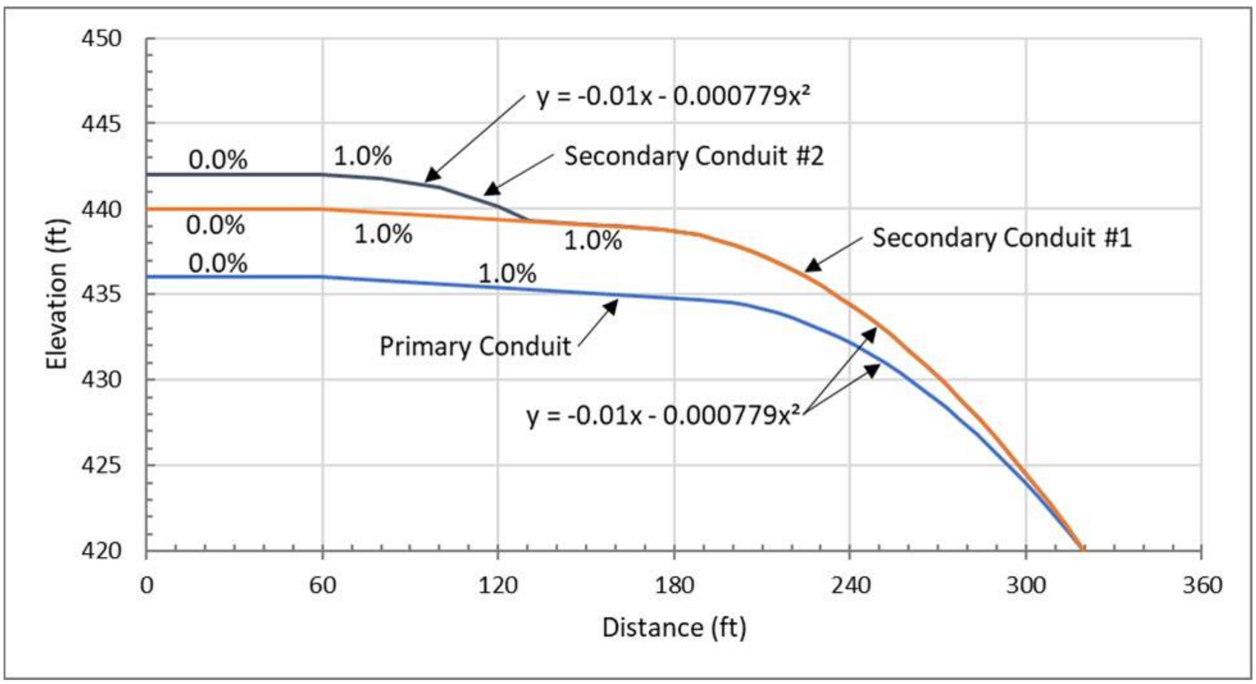


EL: elevation.

Conduit Profiles

The conduit profile is based on three sections, the horizontal section through the gates, a 1 percent slope, and a parabolic profile transitioning the conduit invert elevation into the stilling basin elevation. The parabolic profile is based on the trajectory of a jet under the gravitational forces based on calculated velocities during gate-controlled flows, which provides positive pressures on the invert during all flow events. Figure 6 shows the profile for the primary and secondary conduits.

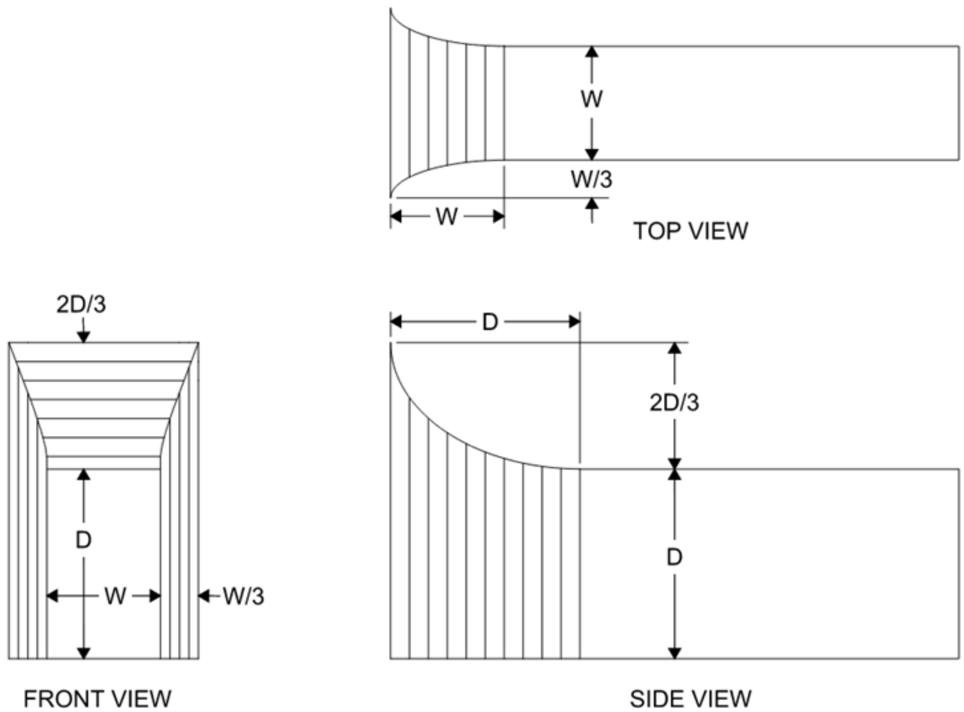
Figure 6. Profiles for Primary and Secondary Conduits



Conduit Entrance Curves

To avoid flow separation and unsatisfactory pressure conditions, a roof curve and sidewall curves were added to the primary and secondary conduit entrances. The roof and sidewall curves are based on an elliptical curve. Figure 7 shows the profile view of the elliptical roof and sidewall entrance curves based on the primary and secondary conduit height and width.

Figure 7. Plan and Section View of Entrance Curves



Conduit Water Surface Profiles

During flow-through conditions, the gates will be fully open with the flow in an open channel state through the structure. Figure 8 through Figure 10 contain the water surface profiles in each of the conduits at different river flow rates from the climate fish low flows to the 2-year (50 percent Annual Exceedance Probability) flow. The downstream end sill will sufficiently backwater the conduits to reduce conduit velocities and provide sufficient depth for the AWS flow to the neighboring fishway via a vertical diffuser screen. At the 2-year flow, the end sill crest gates will be lowered and a hydraulic jump will form within the conduits. The conduits will operate in an open channel condition for flows up to and including the 2-year event.

Figure 8. Primary Conduit Water Surface Profiles

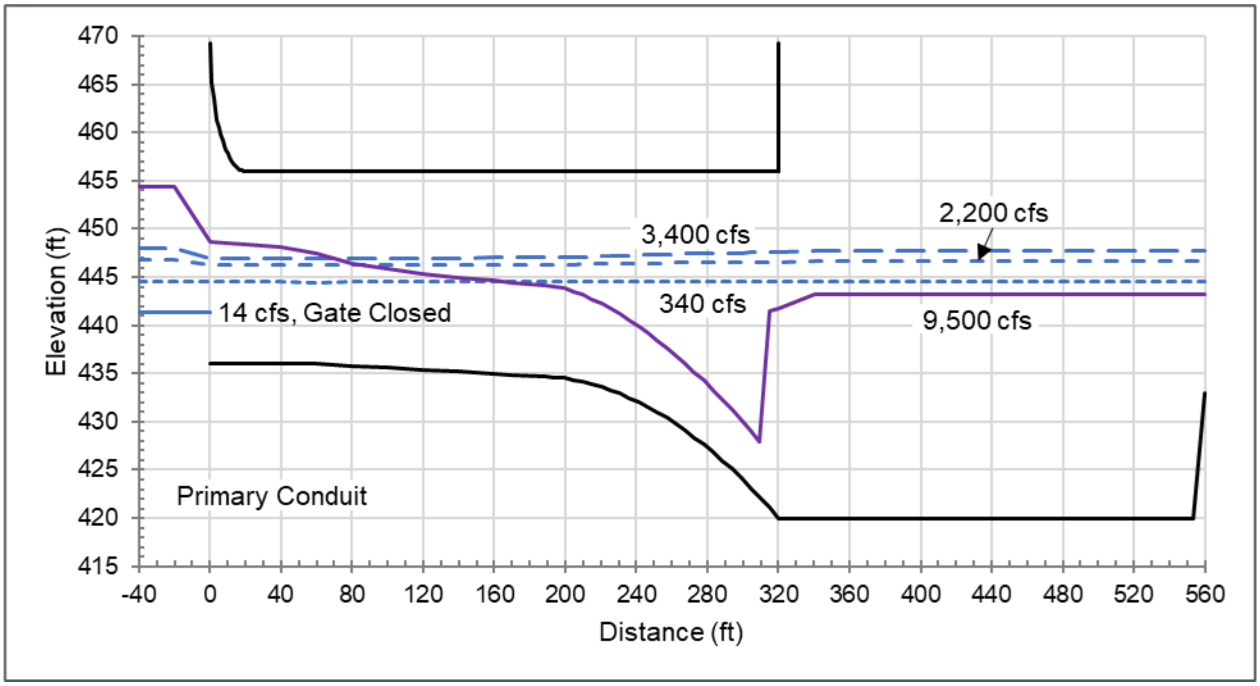


Figure 9. Secondary Conduit Number 1 Water Surface Profiles

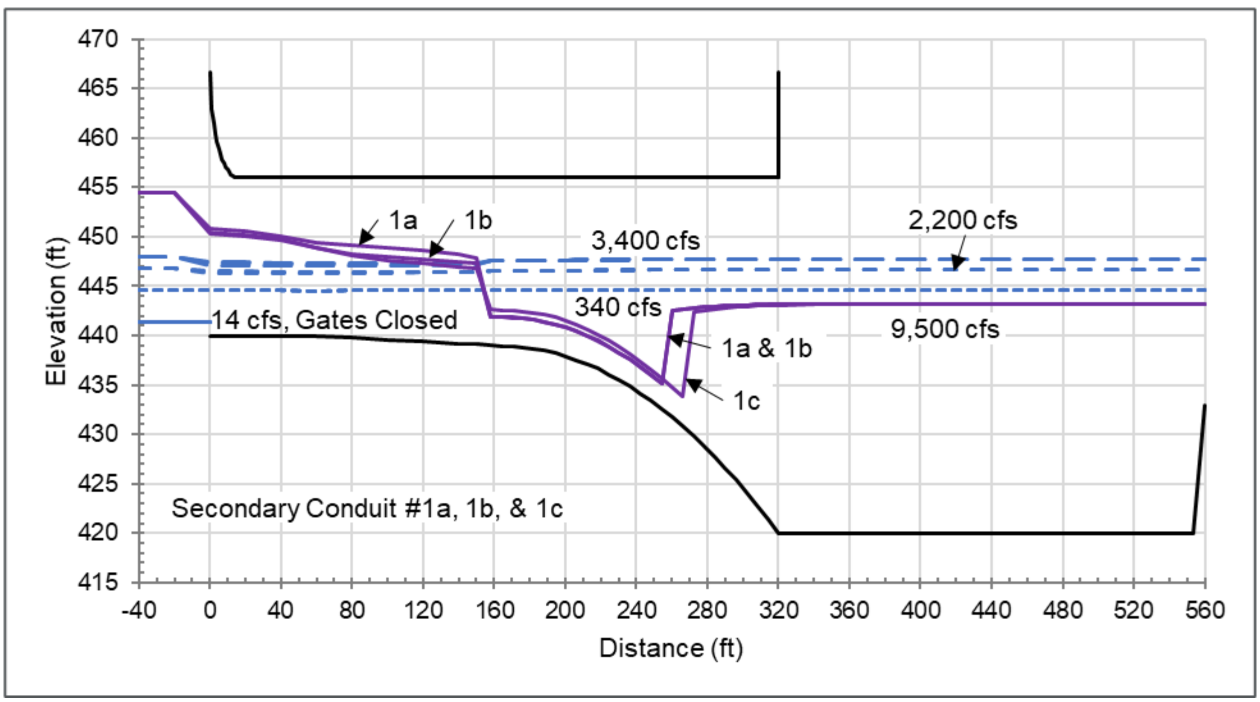
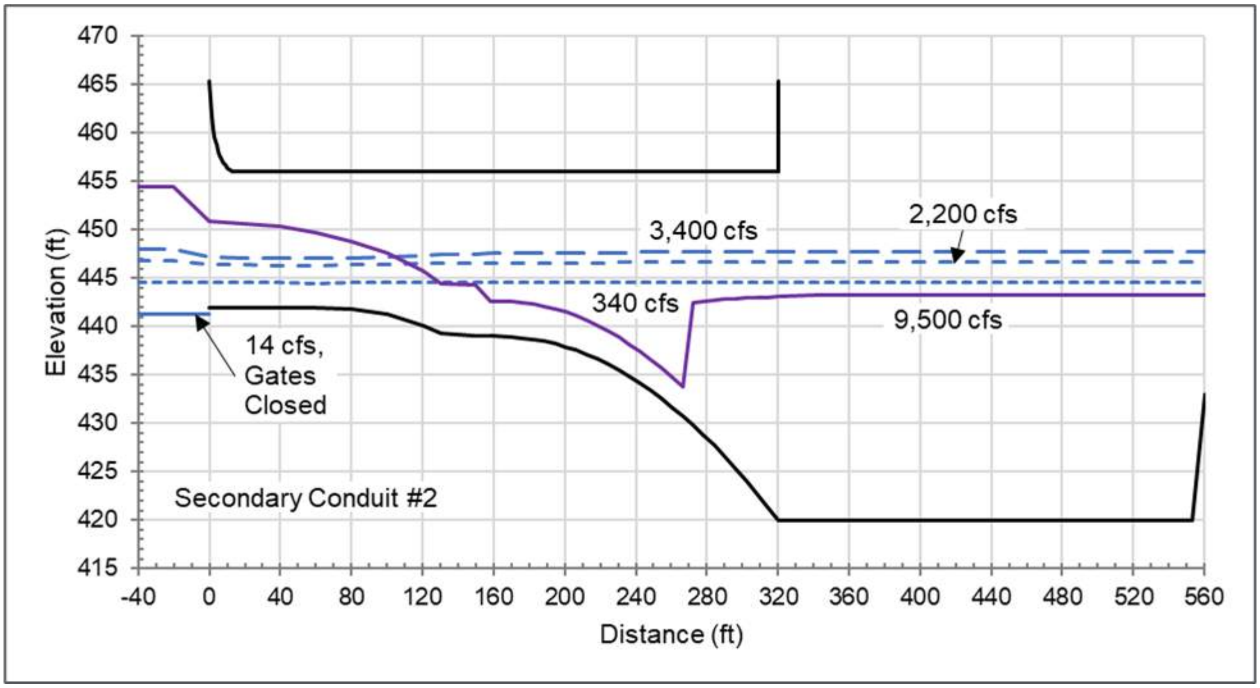


Figure 10. Secondary Conduit Number 2 Water Surface Profiles



Gate Control Flow Capacity for 10% to 80% Open

During flood retention, the primary and secondary conduit gates will be throttled or closed. Figure 11 to Figure 15 provide the gate-controlled flow for the primary and secondary conduits at gate openings between 10 and 80 percent open. The gate-controlled flows are intended to inform operations on specific gates that will best suit the desired flow rates while considering fish sounding depths before transitioning flows to the evacuation conduits.

Figure 11. Primary Conduit Gate-Controlled Flow Rates

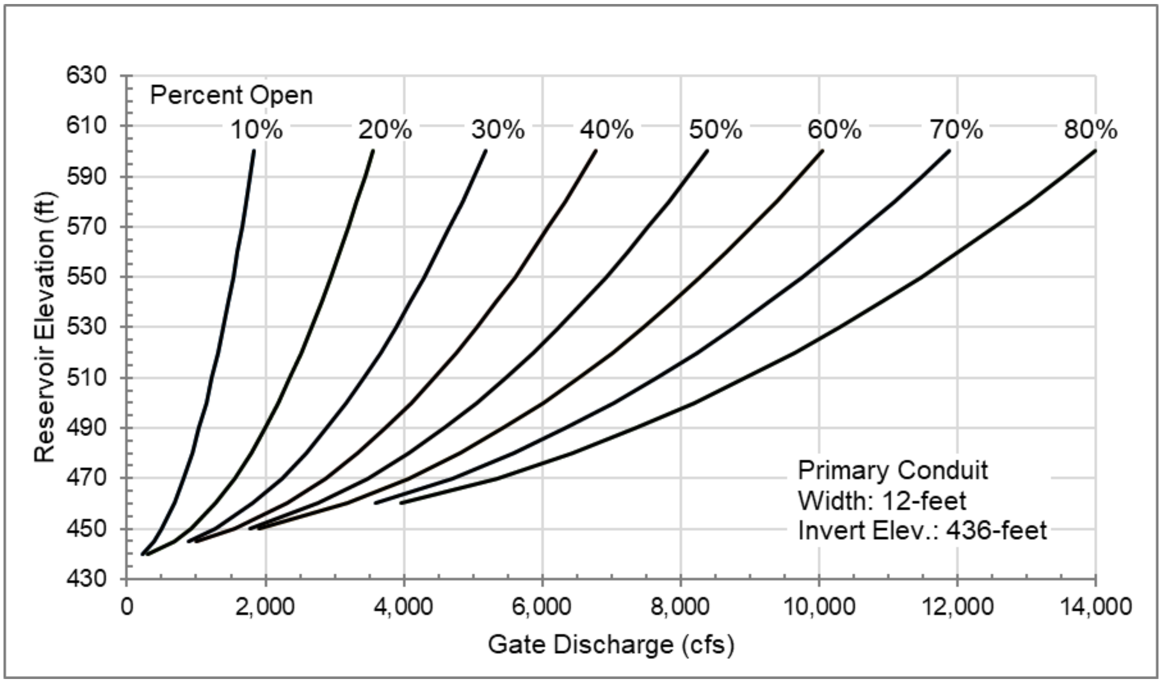


Figure 12. Secondary Conduit 1a Gate-Controlled Flow Rates

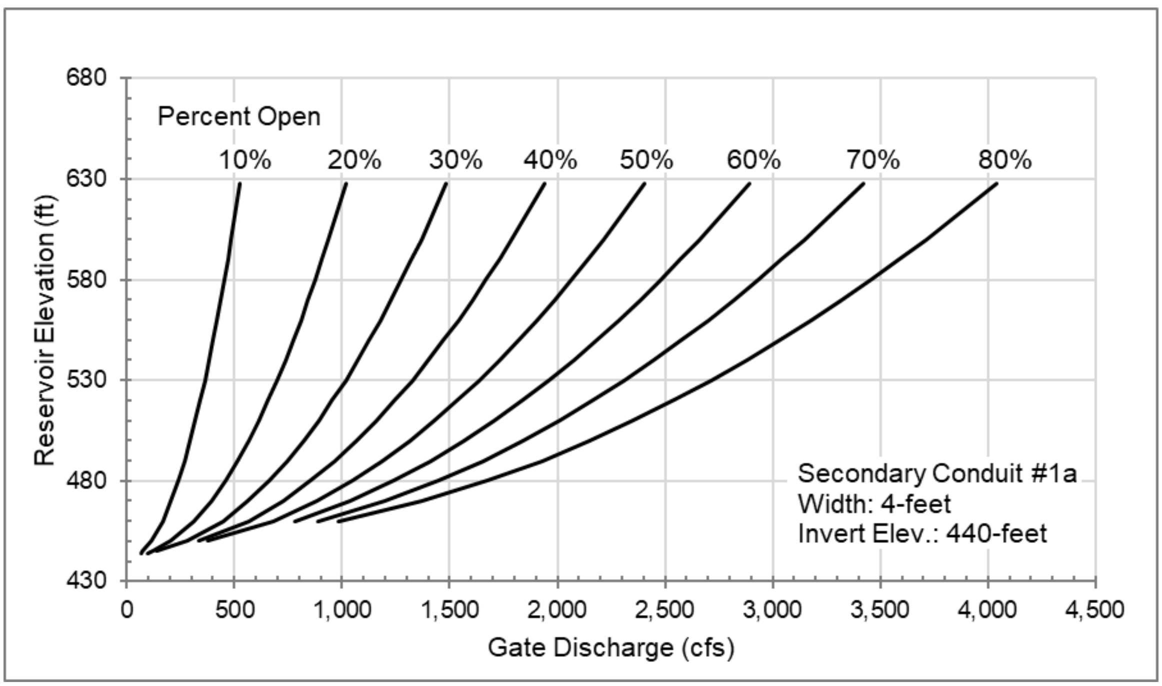


Figure 13. Secondary Conduit 1b Gate-Controlled Flow Rates

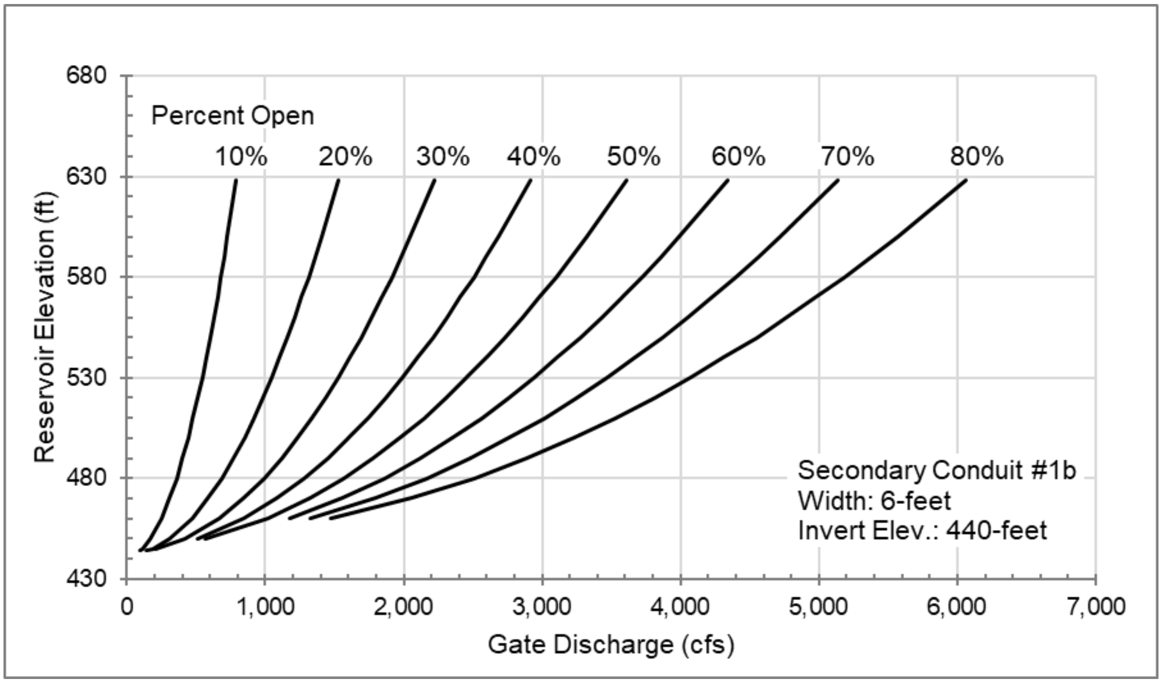


Figure 14. Secondary Conduit 1c Gate-Controlled Flow Rates

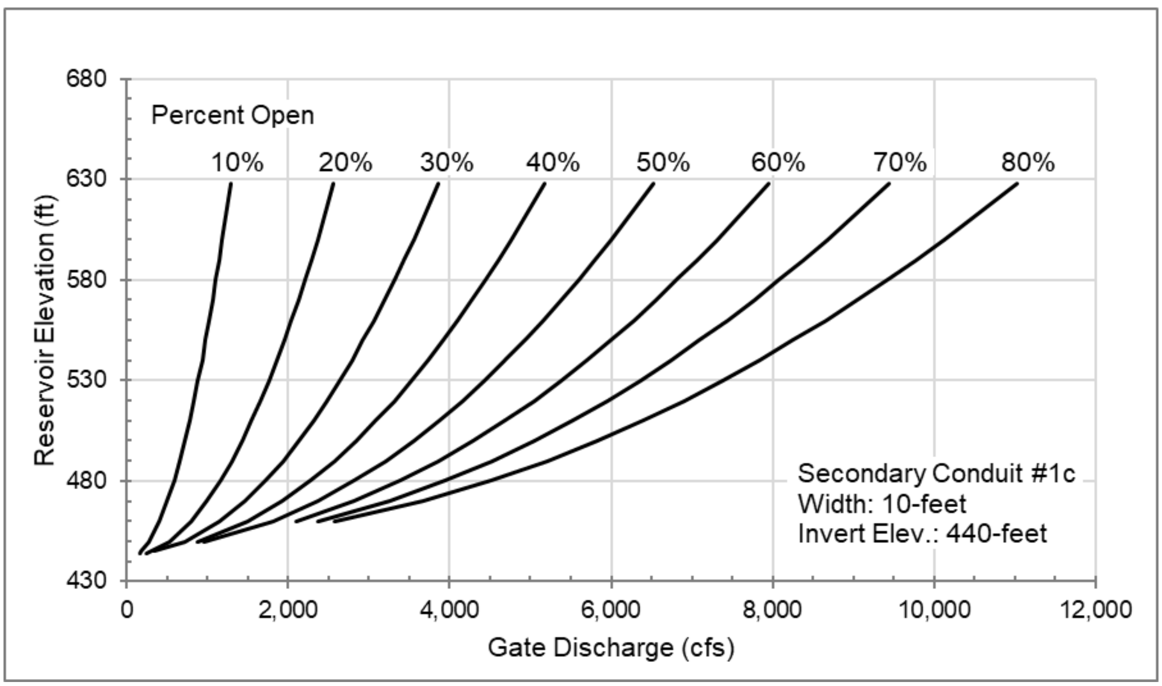
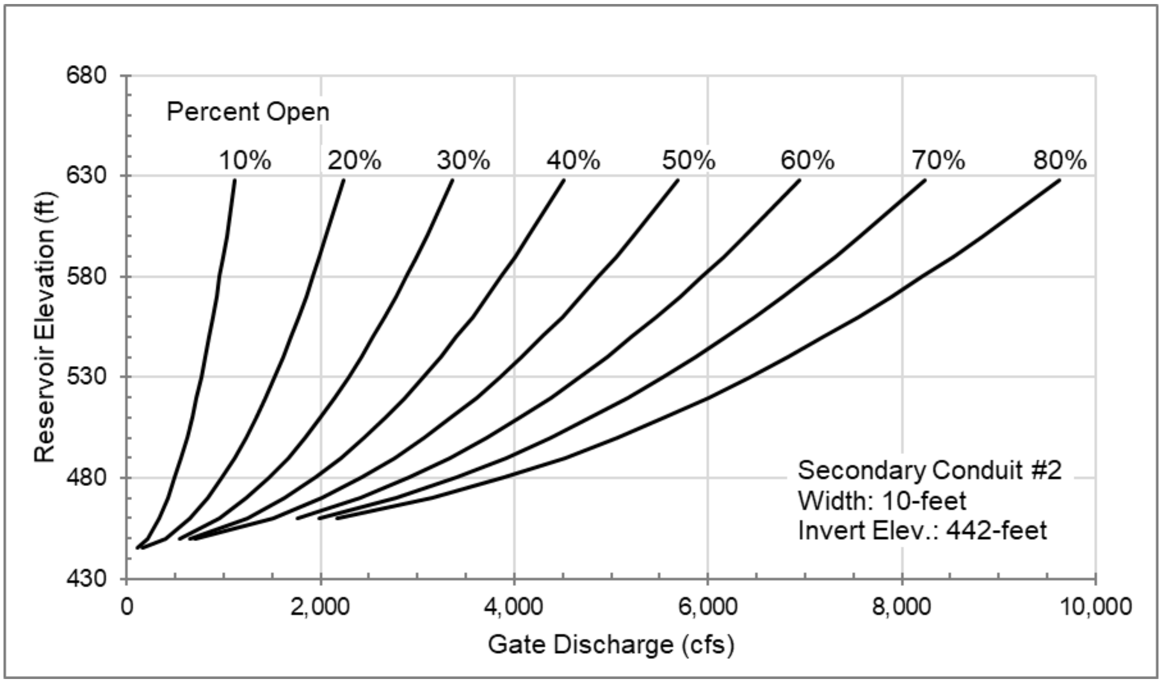


Figure 15. Secondary Conduit 2 Gate-Controlled Flow Rates



5.1.2.3 Stilling Basin Endsill and Vertical Barrier

The fishway entrance is located near the stilling basin endsill. Unlike the original concepts, the stilling basin endsill will be variable with Obermeyer weir or similar overflow concept. This endsill will be in the upright condition during normal river operations and serve as a vertical barrier. In this way, the fishway entrances will serve as the exclusive pathway for upstream movement during these periods, following input from NMFS during consultation. The variable endsill will be operated for fish exclusion during non-FRE operational periods and for conduit hydraulic capacity during evacuation operations. Detailed design of the endsill to accommodate the low fish passage design flow will occur in future phases of design development.

5.1.2.4 Evacuation Conduits

After the conduit gates are closed for flood retention, the reservoir evacuation conduits will be used for reservoir releases but only at elevations exceeding the defined fish sounding depth to provide safe downstream passage through hydraulically favorable gate conditions. The estimated sounding depth reported in the Juvenile Fish Sounding TM (Appendix B) is 30 feet. There will be two main types of evacuation conduits, one for high flows and the other for low flows. The high flow conduits will be rectangular, 5 feet wide and 9 feet tall. The low flow conduits will be a 3-foot-diameter hooded fixed cone valve supplied from a 4-foot-diameter conduit. Each of the evacuation conduits will use the stilling basin as an energy dissipater. During the maximum flow requirement, and when the upstream head is insufficient, the secondary conduits will be used to increase the release capacity. Figure 16 and Figure 17 show the gate-controlled flow rates for the evacuation and low-flow evacuation conduits, respectively.

Figure 16. Evacuation Conduit Gate-Controlled Flow Rates

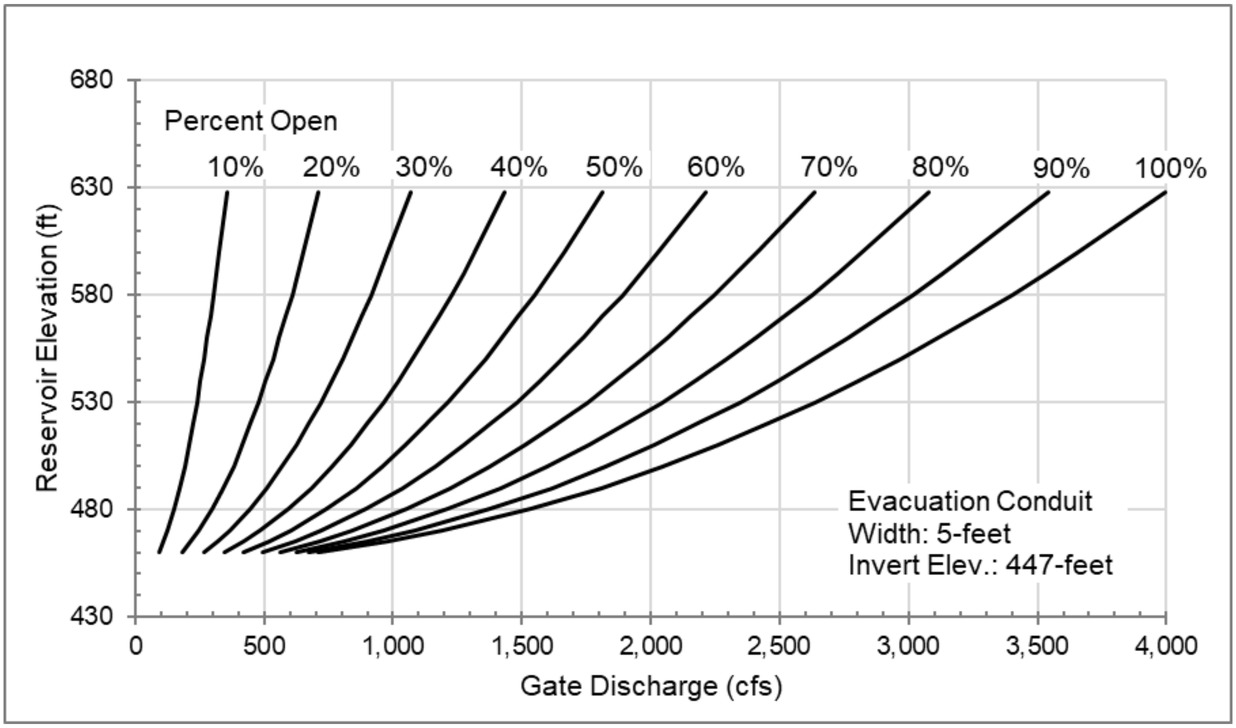
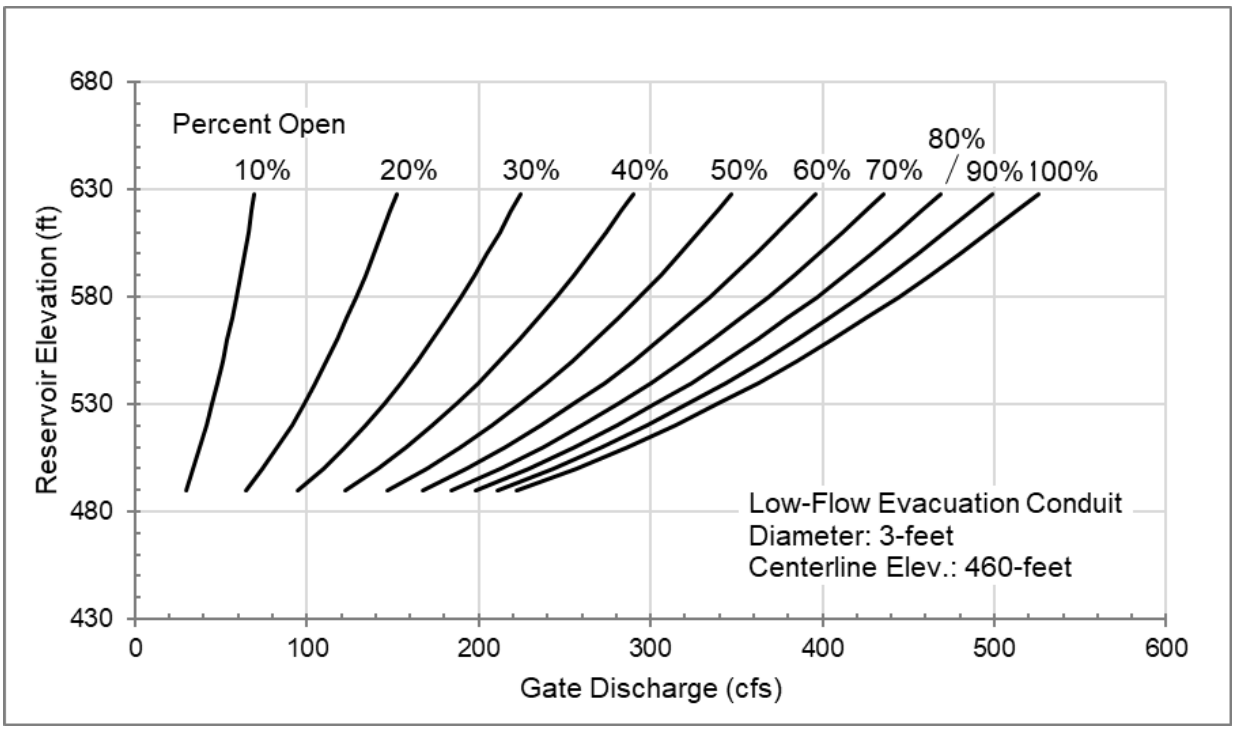


Figure 17. Low-Flow Evacuation Conduit Gate-Controlled Flow Rates



5.1.2.5 Lighting of Fish Passage Conduits

Appendix C (Fishway Lighting TM) describes the potential for artificial lighting within the passage conduits (primary and secondary conduits and the section of each fishway passing through the FRE structure) and considered literature describing the benefits and adverse effects of lighting, under different circumstances. Concern regarding fish delay or holding due to the length of the fish passage conduits if they remain unlit was shared during the January 17, 2024, TWG meeting. The TM concludes that lighting is beneficial only under certain circumstances. Accordingly, the design will not include lighting but seek to accommodate future installation of lighting based on demonstrated need. An integrated monitoring plan should be prepared to assess the need for artificial ambient lighting and evaluate its effects if implemented.

6 Fish Passage Performance

Fishways and other fish passage technologies are designed to provide continuous fish passage at the location of an instream barrier. Performance at fish passage facilities is generally characterized by the proportion of fish that can locate and traverse a fish passage facility from one side to the other. Research on fish passage performance is largely limited to facilities that consist of structures such as fish ladders or floating surface collectors, or facilities composed of natural materials (e.g., rocks and boulders), such as nature-like fishways and roughened channels. Provided herein is an assessment based on current project understanding with regards to anticipated fish passage operations and outcomes. Several terms are used to characterize the effectiveness of fish passage facilities. The term ‘performance’ is how efficiently fish are able to pass a facility, with rapid upstream movement being the most desirable outcome. Individuals may effectively move through a passage facility (“performance”) but can encounter challenges such as fallback after passing the facility, delay entering the facility, or displacement (not being able to access desirable locations). ”Mortality” indicates the complete loss of an individual. Mortality is not necessarily a direct outcome of performance. The inability to reproduce is also included as mortality if long-term displacement leads to segregation from the spawning population. The inverse of mortality is considered “survival.” Generally stated, survival is the proportion of individuals that move on to contribute to the population after encountering the fish passage facility as they otherwise naturally would.

Therefore, caution is urged when considering performance versus survival as the resilience of fish species can lead to survival, including reproduction, with imperfect conditions, such as not effectively moving through a passage facility. Based on the current design progress and available data, modeling is unable to provide direct scientifically supported estimates of mortality versus short-term displacement. It is inaccurate to assume that fish that do not move through a fish passage facility are lost to the local fish population. Fish not ascending or falling back in a fishway may hold for some time and move upstream later or may choose to not ascend but remain productive members of the population downstream of the passage facility. Therefore, populations are defined as “unaffected” or “potentially affected” to more accurately represent current project understanding. It is anticipated that most of the affected fish will survive (as reflected in the survival estimate) but may be affected as discussed above (i.e., fallback, temporary delay, or displacement). A full discussion of unaffected and potentially affected fish for the Proposed Project is provided in Section 6.1 below.

During Normal Operation, fish passage and hydraulic outlet gates are open and the Chehalis River flows through the FRE unimpeded. During Flood Retention Operation, fish passage gates are closed, and hydraulic outlet openings are reduced to temporarily impound floodwaters upstream.

During Normal Operation, upstream passage is provided primarily by dual fishways adjacent to the FRE outlet works, while passage conduits serve as secondary upstream pathways and the primary downstream passage route. The passage conduits typically remain open and convey downstream migrants to the stilling basin and downstream river reach; within the range of fish passage flows, they may also support upstream escape from the stilling basin due to fallback. During Flood Retention Operation, upstream passage is provided by the FFPF. Downstream migrants may experience delay once the temporary inundation area exceeds approximately 30 feet above the evacuation conduits; prior to this depth, during initial retention and final evacuation, downstream passage is supported by the passage conduits. During FRE construction, the existing river, temporary bypass channels, and the completed dual fishways, conduits, and stilling basin will provide upstream and downstream passage on the Chehalis River and Crim Creek.

Several models of fish population use anticipated survival percentages to estimate potential impacts of projects on future fish populations. The discussion above and later in this section explain how it is important to account for changes to the location and timing of fish movement and reproduction and avoid potential mischaracterization of such changes as mortality. For convenience, Table 9 is provided to summarize the estimated percentage of fish encountering and passing the FRE structure and construction location and surviving beyond the structure/project area during construction and operation of the FRE facility. As noted, these survival numbers do not include fish that do not pass the FRE structure/construction location. Fish that do not pass the FRE structure should be accounted for elsewhere.

Table 9. Estimated Percentage of Fish Passing the FRE Facility/Construction Location and Surviving Beyond the FRE Facility Location for Construction and Operation of the FRE Facility[1]

Life Stage	Direction	During Construction[2]	Non-Flood Retention	Flood Retention
		(%)		
Spring-Run Chinook Salmon				
Adult	Upstream	98	95	86
Juvenile	Upstream	88	64	50
Juvenile	Downstream	99	95	60
Fall-Run Chinook Salmon				
Adult	Upstream	97	92	86
Juvenile	Upstream	88	64	50
Juvenile	Downstream	99	98	60
Coho Salmon				
Adult	Upstream	98	95	90
Juvenile[3]	Upstream	88	64	50
Juvenile[3]	Downstream	99	98	60
Steelhead[4]				
Adult	Upstream	98	95	90
Adult	Downstream	98	95	75
Juvenile	Upstream	93	79	55
Juvenile	Downstream	99	98	70
Coastal Cutthroat				
Adult	Upstream	95	85	55
Adult	Downstream	98	95	75
Juvenile	Upstream	88	64	45
Juvenile	Downstream	99	98	55
Pacific Lamprey				
Adult	Upstream	99	96	70 estimated[6]
Juvenile[5]	Downstream	98	95	40

Life Stage	Direction	During Construction[2]	Non-Flood Retention	Flood Retention
		(%)		
Western Brook Lamprey				
Adult	Upstream	99	96	70 estimated[6]
Juvenile[5]	Downstream	98	95	40

Notes

1. The percentages in this table reflect fish that reach the FRE facility location in their movement upstream and downstream, pass the facility location, and survive beyond the facility location. This does not mean that all fish outside these percentages die or fail to contribute to species population. For example, of the 45 percent of juvenile steelhead moving upstream during a flood retention event some may elect to hold until the retention event concludes then move and successfully continue their life history upstream during flow-through operation, some may successfully complete their life-history downstream of the FRE facility location, some may remain downstream of the FRE facility without successfully contributing to the species population, and some may move upstream when flow-through operation resumes without successfully contributing to the species population.
2. “During Construction” estimates are averaged across all phases of construction, including Non-Flood Retention phase.
3. Includes Coho salmon fry, transitional, and smolt life stages.
4. Downstream survival of adult steelhead was estimated because a high proportion of adults migrate downstream to re-enter the ocean and return to their natal stream to spawn again; downstream survival of adult salmon was not estimated because adults die after spawning.
5. Includes ammocoetes and macrophthalmia.
6. Pending more information being provided by the District regarding the low-velocity FFPF entrance; the proposed design is a prototype and has not been developed beyond the 30% level, nor has the prototype been installed or evaluated.

6.1 Unaffected and Potentially Affected Fish

Although the anticipated number of Potentially Affected fish presented in Table 10 (Section 6.3) and Table 11 (Section 6.4) could be lower in reality due to fish adaptability to varying environmental conditions. The species profiles below provide additional context on their resilience and ability to withstand suboptimal conditions including delayed migration to survive.

6.1.1 Steelhead and Cutthroat Trout

Steelhead or rainbow trout (*Oncorhynchus mykiss*) was one of the species evaluated. *O. mykiss* exhibits one of the most complex suites of life-history traits among Pacific salmonids (Quinn 2005). The anadromous form, which migrates to the ocean, is referred to as steelhead, whereas the resident, freshwater form is referred to as rainbow trout. Because both life-history expressions belong to the same species, they are hereafter collectively referred to as *O. mykiss* unless distinction is required. The two forms interbreed regularly, and their offspring may adopt either anadromous or resident life histories (Zimmerman and Reeves 2000; Pearse et al. 2019). Offspring of two steelhead may remain resident, and offspring of two resident parents may adopt an anadromous life history (USFWS 2026), consistent with empirical findings demonstrating significant plasticity in migratory propensity within *O. mykiss* populations (Satterthwaite et al. 2010; Kelson et al. 2020).

Another important life-history attribute of *O. mykiss* is iteroparity (the capability to spawn more than once) whereas other *Oncorhynchus* species assessed for fish passage performance, such as Chinook (*O. tshawytscha*) and Coho salmon (*O. kisutch*), are semelparous and die after a single spawning event (Fleming and Reynolds 2004; Busby et al. 1996). Coastal cutthroat trout (*O. clarkii clarkii*), also present in the Chehalis River Basin, exhibit life histories similar to *O. mykiss*, including migration and iteroparity (Trotter 2008; Johnson et al. 1999).

During Phase 2 of construction and associated flood operations, upstream spawning migrations of adult *O. mykiss* may experience temporary delays. Individuals may require additional time to navigate modified hydraulic conditions, seek temporary refuge until passage conditions improve, spawn downstream of the FFPF, or delay spawning to a later year when hydrologic or ecological cues indicate more suitable passage conditions. Such behavioral plasticity, including flexible migration timing and variable holding behavior, is a well-documented adaptive trait in *O. mykiss* and contributes to long-term persistence of steelhead populations in dynamic and variable river environments (Sykes et al. 2009; Kendall et al. 2015). Delay in migration represents a behavioral response that enhances survival potential and should not be interpreted as mortality.

Given the documented behavioral and physiological adaptability of *O. mykiss*, as well as *O. clarkii clarkii*, it is reasonable to conclude that the performance, survival, unaffected, and potentially affected estimates presented in Table 10 and Table 11 are conservative. This behavioral flexibility is expressed by both juvenile fish navigating the system and adult fish migrating to natal grounds to spawn, and it is recognized as a key component of the species' resilience under different environmental conditions (Satterthwaite & Carlson 2015; Kendall et al. 2021).

6.1.2 Coho Salmon and Chinook Salmon

Chinook salmon (*Oncorhynchus tshawytscha*) and Coho salmon (*O. kisutch*) are two other anadromous Pacific salmon species evaluated for fish passage performance. Both species exhibit complex migration ecology involving freshwater, estuarine, and marine environments. Unlike *O. mykiss*, Chinook and Coho salmon are semelparous, meaning they reproduce once and die following spawning (EPA [2021] for Chinook; NPS [2025] for Coho). Chinook and Coho populations display substantial diversity in run timing and migration rates, traits that are influenced by climatic, hydrologic, and habitat conditions (Crozier et al. 2008; NOAA 2024a review).

During Phase 2 of construction and associated flood operations, downstream migrations of juvenile Chinook and Coho salmon may experience temporary delays. Behavioral studies demonstrate that juvenile Chinook salmon rear and feed in freshwater and migrate to the ocean within a few months of hatching as young-of-year or may choose to stay in freshwater for a full year (NOAA 2024b). In northern portions of their range, spring Chinook commonly remain in freshwater for approximately one year, but in less productive streams where growth is slower, juveniles often prolong their freshwater residency (WDFW 2026).

Migration timing in Chinook has been shown to shift with river temperature, flow, and other environmental cues—reflecting behavioral adaptation in response to environmental variability (Keefer et al. 2025; Di Prinzio et al. 2023).

As far as adult Coho salmon are concerned, they have been observed to delay movement until favorable combinations of streamflow and temperature occur, holding downstream until environmental thresholds for migration are met (Flitcroft 2022; USDA Forest Service 2001).

These migration delays represent adaptive behavioral responses, not mortality. Adult fall run Chinook salmon routinely pause migration to slow down movement until conditions improve (Goniea et al. 2006). Coho salmon similarly demonstrate condition dependent migration timing (Flitcroft 2022). Such environmentally mediated holding behavior is a well-documented aspect of Pacific salmon migration ecology.

Although Chinook and Coho salmon exhibit less life history plasticity than *O. mykiss* due to their semelparous strategy, both species show significant variation in run timing, freshwater residence, and movement strategies that enhances resilience in dynamic river systems (Hill et al. 2003; NOAA 2024). Recent research also highlights alternative juvenile migration strategies in Chinook and Coho that increase population stability (Apgar et al. 2020; Baker et al. 2025), suggesting these species retain considerable behavioral flexibility despite their reproductive constraints.

Given this natural behavioral adaptability, it is reasonable to infer that the performance and survival values reported in Table 10 and Table 11 for Chinook and Coho salmon are conservative. Similar to *O. mykiss* and cutthroat trout discussed above, migration delays should be interpreted as part of the species' adaptive response to suboptimal environmental conditions rather than as indicators of mortality.

6.2 Fish Passage Hydraulic Modeling Results

Hydraulic model results for fish passage conduits and permanent and construction bypass channels demonstrate depths and velocities at the high and low fish passage design flows similar to their analogous and reference reaches.

Two-dimensional hydraulic modeling of the construction bypass channels and the permanent river channels (RPDR Appendix D) confirm that at the fish passage design flows, flow depth and velocity within these channels are similar to, or more favorable than the reference reaches used to design the channels. At the current level of design, there is no evidence to suggest that fish passage performance through the channels will be negatively impacted by the channels themselves, when compared to the existing river at the Proposed Project location. Therefore, fish passage performance and survival through the proposed channels is assumed to match that of the existing natural channel.

Three-dimensional hydraulic modeling of the passage conduits, stilling basin, and end sill was conducted to evaluate passage hydraulics through the conduits through fish passage design flow range. While the passage conduits are not the primary migration pathway, model results depicted favorable conditions in the event of upstream migrant fallback or failure of the vertical barrier.

For an abbreviated summary of anticipated fish passage hydraulic results through the fish passage conduits, see Section 5.1, above.

6.3 Fish Passage Performance During Flood Retention Operation

During flood events, the FFPF will continue to provide upstream passage for adult salmonids and lamprey, juvenile salmonids, and resident fish. Downstream-migrating juveniles and adult species are expected to hold in the mainstem Chehalis River above the temporary inundation pool, tributaries, and the temporary inundation pool until the temporary inundation pool recedes to a level fish choose to safely move downstream through the conduits or until normal flow-through operation resumes.

A temporary impoundment event of short duration may briefly hold fish upstream, preventing downstream movement. While fish are temporarily delayed, the short-term nature of these events limits detrimental consequences to fish mortality. Predatory species generally do not have sufficient time to recruit, establish, or significantly increase in abundance during brief periods of impoundment, though opportunities for predation may occur on occasion. Importantly, a temporary passage delay does not equate to a mortality event. Because the duration is limited, key mortality drivers, such as prolonged food limitation, physiological stress, or resource depletion, are expected to remain minimal, and impounded fish can typically resume normal movement and behavior once flows return to baseline.

Upstream-migrating juvenile fish were assigned lower performance and survival values in Table 10 than adults due to uncertainties associated with their attraction to ladder entrances, greater vulnerability to predation, and variable motivation to ascend into holding galleries. Additional engineered measures that could improve juvenile attraction and safe collection include multiple low-head entrances, reduced head differentials between ladder pools, and segregation zones in holding galleries to decrease predation.

Table 10. Anticipated Upstream and Downstream Fish Passage Performance, Survival, Unaffected, and Potentially Affected Values during Flood Retention Operation

Target Species	Performance[1]	Survival[2]	Unaffected[3]	Potentially Affected[4]
	(%)			
Adult Upstream				
Spring Chinook	93	86	80	20
Fall Chinook	93	86	91	9
Coho	93	90	91	9
Winter Steelhead	93	90	91	9
Coastal Cutthroat	88	55	86	18
Pacific Lamprey	60	70	54	46
Western Brook Lamprey	60	70	54	46

Target Species	Performance[1]	Survival[2]	Unaffected[3]	Potentially Affected[4]
	(%)			
Adult Downstream				
Winter Steelhead	NA	75	NA	NA
Coastal Cutthroat	NA	75	NA	NA
Juvenile Upstream				
Spring Chinook	60	50	30	70
Fall Chinook	60	50	30	70
Coho	60	50	30	70
Winter Steelhead	65	55	36	64
Coastal Cutthroat	60	45	27	73
Pacific Lamprey	NA	NA	NA	NA
Western Brook Lamprey	NA	NA	NA	NA
Juvenile Downstream				
Spring Chinook	>90	60	54	46
Fall Chinook	>90	60	54	46
Coho	>90	60	54	46
Winter Steelhead	>90	70	63	57
Coastal Cutthroat	>90	55	50	50
Pacific Lamprey	>90	40	36	64
Western Brook Lamprey	>90	40	36	64

NA – Juvenile lamprey are neutrally buoyant and do not move under their own power so upstream movement of juvenile lamprey is not applicable.

[1] Performance, the proportion of fish expected to meet route-specific behavioral passage criteria (e.g., finding/entering the route and completing the passage) estimates for adult and juvenile upstream passage are derived from HDR (2017). Juvenile downstream performance estimates are supported by analogous pressurized conduit systems with less than 30 feet of water depth, documented in the Rocky Reach Hydro Project and Clackamas River Hydroelectric Project (Chelan County N.D.; NOAA 2018).

[2] Survival, the proportion of fish that survive the passage event, estimates provided in HDR (2017).

[3] Unaffected, the proportion of the total population expected to pass successfully and survive the passage operation.

[4] The remainder of the population that may experience delay, increased predation risk, physiological stress, or mortality.

The following paragraphs apply specifically to periods when downstream passage occurs during short duration temporary impoundment events in which the inundation pool depth remains less than the juvenile salmonid sounding depth (approximately 30 feet). Under these shallow, short-term conditions, fish continue to encounter engineered passage routes without the protracted delays associated with deeper pools, and the survival expectations described below pertain only to these less than 30-foot events.

Downstream survival during flood retention events must consider the short duration (~4 weeks or less) and infrequent occurrence (once every 5 years to about > once per year) when a temporary pool is held upstream of the FRE structure and must consider the high passage performance through the pressurized conduits when the pool depth is below the fish sounding depth (less than 1 atmosphere). Empirical studies of juvenile passage systems throughout the Pacific Northwest consistently show that engineered bypass conduits and pipelines achieve survival rates of approximately 95 to 99 percent, corresponding to mortality of roughly 1 to 5 percent. Paired-release Passive Integrated Transponder-tag experiments in the Columbia–Snake system document survival of 95.3 to 99.4 percent for yearling Chinook and steelhead passing through pressurized bypass routes (Muir et al. 2001; Ploskey et al. 2011). NOAA and Pacific Northwest National Laboratories (Ploskey et al. 2011) analyses further report dam-passage survival near or above 96 to 98 percent across multiple years (Ploskey et al. 2011). Additional compilations from Bonneville Power Administration and NOAA annual survival programs corroborate these findings and consistently show juvenile bypass systems among the highest-survival passage routes in the hydrosystem (Muir et al. 2001; Ploskey et al. 2011).

Concerns about latent mortality associated with bypass encounters have been raised, primarily relating to stress physiology and size-selective collection. The Independent Scientific Advisory Board (2021) reviewed these hypotheses; however, even under these considerations, direct route-specific survival for bypass passage remains high, and no evidence supports immediate mortality near 15 percent. NOAA analyses similarly find little evidence of significant latent penalties attributable solely to bypass exposure (NOAA Fisheries 2018).

Juvenile downstream survival at the Proposed Project is expected to remain high, though mortality may be slightly elevated relative to fully enclosed conduit systems due to the trashrack at the downstream collection entrance. Trashrack slats are approximately 2 feet wide, with approach velocities beginning near 1.0 ft/s and increasing gradually, producing hydraulics similar to river like conditions commonly encountered by juvenile salmonids. Additional risk can occur if debris accumulates and alters approach velocities or strike potential. Accumulated debris, large woody material, and plant matter, may provide structural habitat for predatory species, increasing predation risk. Predatory species can also use large woody material or floating debris as rafts for dispersal to new locations and ambush predation. Operational mitigation measures remove debris as needed, reducing hydraulic and predator-related risks. Accordingly, any incremental mortality associated with the trashrack and debris is expected to be small, well mitigated, and within survival ranges documented for high performing bypass systems (NOAA Fisheries 2018; Muir et al. 2001; Ploskey et al. 2011).

Data is less readily available for mortality due to short-duration holding in temporary pools. Upon assessing the hydraulic modeling of the Proposed Project under multiple scenarios (see Section 6.2), a critical review was undertaken relative to standard passage criteria (NOAA 2023a-c), past design experience and outcomes, along with project-specific understanding. The result of that review led to the prescribed downstream survival rates, shown in Table 10, in the 60 to 70 percent range based on the compilation of existing information and professional judgement. The rates provided do not fall outside of other research and findings within the literature but provide an incrementally improved and tailored assessment specific to the Proposed Project.

Recent studies from the mid-Columbia and Yakima River systems indicate improved monitoring of adult and juvenile lamprey movements, though these datasets have not yet been fully integrated into survival or performance estimates for trap and transport applications (Liedtke et al. 2022; Grote and Lampman 2025). Evidence from Tribal translocation programs indicates that adult lamprey can survive collection and transport with generally low mortality and contribute to subsequent generations; however, variable passage efficiency at salmonid-designed facilities and limited juvenile-specific data warrant conservative assumptions (Hess et al. 2023; Lampman 2021).

Adult Pacific lamprey moved upstream using trap-and-haul or lamprey-specific passage structures show strong performance, with Tribal programs demonstrating low mortality and successful reproduction that supports values higher than legacy assumptions (Hess et al. 2023; USFWS 2023; CRITFC 2025). For this assessment, adult upstream survival is represented with a value of 70. Downstream migrants will move through conduit systems modeled on tube- and culvert-type designs that have shown high volitional passage efficiency in the Pacific Northwest (Frick et al. 2017; Goodman and Reid 2017; Cates et al. 2020). Regional closed-conduit studies indicate survival typically near the upper end of bypass performance (NOAA Fisheries 2018; Muir et al. 2001; Ploskey et al. 2011; U.S. Geologic Survey [USGS] 2022), but given limited lamprey-specific data, juvenile downstream estimates are conservatively set at 40 for survival while still reflecting fish-friendly routing and analogous system performance.

6.4 Fish Passage Performance During Normal Operation

Fish passage during normal operation is provided through fishways for upstream passage of adults, juveniles, and resident fish and through conduits for downstream passage of all aquatic species and life stages. Survival numbers developed in 2016 to 2017 for the Flood Retention Flow Augmentation (FRFA) dam fish ladder alternative remain appropriate, but performance values should be reconsidered. The FRFA dam fish ladder alternative developed in support of the Programmatic EIS assumed a large permanent reservoir and therefore anticipated reduced upstream fishway performance due to delayed attraction. Under the current configuration, fishways transition directly into the flowing Chehalis River, meaning the performance percentages previously established must be reconsidered.

Adult salmonids migrating upstream through technical fishways at the Columbia and Snake River Dams exhibit high passage efficiency and effective passage performance. According to Keefer et al. (2021), performance rates of upstream passage through technical fishways at the Columbia River and Snake River Dams ranged from 92 to 99 percent across a range of species, seasonal runs, and dams considered. This study considered collected data from an 8-year period for fall and spring Chinook, Sockeye, and steelhead. The mean fishway passage efficiency was determined to be 98 percent.

Upstream juvenile passage values have been added to Table 11 to reflect the possibility that juveniles may enter fishways, while acknowledging that upstream juvenile movement is exploratory rather than required for their life history. Consistent with the 2017 Subcommittee rationale, juvenile performance values are lower than adult values due to uncertainties related to attraction, motivation, and predation risk within fishways. Conditional survival remains high, in the range of 90 percent, consistent with regional juvenile studies. Juveniles that do not enter the fishways remain downstream, and because non-entry is not equivalent to mortality, total survival (a previous considered metric by others representing 'performance survival', which indicated any performance issue lead to mortality) is not applied to juveniles in Table 11 as it is not supported that any juvenile affected by performance would lead directly to mortality.

Table 11. Anticipated Upstream and Downstream Fish Passage Performance, Survival, Unaffected, and Potentially Affected Values during Normal Operation

Target Species	Performance[1]	Survival[2]	Unaffected[3]	Potentially Affected[4]
	(%)			
Adult Upstream				
Spring Chinook	95	95	90	10
Fall Chinook	95	92	85	15
Coho	95	95	90	10
Winter Steelhead	97	95	92	8
Coastal Cutthroat	93	85	79	21
Pacific Lamprey	97	96	93	7
Western Brook Lamprey	97	96	93	7
Adult Downstream				
Winter Steelhead	98	95	93	7
Coastal Cutthroat	98	95	93	7
Juvenile Upstream				
Spring Chinook	65	64	42	58
Fall Chinook	65	64	42	58
Coho	65	64	42	58
Winter Steelhead	80	79	63	37
Coastal Cutthroat	65	64	42	58
Pacific Lamprey	NA	NA	NA	NA
Western Brook Lamprey	NA	NA	NA	NA
Juvenile Downstream				
Spring Chinook	>90	98	59	41

Target Species	Performance[1]	Survival[2]	Unaffected[3]	Potentially Affected[4]
	(%)			
Fall Chinook	>90	98	59	41
Coho	>90	98	59	41
Winter Steelhead	>90	98	64	36
Coastal Cutthroat	>90	98	59	41
Pacific Lamprey	>90	95	NA	NA
Western Brook Lamprey	>90	95	NA	NA

NA – Juvenile lamprey are neutrally buoyant and do not move under their own power so upstream movement of juvenile lamprey is not applicable.

[1] Performance, the proportion of fish expected to meet route-specific behavioral passage criteria (e.g., finding/entering the route and completing the passage) estimates for adult and juvenile downstream passage and juvenile upstream passage are derived from HDR (2017). Adult upstream performance estimates are based on performance values for technical fishways at Columbia and Snake River Dams.

[2] Survival, the proportion of fish that survive the passage event (HDR 2017).

[3] Unaffected, the proportion of the total population expected to pass successfully and survive the passage operation.

[4] The remainder of the population that may experience delay, increased predation risk, physiological stress, or mortality.

Downstream adult passage percentages from the 2017 Combined Dam and Fish Passage Report for winter steelhead and cutthroat trout are still applicable (HDR 2017). These values represent the best available performance estimates for downstream movement through fish-friendly conduits under normal operation. The Fish Passage Subgroup should confirm that including the 2017 values is acceptable for the SEPA EIS.

Downstream juvenile passage through conduits remains highly effective. During normal operation, the entire river passes through fish-friendly conduit structures, resulting in near-complete passage performance (approximately 100 percent). This is consistent with conclusions from the 2017 Subcommittee rationale. Regional data show that juvenile salmonid survival through spillways, sluiceways, and bypass conduits routinely exceeds 90 percent and often falls within the 95 to 99 percent range, as demonstrated by Muir et al. (2001) and USGS (2011). Closed-conduit systems, such as the Clackamas River bypass pipeline, achieve juvenile survival near 97 percent, which aligns with federal performance requirements. Since 2017, conduit designs have been refined and modeled to demonstrate better hydraulic conditions for downstream passage as discussed in Section 6.2, providing additional confidence that downstream survival rates are more likely to be better than those estimated by the Subcommittee in 2017 and closer to those in Muir et al. (2001) and USGS (2011). Based on these findings, downstream juvenile passage is considered approximately 100 percent, with a conservative survival estimate of approximately 98 percent.

Downstream juvenile lamprey passage has been expanded to reflect the current understanding of lamprey behavior and movement. Recent acoustic telemetry work by the USGS in the Yakima River demonstrates that juvenile lamprey have specific movement timing and behavior but does not contradict the expectation that fish-friendly conduit structures can safely pass lamprey during downstream migration. Therefore, juvenile lamprey passage performance remains approximately 100 percent, with a survival value of approximately 95 percent to remain conservative and consistent with both the 2017 Subcommittee assumptions and contemporary regional research.

6.5 Fish Passage Performance During Construction

The construction bypass channels and permanent approach and discharge channels function differently from traditional fish passage structures and are more comparable to restoration channel designs. Their design approach is based on creating physical and hydraulic conditions that replicate those in the Chehalis River and Crim Creek near the Proposed Project. This includes matching slope, channel form, bed material, and habitat complexity along with creating depth, velocity, and flow paths consistent with adjacent natural reaches. Design guidance for this approach is provided both by NOAA Fisheries (2023a, 2023b) and WDFW (2012), with WDFW (2012) stating that this design approach “usually insures fish passage.” The constructed channels are therefore intended to support passage for all species and life stages, with passage performance and survival expected to match baseline conditions in the adjacent natural channel.

Design guidance documents published by WDFW and NOAA Fisheries reinforce that passage performance through the construction bypass channels should be evaluated using design criteria that reflect natural hydraulic complexity, appropriate roughness elements, and sufficient velocity refugia based on the reference reach. The construction bypass and permanent channels have been hydraulicly modeled to demonstrate that the channels achieve hydraulic conditions suitable for upstream and downstream passage as discussed in Section 6.2. As the design progresses, channel hydraulics will be analyzed through hydraulic modeling to confirm that water depths, flow velocities, and channel roughness remain within the envelope of conditions known to support fish movement. The construction bypass channel will be required to meet state and federal fish passage and permit requirements, and passage performance reflects a project that will be designed and constructed to those standards.

Fish passage during construction varies by phase. In all phases, fish passage routes provide volitional upstream and downstream fish passage for all species and life stages. During Phase 1, passage occurs in the existing natural channel, which is unimpacted by construction activities therefore no reduction in survival or performance is anticipated in this Phase. During Phase 2, passage occurs through the construction bypass channels described above. As stated above, upstream and downstream passage performance and survival for all species and life stages is anticipated to match that of the existing natural channel. During Phases 3 and 4, upstream and downstream fish passage for all species and life stages occurs through the completed fishways, conduits, and stilling basin. Passage performance and survival for these phases is therefore consistent with the values described for fish passage during Normal Operation (Section 6.4). The combined approach provides passage conditions that remain consistent with or similar to baseline conditions during early construction phases and transition to the permanent fish passage facilities as they are brought online. Passage survival values during construction are an average of the three passage routes described in this paragraph and listed in Table 9.

7 Roadmap for Future Fish Passage Design

Fish passage design continues to be refined in discussion with NOAA Fisheries and, in future discussion, with WDFW, USFWS, and other state, federal, and indigenous members. The fish passage design will be integrated and compatible with the overall facility design. Future design phases will incorporate cross-discipline design development, design evaluations and analyses, coordination meetings, and configuration decisions to achieve a complete project. Some aspects of fish passage design that will be refined include:

- NOAA climate change guidance for long-term projects (2023a)
- FFPF
- Primary and secondary conduits
- Conduit stilling basin and adjustable end sills
- Dual dedicated fishways
- Construction bypass channels
- Permanent river and creek channels immediately upstream and downstream of the FRE structure
- Two- and three-dimensional hydraulic modeling

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Appendix A. In-Water Work Steps During Construction TM

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Technical Memorandum

Date:	Oct 11, 2024
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	Jacob Hyles, PE
Subject:	**In-Water Work Steps During Construction**

1.0 Introduction

1.1 Background

The Chehalis River Basin Flood Damage Reduction project (Project) objective is to develop recommendations for a series of measures aimed at reducing damage to the communities of the Chehalis River Basin from Pe Ell to Centralia during major flood events. Among these measures is a proposed Flood Retention Expandable (FRE) structure on the Chehalis River, south of the town of Pe Ell.

The Chehalis River Basin Flood Damage Reduction, Revised Project Description Report (RPDR) is a supplemental report documenting the relocation of and changes to the FRE facility as originally documented within the Combined Dam and Fish Passage Conceptual Design Report (HDR Engineering, Inc. [HDR] 2017) and FRE Dam Alternative Report (HDR 2018).

The RPDR describes, supports, contrasts, and illustrates the changes to the proposed upstream FRE in a single comprehensive document.

1.2 Document Purpose

As a standalone attachment to Appendix K: Constructability Report to the RPDR, this technical memorandum (TM) provides additional detail to describe flow diversion aspects of construction phasing to include:

- Major elements of in-water work associated with flow diversion,
- Planned steps to transition construction phases,
- Conditions based requirements to progress from one step to the next, and
- Discussion of next steps and items for future consideration.

1.3 Previous Related Documentation

The RPDR provides a revised project description, and details activities and studies related to new and revised project elements. In addition to Appendix K, two additional appendices provide information related to the proposed channel diversion during construction.

Appendix D2: Hydraulic Design of Fish Passage and Evacuation Conduits TM

This TM documents the hydraulic analysis of the fish passage and evacuation conduits. The TM includes the permanent approach and discharge channels. The Approach Channel connects existing reaches of Crim Creek and the Chehalis River to the FRE passage conduits. The Discharge Channel connects the passage conduit stilling basin to the Chehalis River downstream. Both channels constitute the proposed project condition but are preliminary concepts only.

Appendix D3: Chehalis Construction Bypass Hydraulic Modeling TM

This TM documents the hydraulic analysis of the proposed Chehalis River and Crim Creek construction bypass channels (Bypass Channel), which characterizes hydraulic conditions (i.e., depth, velocity) within the proposed channels in relation to cost estimating, constructability, and fish passage. The preliminary designs are based upon existing conditions within reference reaches in the vicinity of the project. The proposed Bypass Channel mimics the hydraulics of these reference reaches to support upstream and downstream movement of aquatic organisms. The Bypass Channel can contain the 25-year annual exceedance probability (AEP) discharge.

2.0 Construction Sequence Overview

2.1 FRE Construction Sequence

The general FRE construction sequence consists of five phases presented in Table 1. In order to maintain volitional fish passage in the Chehalis River throughout the overall construction period, the dam structure will be constructed in three segments. A bypass channel will be installed to maintain river flows during construction of the second segment of the facility in Phase 2. This flow will be transitioned into the permanent channel and through the FRE conduits for remaining construction during phases 3 and 4. Additional discussion is included in the RPDR.

Table 1. Construction Sequence Summary

Phase	Work	Duration (months)
0	Preliminary work independent of the river	6-12
1	Site preparation, right side foundation construction, Chehalis and Crim Creek bypass channel construction	10-12

2	Outlet works and conduit construction, left side foundation construction, grading	20-24
3	Remove bypass channel and restore vegetation, foundation closure - connect left and right foundations	10-12
4	Complete facility construction, finishing touches, finalize the facility for use	6-12

2.2 Construction Phase Transitions

The transitions between construction phases are based upon several criteria being met. For the purposes of this TM, the transitions presented here are defined by the conditions surrounding the diversion and handling of the Chehalis River and Crim Creek. Specifically, this TM details the conceptual transitions from Phase 1 to Phase 2 and from Phase 2 to Phase 3.

2.3 In-water Work Window

Based on the project design it is anticipated that permitting variances will be required to extend normal in-water work windows. The Washington State Department of Fish and Wildlife (WDFW) approved in-water work window for the Chehalis Basin upstream of the South Fork is August 1 to August 31, and the US Army Corps of Engineers (USACE) approved in-water work window for the same river reach is July 1 to August 31. To minimize impacts during construction by making use of the optimal hydrologic conditions as previously described, and to avoid impacts from continuous construction over a longer period of time, an extension of the in-water work window from July 1 to September 30 will be requested from WDFW and USACE.

2.4 In-water Work Items

Diversion structures
In-water work will include structures constructed to divert flows from one flow path to another to facilitate construction activities. These structures have not been designed, but temporary berms may need to be structurally designed, lined, or otherwise stable and suitable for sustained flows and favorable to support dewatering needs. Temporary diversion methods may be employed to reduce in-water work duration to allow for more permanent structures to be constructed.

Aquatic Species Stranding and Fish Rescue Surveys
Avoiding stranding of aquatic species is an essential activity during the in-water activities. While flow diversion activities will be planned and executed to limit stranding potential, monitoring teams will be in place to identify, recover, and re-locate stranded fish as flows recede and as conveyance channels are de-watered. As water depths reduce, corralling and seining of remaining individuals will be conducted towards the downstream channel connection. As flows become shallower, electrofishing and relocation will be conducted. Mussel salvage and relocation activities will be completed once water levels allow.

Salvage and relocation may only be conducted by personnel deemed qualified by the governing fisheries regulatory agencies. Fish salvage or relocation personnel may be government staff or private professionals, employed by the government or by the Chehalis Basin Flood Control

Zone District (District), as mutually agreed upon by the District and governing fisheries regulatory agencies. The District's construction contractor will responsible for fish exclusion, as well as coordination with and physical support of fish salvage/relocation personnel and the governing fisheries agencies. The District will require the contractor to adhere to typical construction BMPs for the protection of fish including:

- Adherence to the agency approved in-water work window.
- Coordination with agencies to implement fish salvage plans for each stage of in-water work.
- Fish salvage would be conducted in accordance with WSDOT fish exclusion protocols (WSDOT 2016).
- Electroshocking would occur in accordance with National Marine Fisheries Service (NMFS) (2000) electrofishing guidelines.
- All electrofishing will be conducted by a person with electrofishing training on-site to direct all electrofishing activities.
- All captured and collected fish will be transported to the upstream end of the project area and released at a location sufficient for fish to recover and re-orientate to the stream environment (slow moving pool habitat).
- Monitoring of temperature and dissolved oxygen during operations and subsequent refill periods.
- Screening of intakes - pump intakes must be screened compliant with NOAA-Fisheries and WDFW requirements.
- Maintaining fish screen to prevent injury or entrapment of fish.

Screened De-watering
De-watering (i.e., removing water from a surface hole or collection) may be required during brief periods and in limited locations when diversions are made from one phase to the next. De-watering will be slow, deliberate, and screened to facilitate safe and timely removal of any fish trapped in pools. The rate of dewatering will be commensurate with permit requirements from WDFW or as defined during Endangered Species Act (ESA) consultation. Contractor will be required to implement a specific de-watering rate to avoid stranding and to allow adequate aquatic species relocation.

2.5 In-water Work Tenets

The conceptual process of flow diversions as it relates to transitioning construction phases was developed with several tenets, which guide the timing and sequencing of the proposed steps. These tenets include:

1. **Limit in-water work.** Regardless of mitigation measures in-place, in-water work has the potential to be detrimental to the function and health of the river and its ecology. Reducing the duration of in-water work reduces this risk for impacts. Performing in-water work concurrently, instead of a long sequence of steps, is one way to reduce work duration.
2. **Prevent abrupt dewatering.** To limit the risk of fish stranding, diverting river flow from one active channel to another should not result in the rapid dewatering of the once active

channel. Closure of the active change, via constructed berm or other approved methodology, should allow for deliberate reduction of flows to allow fish to safely vacate.

3. **Maintain control.** Deliberate and methodical execution of the process of diverting flows is critical to diversion success and worker safety. New channels should be first opened from the downstream end. Upstream berms should be opened at a similar rate to the closure of the channels to be abandoned.
4. **Aquatic species salvage is continuous.** Pro-active efforts to exclude and remove aquatic species is a priority. Actions of each in-water work steps must be planned and executed in support of aquatic species salvage efforts as required under permit documentation.

3.0 Construction Phase Transition and In-water Work Steps

3.1 Phase 1 to Phase 2 Transition

The flows from the Chehalis River and Crim Creek will first be diverted from the existing channels during the transition from Phase 1 to Phase 2. The combined flows will be diverted from their current channels into the Bypass Channel designed and constructed for use during Phase 2 and Phase 3 of construction. This transition includes three steps and ends when the combined flows are fully diverted and when fish salvage and de-watering operations have concluded. Each step is described below, to include the conditions at the beginning and end of each step and the major actions taken during the step. An exhibit for each step is attached.

3.1.1 Step 1

Begins: Chehalis River flows through the FRE project site in the existing channel. Crim Creek flows join the Chehalis River at the existing confluence location. The Bypass Channel is constructed and ready for use, but stream flows are precluded by the natural bank serving as a barrier to flow.

Actions Taken:

Actions during this step are limited to the work necessary to remove the existing riverbank at the downstream end of the Bypass Channel. This embankment will be removed in such a manner as to reduce the duration of in-water activity. This would include excavation as much of the existing channel bank from the dry Bypass Channel, and only breaching the embankment at the end of the operation.

Ends: This step ends when the existing riverbank at the downstream end of the Bypass Channel is fully breached and flow is allowed to backwater into the Bypass Channel.

3.1.2 Step 2

Begins: This step begins when the existing riverbank at the downstream end of the Bypass Channel is fully breached and flow is allowed to backwater into the Bypass Channel. The Chehalis River flows through the FRE project site in the existing channel. Crim Creek flows join the Chehalis River at the existing confluence location.

Actions Taken:

This step is characterized primarily by the actual diversion of flows into the Bypass Channel. The specific actions include:

- Initial breach of the channel embankments to allow flow into the Bypass Channel via the Crim Creek and Chehalis River flow paths.
- Concurrent to the initial breach of the channel embankments, construction of the flow diversion features at Crim Creek and Chehalis River will be initiated. These diversion structures have yet to be engineered, but could include earthen/rock berms, piling, super sacks or other methods.
- The Bypass Channel embankment breaches are widened, allowing for a gradual increase in flow into the Bypass Channel. Simultaneously, the diversion features continues to reduce flow into existing Chehalis Channel.
- As flow in the Existing Channel is reduced, aquatic species salvage commences.
- Diversion structures will isolate the existing river channel between the Crim Creek and Chehalis flow paths into the Bypass Channel. Aquatic species salvage will be conducted, followed by dewatering, as necessary.

Ends: This step ends when Chehalis River and Crim Creek flows are completely diverted into the constructed bypass. The existing Chehalis River channel is closed at Crim Creek. The existing channel located between the Crim Creek and Chehalis portions of the Bypass is closed to stream flow and aquatic species salvage is complete. The downstream end of the Existing Channel, adjacent to the Bypass Channel outfall, is open.

3.1.3 Step 3

Begins: This step begins when Chehalis River and Crim Creek flows are completely diverted into the constructed Bypass Channel. The upstream end of the existing Chehalis River channel is closed at Crim Creek, but remains open at the downstream end, adjacent to the Bypass Channel.

Actions Taken:

This step consists of the downstream closure of the existing Chehalis River channel. The specific actions include:

- With complete diversion of streamflow into the Bypass Channel, the downstream end of the existing Chehalis River channel can be closed. This closure will be gradual and in-concert with aquatic species salvage efforts in the channel.
- As the existing Chehalis River channel will be subject to backwater conditions only, the final closure will isolate a final pool of water within the channel. This pool will be gradually dewatered via screened pumps, at a rate necessary to support aquatic species salvage as required in the approved in-water work plan.

Ends: This step ends when the existing river channel between Crim Creek and the downstream end of the Bypass Channel is closed to streamflow. De-watering is complete. Aquatic species salvage efforts are complete.

3.2 Phase 2 to Phase 3 Transition

The transition from Phase 2 to Phase 3 is the second and last proposed diversion of Chehalis River and Crim Creek flows construction. The combined flows will be diverted from the Bypass Channel into the Approach Channel. Flows from the Approach Channel will pass through the FRE via the passage conduits and stilling basin and into the Discharge Channel. The Discharge Channel will pass the combined flows back into the downstream, existing reach of the Chehalis. This transition includes three steps and ends when the combined flows are fully diverted and when fish salvage and unwatering operations have concluded.

3.2.1 Step 1

Begins: Chehalis River and Crim Creek flows pass through the FRE project site via the Bypass Channel. The FRE conduits and stilling basin are constructed and ready to receive flow. The permanent Approach Channel upstream and the Discharge Channel downstream of the FRE conduits are constructed and ready to receive flow, but flow is precluded by constructed berms at the upstream and downstream ends.

Actions Taken:

Actions during this step are limited to the work necessary to remove the constructed embankment at the downstream end of the permanent Discharge Channel.

Ends: This step ends when the berm at the downstream end of the Discharge Channel is fully breached and flow is allowed to backwater into the Discharge Channel.

3.2.2 Step 2

Begins: This step begins when the berm at the downstream end of the Discharge Channel is breached and flow is allowed to backwater into the Discharge Channel.

Actions Taken:

This step is characterized primarily by the actual diversion of flows into the permanent Approach Channel. The specific actions include:

- Initial breach of the diversion structures to allow flow into the Approach Channel via the Crim Creek and Chehalis River flow paths. This includes breaching the diversion structures isolating the portion of the existing Chehalis River channel between the Crim Creek and Chehalis River entrances to the Bypass Channel.
- Concurrent to degrading the diversion structures of the Bypass Channel, new diversion structures at the Crim Creek and Chehalis River entrances to the Bypass Channel will be initiated in order to gradually reduce flow into the Bypass Channel.
- As flow in the Bypass Channel is reduced, aquatic species salvage commences.

Ends: This step ends when Chehalis River and Crim Creek flows are completely diverted into the Approach Channel. The upstream end of the Bypass Channel is closed but remains open at the downstream end.

3.2.3 Step 3

Begins: This step begins when Chehalis River and Crim Creek flows are completely diverted into the Engineered Channel, passage conduits, and stilling basin. The Bypass Channel is closed at the upstream end but remains open at the downstream end.

Actions Taken:

This step consists of the downstream closure of the Bypass Channel. The specific actions include:

- With complete diversion of streamflow into the Approach Channel, the downstream end of the Bypass Channel can be closed. This closure will be gradual and in-concert with aquatic species salvage efforts in the channel.
- As the Bypass Channel will be subject to backwater conditions only, the final closure will isolate a final pool of water within the channel. This pool will be gradually dewatered via screened pumps, at a rate necessary to support aquatic species salvage.

Ends: This step ends when the Bypass Channel is closed to streamflow at both ends. De-watering is complete. Aquatic species salvage efforts are complete.

4.0 Next Steps

Construction activities, timing, and sequencing are still under development. Means and methods of diversion activities have yet to be determined, but should support the tenets provided here-in The in-water work sequencing presented herein is a feasible option; however, the selected contractor may develop alternative plans which will be subject to review by the District and regulatory agencies to ensure consistency with existing environmental authorizations.

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6.0 Acronyms/Abbreviations

AEP	Annual Exceedance Probability
Ecology	Washington State Department of Ecology
ESA	Endangered Species Act
FFPF	Flood Fish Passage Facility
FRE	Flood Retention Expandable
HDR	HDR Engineering, Inc.
NMFS	National Marine Fisheries Service
RPDR	Revised Project Description Report
USACE	US Army Corps of Engineers
WDFW	Washington State Department of Fish and Wildlife

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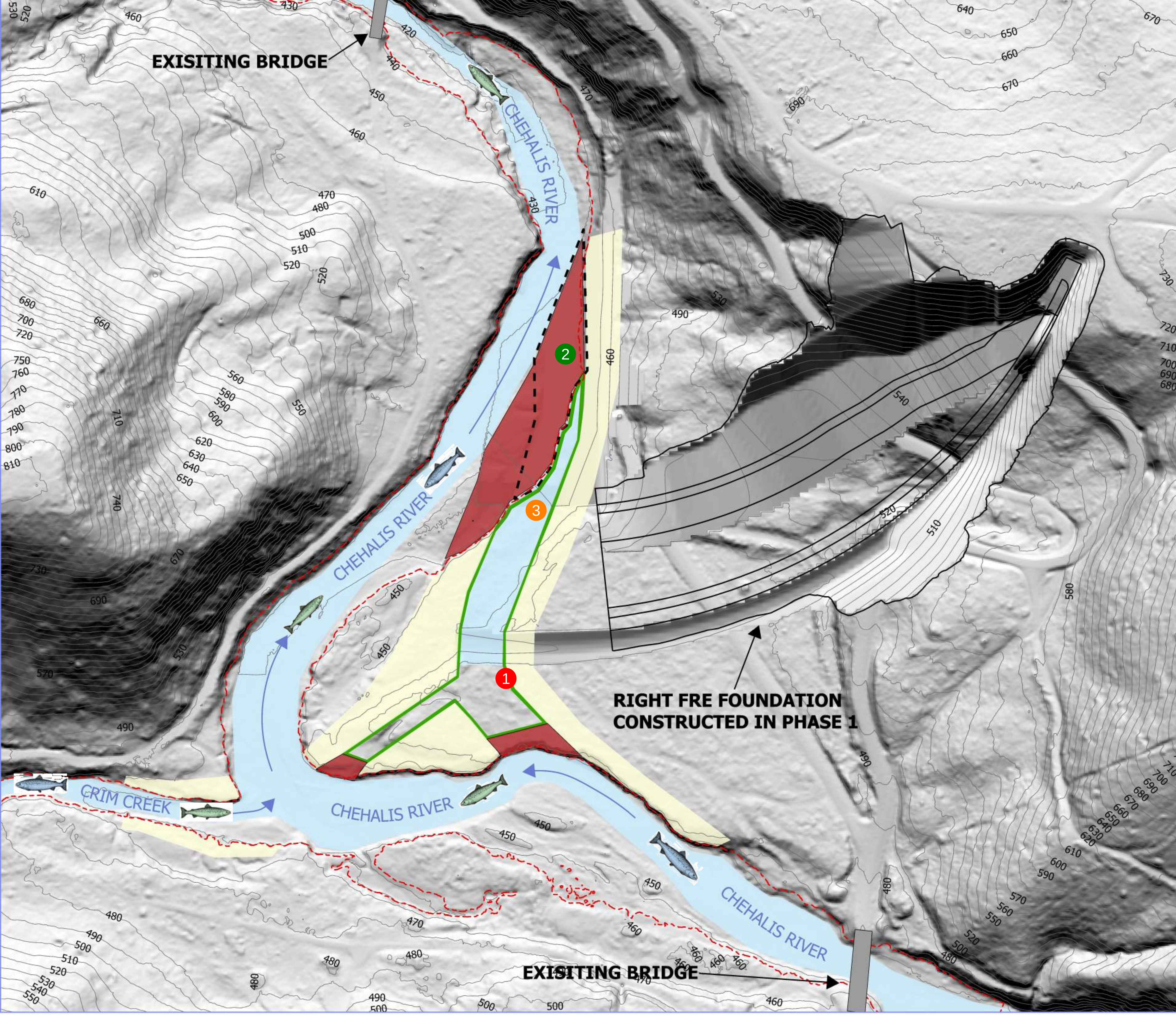
Attachment A. Phase 1-2 Transition, Step 1



CONSTRUCTION IN-WATER WORK STEPS

YEAR 1
IN-WATER WORK WINDOW 1
TRANSITION FROM PHASE 1 TO PHASE 2
STEP 1

Legend

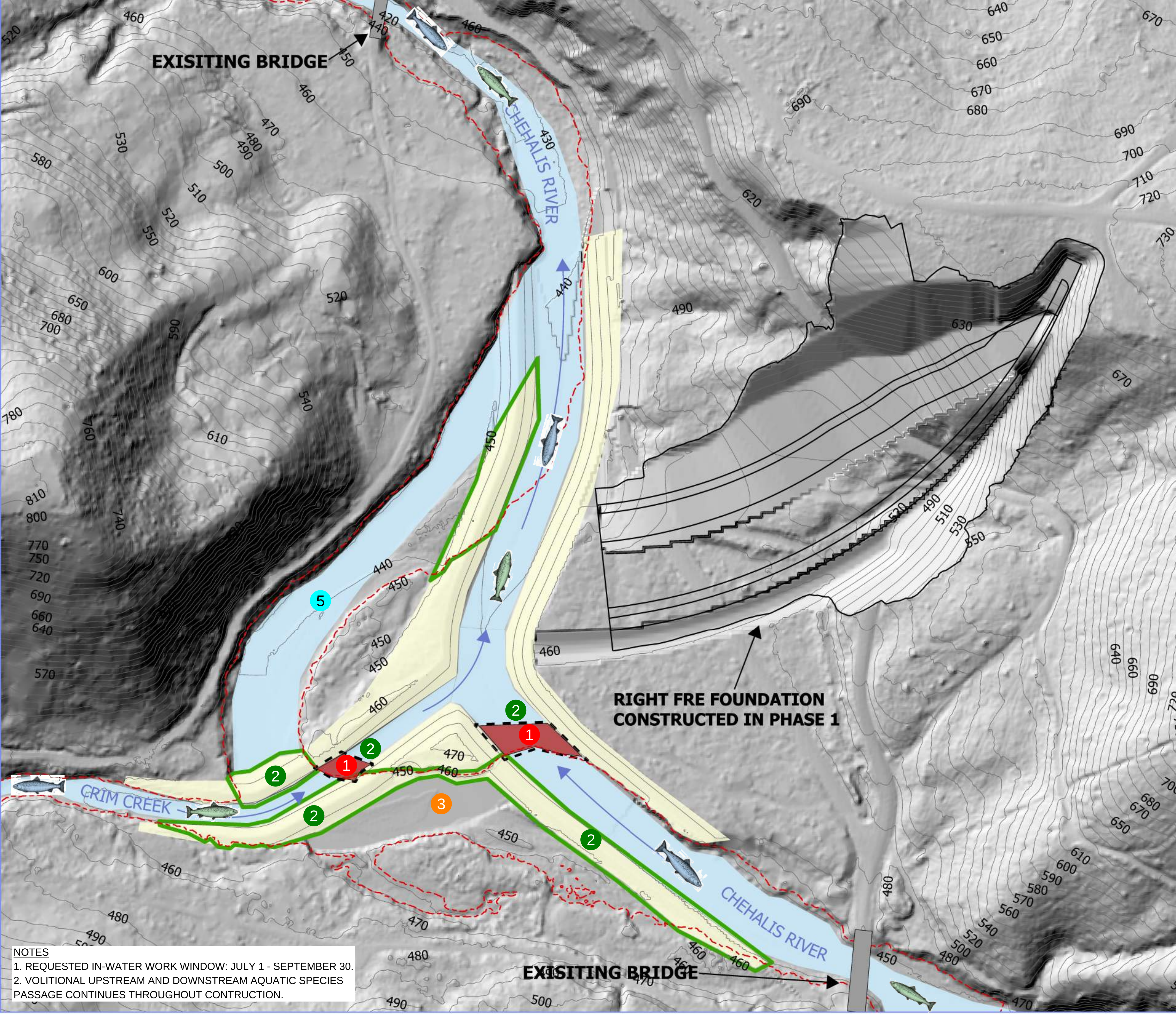
- FRE FACILITY
- EXISTING OHWM - 2YR WSEL
- 10 FT CONTOUR
- CHANNEL BREACH
- DIRECTION OF FLOW
- EXISTING RIVER BANK
- BYPASS CHANNEL EMBANKMENT
- BYPASS CHANNEL
- APPROX. SUMMERTIME WETTED AREA
- UPSTREAM FISH PASSAGE ROUTE
- DOWNSTREAM FISH PASSAGE ROUTE

1. BYPASS CHANNEL AND BYPASS CHANNEL EMBANKMENT ABOVE OHWM CONSTRUCTED IN THE DRY, BEHIND THE EXISTING RIVER BANK, PRIOR TO STEP 1.
2. EXISTING RIVER BANK BREACHED DURING STEP 1, CONNECTING BYPASS CHANNEL TO EXISTING CHEHALIS RIVER. BYPASS CHANNEL BACKWATERED BY CHEHALIS RIVER. AQUATIC SPECIES EXCLUDED AND REMOVED FROM WORK AREA PRIOR TO CONSTRUCTION BELOW OHWM.
3. AQUATIC SPECIES EXCLUSION REMOVED FROM WORK AREA FOLLOWING CONSTRUCTION BELOW OHWM. AQUATIC SPECIES HAVE ACCESS TO BACKWATERED BYPASS CHANNEL.

NOTES
1. REQUESTED IN-WATER WORK WINDOW: JULY 1 - SEPTEMBER 30.
2. VOLITIONAL UPSTREAM AND DOWNSTREAM AQUATIC SPECIES PASSAGE CONTINUES THROUGHOUT CONTRUCTION.

0 425 850
Feet

Attachment B. Phase 1-2 Transition, Step 2



NOTES
1. REQUESTED IN-WATER WORK WINDOW: JULY 1 - SEPTEMBER 30.
2. VOLITIONAL UPSTREAM AND DOWNSTREAM AQUATIC SPECIES PASSAGE CONTINUES THROUGHOUT CONTRUCTION.

CONSTRUCTION IN-WATER WORK STEPS

YEAR 1
IN-WATER WORK WINDOW 1
TRANSITION FROM PHASE 1 TO PHASE 2
STEP 2

Legend

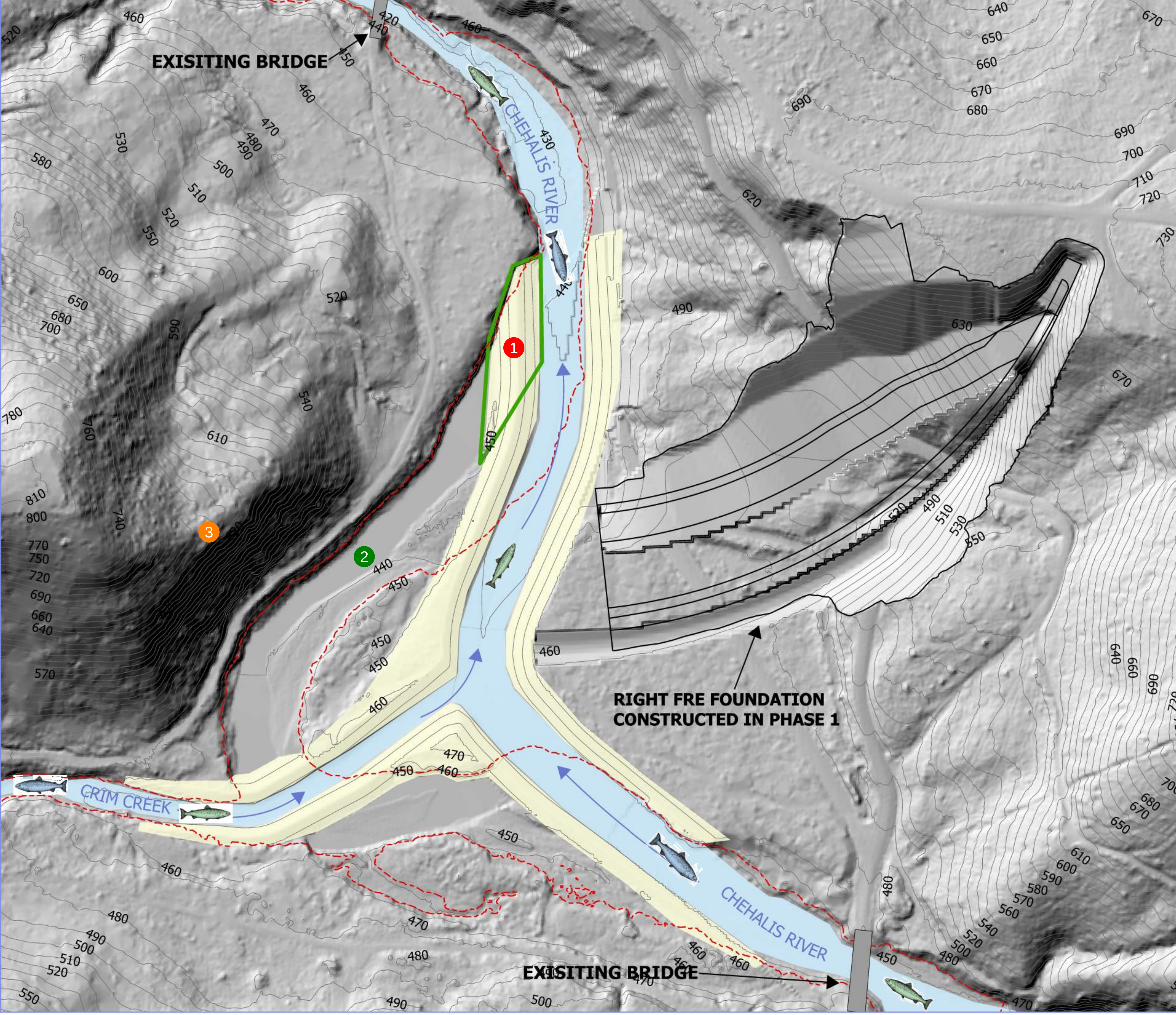
- FRE FACILITY
- EXISTING OHWM - 2YR WSEL
- 10 FT CONTOUR
- CHANNEL BREACH
- DIRECTION OF FLOW
- EXISITING RIVER BANK
- CONSTRUCTED EMBANKMENT
- BYPASS CHANNEL EMBANKMENT
- APPROX. SUMMERTIME WETTED AREA
- UPSTREAM FISH PASSAGE ROUTE
- DOWNSTREAM FISH PASSAGE ROUTE

1. PERFORM INITIAL BREACH OF EXISTING RIVER BANKS TO ALLOW CHEHALIS RIVER AND CRIM CREEK INTO THE BYPASS CHANNEL.
2. GRADUALLY WIDEN BREACHES OF EXISTING RIVER EMBANKMENTS WHILE SIMULTANEOUSLY CONSTRUCTING BYPASS CHANNEL EMANKMENTS. AS FLOW GRADUALLY DIVERTS INTO THE BYPASS CHANNEL THE WSEL IN THE EXISTING CHEHALIS RIVER WILL SLOWLY LOWER. PERFORM AQUATIC SPECIES RELOCATION CONTINUOUSLY THROUGHOUT IN-WATETR WORK. WORK CONTINUES UNTIL EXISTING CHANNEL AREAS WITHIN THE FINAL BYPASS FOOTPRINT ARE FULLY BREACHED, BYPASS EMBANKMENTS ARE COMPLETE, AND FLOW IS FULLY DIVERTED FROM THE EXISTING CHEHALIS RIVER AND CRIM CREEK TO THE BYPASS CHANNEL.
3. RELOCATE AQUATIC SPECIES FROM THE EXISTING RIVER CHANNEL AS WSEL DROPS. PUMP OUT REMAINING WATER AND RELOCATE FISH SIMULTANEOUSLY UNTIL CHANNEL IS DRY.
4. CONSTRUCT PART OF DOWNSTREAM, LEFT BANK BYPASS CHANNEL EMBANKMENT. EXCLUDE AND RELOCATE AQUATIC SPECIES PRIOR TO STARTING IN-WATER WORK.
5. AQUATIC SPECIES HAVE ACCESS TO BACKWATERED EXISTING CHEHALIS RIVER CHANNEL.

N

0 425 850
Feet

Attachment C. Phase 1-2 Transition, Step 3



CONSTRUCTION IN-WATER WORK STEPS

YEAR 1
IN-WATER WORK WINDOW 1
TRANSITION FROM PHASE 1 TO PHASE 2
STEP 3

Legend

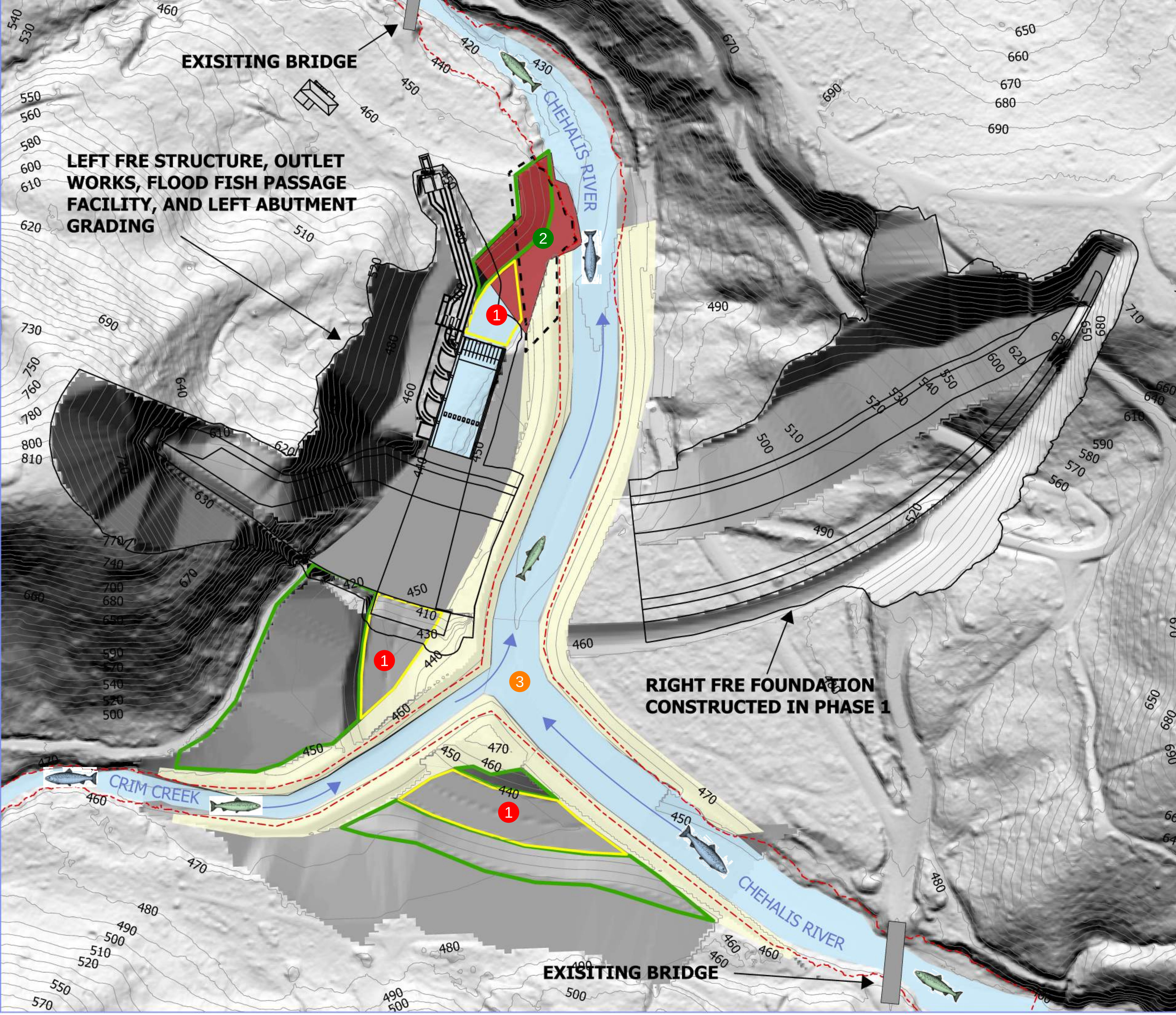
- FRE FACILITY
- EXISTING OHWM - 2YR WSEL
- 10 FT CONTOUR
- DIRECTION OF FLOW
- CONSTRUCTED EMBANKMENT
- BYPASS CHANNEL EMBANKMENT
- APPROX. SUMMERTIME WETTED AREA
- UPSTREAM FISH PASSAGE ROUTE
- DOWNSTREAM FISH PASSAGE ROUTE

1. EXCLUDE AQUATIC SPECIES FROM THE WORK AREA. GRADUALLY CONSTRUCT FINAL BYPASS CHANNEL EMBANKMENT SIMULTANEOUSLY WITH AQUATIC SPECIES RELOCATION.
2. RELOCATE AQUATIC SPECIES FROM THE EXISTING RIVER CHANNEL AS WSEL DROPS WHILE FINAL BYPASS CHANNEL EMBANKMENT IS CONSTRUCTED. PUMP OUT REMAINING WATER AND RELOCATE AQUATIC SPECIES SIMULTANEOUSLY UNTIL OLD CHEHALIS RIVER CHANNEL IS DRY AND AQUATIC SPECIES ARE SAFELY RELOCATED.
3. PHASE 2 WORK COMMENCES FOLLOWING CONCLUSION OF IN-WATER WORK WINDOW 1.

NOTES
1. REQUESTED IN-WATER WORK WINDOW: JULY 1 - SEPTEMBER 30.
2. VOLITIONAL UPSTREAM AND DOWNSTREAM AQUATIC SPECIES PASSAGE CONTINUES THROUGHOUT CONTRUCTION.

N
0 425 850
Feet

Attachment D. Phase 2-3 Transition, Step 1



CONSTRUCTION IN-WATER WORK STEPS

YEAR 3
IN-WATER WORK WINDOW 2
TRANSITION FROM PHASE 2 TO PHASE 3
STEP 1

Legend

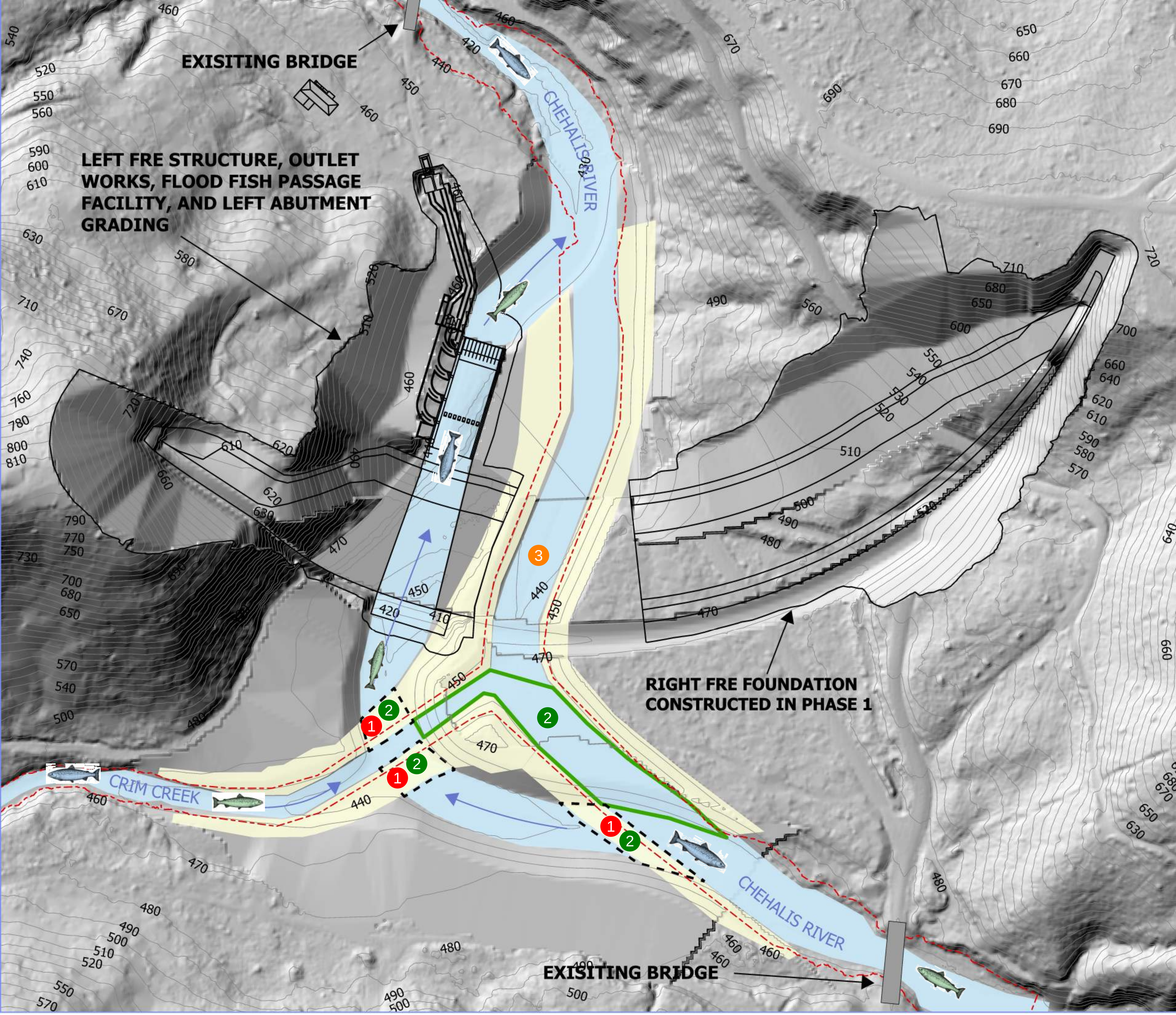
- FRE FACILITY
- OHWM - 2YR WSEL
- 10 FT CONTOUR
- CHANNEL BREACH
- CONSTRUCTED EMBANKMENT
- BYPASS CHANNEL EMBANKMENT
- APPROX. SUMMERTIME WETTED AREA
- EXISTING RIVER BANK
- PERMANENT CHANNEL
- DIRECTION OF FLOW
- UPSTREAM FISH PASSAGE ROUTE
- DOWNSTREAM FISH PASSAGE ROUTE

1. PERMANENT RIVER CHANNEL CONSTRUCTED IN THE DRY IN PHASE 2, PRIOR TO IN-WATER WORK WINDOW 2.
2. CHANNEL EMBANKMENT CONSTRUCTED AND EXISTING RIVER BANK BREACHED DURING STEP 1. CHEHALIS RIVER CONNECTED TO PERMANENT CHANNEL AND FISH PASSAGE CONDUIT STILLING BASIN BY BREACH. FISH PASSAGE CONDUIT STILLING BASIN AND PERMANENT CHANNEL DOWNSTREAM BACKWATERED BY CHEHALIS RIVER. AQUATIC SPECIES EXCLUDED AND REMOVED FROM WORK AREA PRIOR TO CONSTRUCTION BELOW OHWM. AQUATIC SPECIES EXCLUDED FROM FISH PASSAGE CONDUIT STILLING BASIN THROUGHOUT STEP 1.
3. UPSTREAM AND DOWNSTREAM VOLITIONAL AQUATIC SPECIES PASSAGE CONTINUES VIA BYPASS CHANNEL.

NOTES
1. REQUESTED IN-WATER WORK WINDOW: JULY 1 - SEPTEMBER 30.
2. VOLITIONAL UPSTREAM AND DOWNSTREAM AQUATIC SPECIES PASSAGE CONTINUES THROUGHOUT CONTRUCTION.

N
0 425 850
Feet

Attachment E. Phase 2-3 Transition, Step 2



CONSTRUCTION IN-WATER WORK STEPS

YEAR 3
IN-WATER WORK WINDOW 2
TRANSITION FROM PHASE 2 TO PHASE 3
STEP 2

Legend

- FRE FACILITY
- BYPASS CHANNEL EMBANKMENT
- 10 FT CONTOUR
- CHANNEL BREACH
- APPROX. SUMMERTIME WETTED AREA
- OHWM - 2YR WSEL
- CONSTRUCTED EMBANKMENT
- DIRECTION OF FLOW
- UPSTREAM FISH PASSAGE ROUTE
- DOWNSTREAM FISH PASSAGE ROUTE

1 PERFORM INITIAL BREACH OF BYPASS CHANNEL TO ALLOW CHEHALIS RIVER AND CRIM CREEK INTO THE PERMANENT CHEHALIS RIVER CHANNEL.

2 GRADUALLY WIDEN BREACHES OF BYPASS CHANNEL EMBANKMENTS WHILE SIMULTANEOUSLY CONSTRUCTING PERMANENT CHANNEL EMANKMENTS. AS FLOW GRADUALLY DIVERTS INTO THE PERMANENT RIVER CHANNEL THE WSEL IN THE BYPASS CHANNEL WILL SLOWLY LOWER. PERFORM AQUATIC SPECIES RELOCATION CONTINUOUSLY THROUGHOUT IN-WATETR WORK. WORK CONTINUES UNTIL BYPASS EMBANKMENT AREAS WITHIN THE PERMANENT CHANNEL FOOTPRINT ARE FULLY BREACHED, PERMANENT EMBANKMENTS ARE COMPLETE, AND FLOW IS FULLY DIVERTED FROM THE BYPASS CHANNEL TO THE PERMANENT CHANNEL.

3 AQUATIC SPECIES HAVE ACCESS TO BACKWATERED EXISTING CHEHALIS RIVER CHANNEL.

NOTES
1. REQUESTED IN-WATER WORK WINDOW: JULY 1 - SEPTEMBER 30.
2. VOLITIONAL UPSTREAM AND DOWNSTREAM AQUATIC SPECIES PASSAGE CONTINUES THROUGHOUT CONTRUCTION.

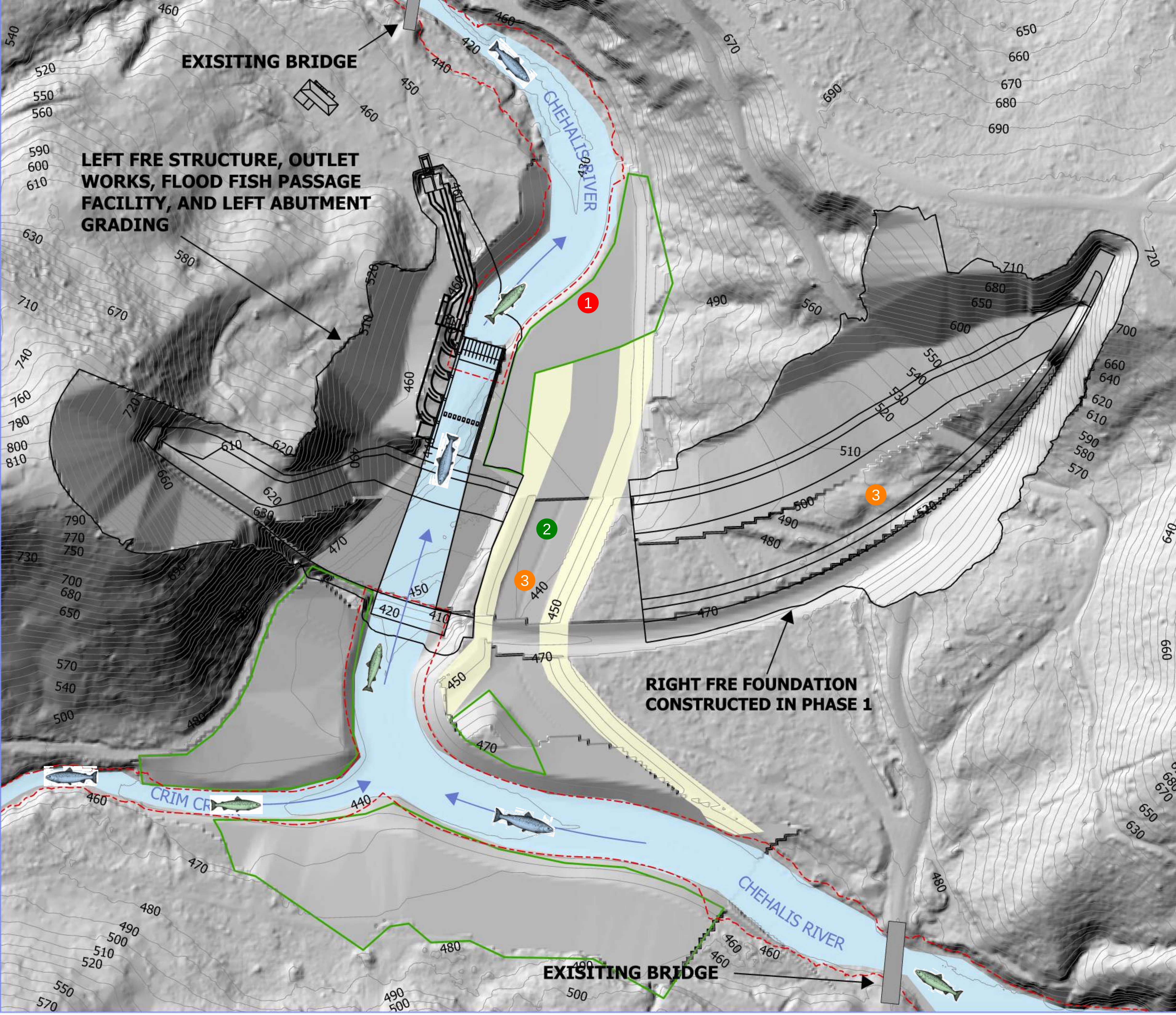
N

0 425 850
Feet

Attachment F. Phase 2-3 Transition, Step 3

CONSTRUCTION IN-WATER WORK STEPS

YEAR 3
IN-WATER WORK WINDOW 2
TRANSITION FROM PHASE 2 TO PHASE 3
STEP 3



Legend

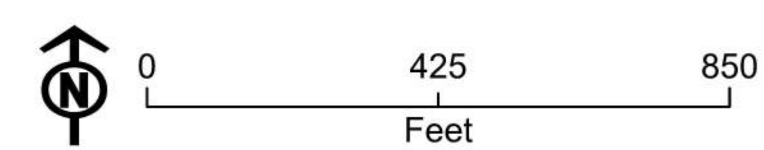
- FRE FACILITY
- PROPOSED OHWM - 2YR WSEL
- 10 FT CONTOUR
- DIRECTION OF FLOW
- CONSTRUCTED EMBANKMENT
- BYPASS CHANNEL EMBANKMENT
- APPROX. SUMMERTIME WETTED AREA
- UPSTREAM FISH PASSAGE ROUTE
- DOWNSTREAM FISH PASSAGE ROUTE

1. EXCLUDE FISH FROM THE WORK AREA. GRADUALLY CONSTRUCT FINAL PERMANENT CHANNEL EMBANKMENT SIMULTANEOUSLY WITH AQUATIC SPECIES RELOCATION.

2. RELOCATE AQUATIC SPECIES FROM THE BYPASS CHANNEL AS WSEL DROPS WHILE PERMANENT EMBANKMENT IS CONSTRUCTED. PUMP REMAINING WATER OUT OF BYPASS CHANNEL AND RELOCATE AQUATIC SPECIES SIMULTANEOUSLY UNTIL BYPASS CHANNEL IS DRY AND FISH ARE SAFELY RELOCATED.

3. PHASE 3, INCLUDING CONSTRUCTION OF RIGHT SIDE OF FRE STRUCTURE AND FILLING OF DRY BYPASS CHANNEL, COMMENCES FOLLOWING CONCLUSION OF IN-WATER WORK WINDOW 2.

NOTES
1. REQUESTED IN-WATER WORK WINDOW: JULY 1 - SEPTEMBER 30.
2. VOLITIONAL UPSTREAM AND DOWNSTREAM AQUATIC SPECIES PASSAGE CONTINUES THROUGHOUT CONTRUCTION.



Appendix B. Juvenile Fish Sounding TM

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Technical Memorandum

Date: November 21, 2025

Project: Chehalis River Basin Flood Damage Reduction Project

To: Chehalis Basin Flood Control Zone District

From: Cheyenne Ginther, HDR, Environmental Scientist
Peter Drobny, HDR, Senior Fisheries Scientist
Norm Ponferrada, HDR, Senior Fisheries Project Manager

Subject: **Juvenile Fish Sounding (Draft)**

1.0 Background

The Proposed Chehalis River Basin Flood Damage Reduction project (Proposed Project) objective is to implement a series of measures aimed at reducing damage to the communities of the Chehalis River Basin from Pe Ell to Centralia during major flood events. Among these measures is a proposed Flood Retention Expandable (FRE) structure on the Chehalis River, south of Pe Ell, Washington.

The Proposed Project's draft Preliminary Design Report (PDR) documents development of the preliminary design of the FRE facility and related elements. Development of the draft PDR began following submittal of the Revised Project Description Report (HDR Engineering, Inc. [HDR] 2024), which was used as the baseline for the draft PDR, submitted for information-only purposes on June 30, 2025 (HDR 2025a). This draft PDR reflects design development that has occurred since submittal of the June 30, 2025, draft PDR.

The draft PDR documents the design basis for each Proposed Project element, including a record of design decisions, assumptions, and methods related to the development of the design of the FRE structure and related elements. The draft PDR also presents the technical details of the main features of the Proposed Project elements..

2.0 Introduction

The Chehalis River Basin Flood Control Zone District is proposing the construction and operation of an FRE structure at river mile (RM) 108.4 near the town of Pe Ell, Washington to reduce damage during a major flood. FRE facility designs, construction methods, and operation plans presented herein are subject to updates during future design phases.

The Proposed Project involves construction and operation of a flow-through dam for flood control, which is unlike a traditional detention dam. The Proposed Project's hydraulic outlets and fish passage structures will be built at the same height as the existing riverbed. Except during operations for infrequent major storm events (defined in Section 3.0), the mainstem of the Chehalis River will flow freely through the fish passage structure system. Because flow-through dams minimally affect a river's natural flow under normal conditions, consequences such as blocking fish migration routes, accumulating sediment, restricting water flow to downstream communities, and other negative fish impacts are avoided or minimized.

The Proposed Project will not involve a permanent pool or reservoir. Rather, an area behind the dam will be inundated only temporarily when the structure is being operated for downstream flood reduction. Following passage of the peak flood flow, the inundated area will be drained and flow-through conditions re-established. There is a risk that juveniles may be entrained into hydraulic outlets while the temporary inundation pool is drained. Entrained juveniles may be at risk of injury or death if the outlets are unscreened or not hydraulically conducive to safe fish passage.

2.1 Purpose and Scope of the Memorandum

This memorandum presents available research to inform design and recommend potentially appropriate depths for hydraulic outlets to limit the risk of entrainment to fish moving downstream during temporary impoundment events. This recommendation is reached by assessing the juvenile outmigrant entrainment risk during evacuation of the temporary reservoir. The memo describes the potential risk of entrainment into the hydraulic outlet gates opening at depth due to "juvenile fish sounding" or movement into deeper water toward the end of the temporary inundation area.

The analyses focuses on salmonids, primarily spring-run and fall-run Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*) and winter-run steelhead (*O. mykiss*) which are prey items for the endangered Southern Resident Killer Whale (*Orcinus orca*), resulting in their coverage under Section 7 of the federal Endangered Species Act (ESA). While this document focuses on salmonids, the project overall is designed to be relevant for a wide range of other aquatic species and life stages. Therefore, the research presented in this technical memorandum may have some applicability to other species listed in Table 1 that may be impacted by the flood retention operations due to research on the other species being limited or non-existent.

2.2 Proposed Project Overview

The FRE structure includes fish passage and hydraulic outlet gates. When a temporary reservoir is held upstream of the FRE structure, the fish passage gates are closed, and the hydraulic outlet gates will be used for reservoir releases.

3.0 Characterization of Facility Operation

For this technical memorandum, operation of the FRE facility occurs in two main operational states:

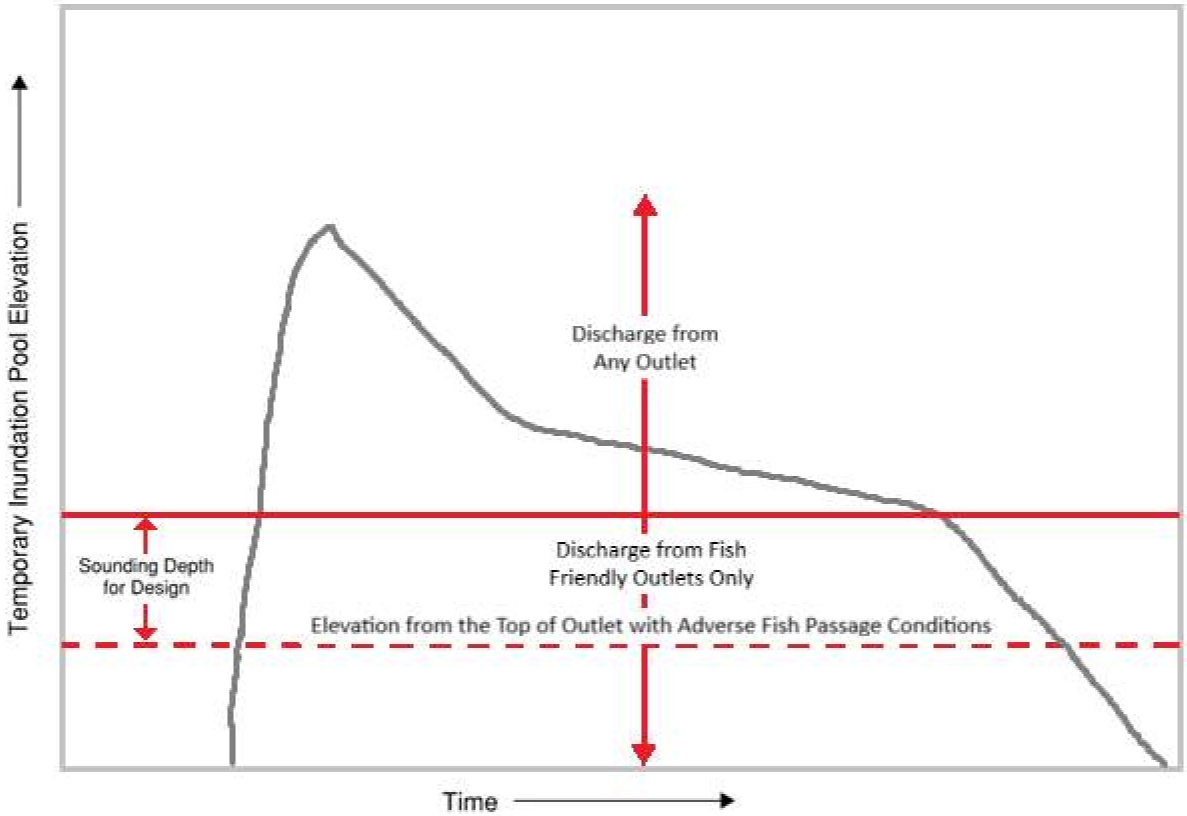
- **Normal Flow-Through Operation**: When the fish passage and hydraulic outlet gates are open and the Chehalis River flows through the FRE unimpeded.

- **Flood Retention Operation**: When the fish passage gates are closed and openings on the hydraulic outlets are reduced to impound incoming floodwaters behind the FRE.

Flood retention operation will occur when operational rules triggered. For example, an operational trigger may be that a specific flow is forecast for the Chehalis River at a specific location or river mile. Based on the hydraulic record, the hydrologic and operations modeling indicates that these events are expected to trigger flood retention operations every 4 to 5 years between the months of November to February. Flood retention operations are likely to increase every 2 to 3 years in frequency over time, during the months of November to April, due to climate changes by the year 2080 (HDR 2024b).

Error! Reference source not found. Figure 1 shows that when an impoundment event occurs, flood retention operations will trigger the fish passage gates to be closed, resulting in the reservoir elevation rising to store water and reduce flooding downstream. When the temporary reservoir elevation exceeds the depths for which fish are more likely to dive or sound, water will be released through unscreened, high-velocity hydraulic outlets. As the reservoir elevation drops, the flood retention operations eventually will switch to hydraulic outlets that exclude fish or provide hydraulically favorable conditions for downstream passage. Discharge through these “fish friendly” hydraulic outlets will continue as the facility transitions from flood retention operations to normal flow-through operations. Managing which hydraulic outlets are used based on reservoir depth will reduce the risk of entrainment to fish because discharge through any outlet will be at depths greater where fish are less likely to sound.

Figure 1. Hydraulic Outlet Operation and Sounding Depth for Design When Holding a Temporary Inundation Pool



Temperature stratification of the temporary inundation pool is not expected due to the temporary nature of the flood retention operations. Filling and draining rates for the temporary pool, and high flow rates of the Chehalis River entering the pool during and following storm events, are expected to result in high levels of mixing and turbidity, which prevent the conditions necessary for stratification. In addition, extended periods of time with low levels of mixing are necessary for stratification to occur. Impoundment events are anticipated to be of short duration – less than six weeks. This is supported by recent operations modeling. Such durations, with the high levels of mixing expected, make stratification further unlikely especially given that impoundment events are most likely to occur during the winter months when fish are less likely to sound deeper seeking cooler water temperatures. Target Species of Concern

The Proposed Project is being developed for fish passage to address fish species that use the Chehalis River, as indicated in Table 1Table 1. Although no aquatic species are federally listed as endangered or threatened in this part of the Chehalis River, under Section 7 of the federal ESA, spring-run and fall-run Chinook Salmon, Coho Salmon, and winter-run steelhead are species known to be prey items for the endangered Southern Resident Killer Whale. Therefore, this technical memorandum will focus on these three salmonid species that may indirectly impact Southern Resident Killer Whales due to potential entrainment during flood retention operations.

Table 1. Fish Species and Life Stages Selected for Fish Passage Design

Species	Upstream Passage	Downstream Passage
Spring-run and Fall-run Chinook Salmon (*Oncorhynchus tshawytscha*)	Adult, juvenile	Juvenile
Coho Salmon (*Oncorhynchus kisutch*)	Adult, juvenile	Juvenile
Winter-run Steelhead (*Oncorhynchus mykiss*)	Adult, juvenile	Adult, juvenile
Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*)	Adult, juvenile	Adult, juvenile
Pacific Lamprey (*Entosphenus tridentatus*)	Adult	Larvae
Western Brook Lamprey (*Lampetra richardsoni*)	Adult	Larvae
Resident fish: River Lamprey, Largescale Sucker, Salish Sucker, Torrent Sculpin, Reticulate Sculpin, Riffle Sculpin, Prickly Sculpin, Speckled Dace, Longnose Dace, Peamouth, Northern Pikeminnow, Redside Shiner, Rainbow Trout, Mountain Whitefish	Adult	Adult

Source: HDR 2018

The target salmonid species (Chinook Salmon, Coho Salmon, and steelhead) are known to have unique migration behaviors that allow them to pass upstream or downstream through the FRE site at specific times of the year. As presented in Figure 2, fish species migration timing and duration influence the design and operation of proposed fish passage facilities by defining the physical, operational, and environmental conditions expected to occur while passage is required. The timing and duration of migration for these fish species and life stages were discussed at the 2016-2017 Fish Passage Subcommittee meetings (Appendix I: Fish Passage Report; HDR 2025b) as new information was aggregated and analyzed. The periods shown in Figure 2 incorporate anecdotal data of species' presence at the extreme ends of known movement periods and are potentially likely broader than what may be found in the river.

Figure 2. Anticipated Migration Periods of the Targeted Species and Life Stages (Periodicity)

The following sections focus on general information for Chinook Salmon, Coho Salmon, and steelhead in the Chehalis Basin, detailing each species' juvenile outmigration, which has a greater potential to be affected by implementation of the flood retention operations due to entrainment.

3.1 Chinook Salmon

The Chehalis Basin has both spring- and fall-run Chinook Salmon which are part of the Washington Coast Evolutionarily Significant Unit (ESU). Spawn timing is distinguished between spring- and fall-run Chinook Salmon in the Chehalis River Basin. While timing may overlap, for practical purposes, October 15th is the current accepted spawning date used to differentiate the spring-run from the fall-run Chinook Salmon (Ashcraft et al. 2017). Brown et al. (2017) found Skookumchuck and upper Chehalis Rivers spring-run Chinook Salmon introgressed with the fall-run and timing may not reflect actual run type. Brown et al. (2017) revealed that fall and spring runs were not genetically distinct and found slight differentiation between downstream and upstream collections (i.e., those upstream and downstream of the confluence with the Skookumchuck River), and states that "this was likely driven by isolation by distance." Based on this information from Brown et al. (2017), individuals that spawn upstream of the FRE have "a low degree of differentiation" from those that spawn in the mainstem Chehalis River upstream of the confluence with the Skookumchuck River (RM 67).

Most Chinook Salmon in the Chehalis Basin exhibit ocean-type life histories (Smith and Wenger 2001). Most spring- and fall-run Chinook Salmon juveniles emerge the following spring, distribute downstream, and emigrate in their first spring. A small proportion are assumed to delay emigration until the following spring to emigrate as yearlings. The following are juvenile life-history patterns for spring- and fall-run Chinook Salmon including their allocation across the modeled life-history trajectories (McConnaha et al. 2017):

- **Fry Migrant (45 percent)**: Rapid downstream migrant about 3 weeks after emerging between January to mid-March. Extended residence in the estuary.

- **Fingerling Migrant (45 percent)**: Conventional ocean-type Chinook Salmon. Soon after emergence, they begin moving downstream slowly, eventually increasing speed to enter the estuary in late spring between April to July.
- **Yearling Migrant (10 percent)**: Stream type. Spends winter in or near natal reach, eventually goes through a smoltification process (i.e., change in osmoregulation to be able to transition from freshwater to saline or ocean environments) the following spring and moves rapidly downstream to the estuary.

3.2 Coho Salmon

Coho Salmon in the Chehalis River are part of the Southwest Washington Coho Salmon ESU, for which no major spawning groups have been specified (WDFW 2019). In a genetic study of Coho Salmon in the Chehalis Basin, Seamons et al. (2019) found genetic differences between groups of Coho Salmon from the same spawning location, among spawning tributaries, and based on run timing (early and late). Coho Salmon in the upper Chehalis Basin (i.e., upstream of the proposed FRE site) were genetically distinct from Coho Salmon spawning in other locations, suggesting population differences among subbasins (Seamons et al. 2019).

Coho Salmon in the Chehalis Basin were assumed to follow a standard Coho Salmon stream-type life history (Smith and Wenger 2001). Juveniles emerge in the spring between February to May and spend the next year in various habitats within the Chehalis River Basin which includes side channels, beaver ponds, floodplain wetlands, and backwaters for overwintering and summer rearing. Emigration from the system typically occurs in the second spring after one year in freshwater between March to June. The following are juvenile life-history patterns for Coho Salmon including their allocation across the modeled life-history trajectories (McConnaha et al. 2017):

- **Resident (50 percent)**: Migrates no more than 40 kilometers (24 miles) downstream of natal reach during juvenile rearing, moves rapidly downstream in the second spring-run to the estuary.
- **Migrant (50 percent)**: Extended downstream movement including fall-run redistribution downstream. Could migrate almost to the estuary during juvenile rearing, reaching the estuary in second spring-run.

Juvenile Coho Salmon have been documented to move upstream up to a few kilometers (more than 1 mile) in some Chehalis Basin tributaries. Upstream movements primarily occurred during warmer months, which may indicate a need to access cold water refugia (Winkowski et al. 2018). Warm summer stream temperatures and the presence of competitive cyprinids in lower reaches appear to limit the amount of suitable juvenile rearing habitat in the Chehalis Basin (Winkowski et al. 2018; Winkowski and Zimmerman 2019). During 2015, juvenile salmon distribution surveys conducted upstream of the FRE site, Winkowski et al. (2016) found juvenile Coho Salmon throughout the maximum modeled FRE temporary inundation area.

3.3 Steelhead

Winter-run steelhead are present throughout the Chehalis River. The upper Chehalis River supports a relatively large number of wild winter-run steelhead (Ashcraft et al. 2017). Winter-run steelhead spend the greatest amount of time in freshwater compared to other anadromous salmonids. Fry start to emerge from the gravels between May to September and freshwater rearing ranges from 1 to 3 years before emigration in the summer between April to August. Fry use low-velocity margin habitats after emergence and juveniles move into areas of fast water and large substrate as they grow. Like Coho Salmon, more structurally complex habitats (e.g., with more wood) can support more juvenile steelhead. The following are Juvenile life-history patterns for steelhead including their allocation across the modeled life-history trajectories (McConnaha et al. 2017):

- 85 percent spend 2 years in freshwater; 15 percent spend 3 years in freshwater.
- **Resident (50 percent)**: Stays relatively close to natal reach before smolting.
- **Transient (50 percent)**: Alternating periods of rearing and migration throughout the summer rearing period in all pre-smolting years.

4.0 Fish Sounding Behavior

Juvenile fish passage through the FRE structure and expected juvenile fish migration depths when faced with a temporary passage barrier are discussed in the following sections.

4.1 Downstream Juvenile Salmonid Fish Passage at FRE

When open during Normal Operations, the fish passage gates will help facilitate the downstream juvenile salmonid passage. When closed during Flood Retention Operations, a small number of outmigrating fish could potentially sound to 30 feet or more depending on outmigrant size of the temporary inundation area is evacuated, there is a risk that juvenile salmonids may be entrained into the evacuation conduits outmigrants and length of impoundment, which if (i.e., 0or greater) may put them at risk of entrainment in the hydraulic outlets (Dauble et al. 1989; Li et al. 2015; Smith 1974). The depth at which fish are likely to sound is further described in Section 5.2. It is important to understand that the FRE is being designed to reduce the impact on juvenile salmonids during the flood retention operations (as stated in Section 3.0), which would be expected to typically occur outside outmigration timing (as shown in Figure 2).

Coho Salmon and steelhead rear in the Chehalis River for more than 1 year and up to 2 years, respectively, before outmigrating. In contrast, both spring and fall Chinook Salmon from the upper Chehalis Basin outmigrate to the estuary as parr, or, in limited cases, fry (Campbell et al. 2017). According to Miller-Nelson et al. (2024), a juvenile salmonid monitoring study in 2023 using a rotary screw trap at RM 94.3 on the upper Chehalis River mainstem near Pe Ell determined the following:

- Of 820 Coho Salmon captured, 274 scale samples were collected, with 95.6 percent being successfully aged finding that the outmigrants were predominantly of the yearling (or 1+) age class (98.5 percent) with a small group of 2+ year-old (1.5 percent) outmigrating.
- Of 591 steelhead captured, 250 scale samples were collected, with 79.6 percent being successfully aged finding that the migrants had a mix of Age-1 representing 33.7 percent,

Age-2 representing 65.3 percent, and Age-3 representing 1 percent of juveniles outmigrating.

- A total of 7,723 Chinook Salmon outmigrants were captured, and no scale samples were taken because they were all assumed to be subyearlings based on their fork length between 45 to 150 millimeters.

When comparing the data derived from McConnaha et al. (2017), the authors used an Ecosystem Diagnosis and Treatment model to evaluate the biological significance of environmental changes regarding regarding the potential of the basin to support salmonids at basin and sub-basin scales due to flood damage reduction and habitat restoration actions. Whereas Miller-Nelson et al. (2024) focused on captured salmonids in the upper Chehalis Basin downstream of the proposed FRE, both assumed juvenile Coho Salmon and steelhead are highly mobile during the summer low-flow period in the upper mainstem Chehalis River due to the variable ages observed in outmigrants throughout the Chehalis River. Therefore, these age ranges should be considered as larger, older fish may distribute deeper into the water column compared to smaller, younger fish, leaving them more vulnerable to entrainment during flood retention operations.

Findings from McConnaha et al. (2017) and Nelson et al. (2024) are further corroborated by local data collected in summer 2015 where juvenile salmon distributions were surveyed around and within the inundation area of the proposed temporary reservoir, in the upper mainstem Chehalis River near the upper extent of the reservoir inundation area at RM 116 and extending approximately 10 RM upstream (Winkowski et al. 2016). Juvenile Coho Salmon and trout (cutthroat and rainbow/steelhead) were found throughout the proposed temporary reservoir inundation area, which includes stretches of the upper mainstem Chehalis River and 10 RM of several small tributary creeks. Juvenile Coho Salmon and trout were also observed in reaches above the proposed temporary reservoir inundation area. Subyearling and yearling steelhead rear in the area throughout the summer, moving frequently upstream and downstream at the proposed FRE facility site, presumably to forage and maintain optimal body temperature and condition (Winkowski and Zimmerman 2017). Unlike Coho Salmon and steelhead which rear for longer periods in freshwater, subyearling juvenile Chinook Salmon rear in the upper Chehalis River above the proposed FRE facility during their first spring and summer with outmigration from the upper Chehalis Basin generally complete by August (Winkowski and Zimmerman 2017).

Most juvenile salmon and steelhead in the Chehalis River will likely will have migrated downstream from the headwaters to rear in other freshwater habitats in the lower mainstem, off-channel, or floodplain wetlands prior to migrating to the ocean (Schroeder et al. 2025). Ocean migration would occur during the typical outmigration window between February to August, depending on species as detailed in Section 4, outside expected impoundment events that would be expected to occur between November to February that would trigger flood retention operations. This has been observed in other coastal rivers, but this behavior is not well defined for the Chehalis River populations. Juvenile Coho Salmon and steelhead that reside in freshwater longer compared to juvenile Chinook Salmon are likely to be most impacted by the expected impoundment events because they may use upstream rearing sites and need to access habitats downstream during these high winter flood events, which provide foraging opportunities and refuge from predators and other environmental stressors. Additionally, climate change may also impact timing of these impoundment events (i.e., more variable weather pattern timing), which would result in all other juvenile salmonid species potentially being affected by impoundment events if the flood retention operations occurred during their typical outmigration timing, increasing their risk of entrainment.

4.2 Juvenile Migration Depths

Operation of the FRE for flood control may have unintended consequences when activated to prevent downstream flooding as it can increase juvenile salmonids' potential risk of entrainment into the hydraulic outlets that operate at depths deeper than the fish passage outlets. The ability of juvenile fish to redistribute, both upstream and downstream, into favorable rearing habitats, has also been deemed important to the continued viability of many stocks. Fish migration and passage behaviors have a strong influence on the selection of routes associated with depth, especially for juvenile salmonids which typically prefer to stay in the top 20 feet of the water column as they migrate downstream (NOAA Fisheries 2019). However, according to Ploskey et al. (2006), vertical distribution data usually showed that more than 80 percent of the fish were in the upper 49 feet of the water column.

Faber et al. (2005) looked at smolt-sized fish which included Chinook Salmon, steelhead, Coho Salmon, and Sockeye Salmon (*Oncorhynchus nerka*) at The Dalles Dam on the Columbia River. During the spring, 80 percent of fish were above 5.6 meters (18.4 feet) and 4.7 meters (15.4 feet) of depth during the day and night, respectively. During summer, fish were similarly distributed in the day and night with 80 percent of the fish in the upper 4.5 meters (14.8 feet) and 4.7 meters (15.4 feet) of the water column, respectively. The vertical distribution of smolt-sized fish was also found to be skewed toward the upper water column for all season/diel categories. They also found that smolt-sized fish were distributed deeper in the water column in the center of the channel than near the edges.

A study focused on juvenile Coho Salmon at the Merwin Dam on the Lewis River found that 72 percent of Coho Salmon distributed from the surface to the upper 10 feet (Erho 1964). However, the incidence of Coho Salmon in deeper nets increased as the season progressed with only 52 percent distributing from the surface to the upper 10 feet and 40 percent distributing from 10 to 20 feet by June. It was theorized that surface temperature rising from 5.6 degrees Celsius (ºC) in March to 14.7ºC in June may have resulted in Coho Salmon distributing deeper into the water column.

Another study focused on the Lower Monumental Dam on the Snake River, which has a reservoir with a maximum depth of 115 feet, had two sampling stations established: one station sampled to a depth of 48 feet and one sampled to a depth of 96 feet. The study found that 58 percent of juvenile Chinook Salmon and 36 percent of juvenile steelhead traveled in the upper 12 feet of the reservoir as shown in Table 2 (Smith 1974). Of fish caught in the upper 12 feet, most were predominantly found between the surface and 6 feet.

Table 2. Vertical Distribution of Juvenile Chinook Salmon and Steelhead Caught at Shallow and Deep Stations in the Forebay of the Lower Monumental Dam in 1973

Shallow and Deep Stations Combined				
Depth (feet)	Chinook Salmon		Steelhead	
	# of Fish	Percent	# of Fish	Percent
0 – 12	143	58	441	36
12 – 24	63	26	291	24
24 – 36	19	8	189	15
36 - 48	4	2	106	8
48 – 60	3	1	61	5
60 – 72	6	2	62	6
72 – 84	2	1	32	2
84 – 96	5	2	48	4

Source: Smith (1974)

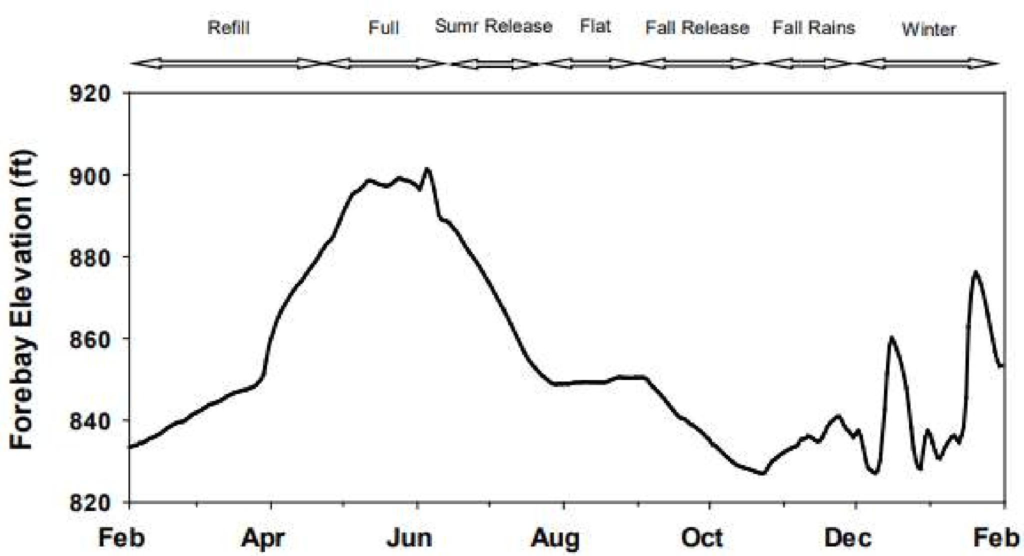
Vertical fish distribution was also examined to determine changes between day and night periods. Smith (1974) found that juvenile Chinook Salmon were observed to be more surface-oriented at night, with 60 percent being captured in the upper 24 feet of the reservoir. Steelhead were observed to be more surface-oriented during the day, with 74 percent being captured in the upper 24 feet of the reservoir. Therefore, steelhead were found to be more surface-oriented during the day whereas juvenile Chinook Salmon were more surface-oriented at night.

A study by Li et al. (2015) focused on juvenile Chinook Salmon and steelhead and compared data across two years (2012 and 2013) in the forebays of two dams on the Snake River, Little Goose Dam and Lower Monumental Dam. The study found that the median depth at which juvenile salmonids approached turbines ranged from 2.8 to 12.2 meters (9.2 to 40 feet), with depths varying by species/life history, year, location (which dam) and diel period (denoting a 24-hour period). The study also showed that fish with estimated deeper vertical depth distributions resided deeper in the forebay prior to passing through the turbines (≤18.4 meters [≤60.4 feet] at Little Goose Dam and 17.0 meters [55.8 feet] at Lower Monumental Dam) compared to those passing through the juvenile bypass system (≤13.0 meters [≤42.7 feet]) at Little Goose Dam and 13.8 meters [45.3 feet]) at Lower Monumental Dam (Li et al. 2015). This was reconfirmed by Li et al. (2018) where they found that juvenile salmonids that passed through deeper routes swam deeper in the water column when approaching the dams which increased the probability of powerhouse passage (i.e., turbine) significantly. While subyearling Chinook salmon that were detected at least once shallower than 12.5 meters (41 feet) were more likely to be guided by the spillway weir.

Li et al. (2015) also noted that most (75 percent) of the fish that passed at night had acclimation depths of ≤7.0 meters (≤30.0 feet), while most of the fish passing during the day had acclimation depths of ≤5.0 meters (≤16.4 feet). For all three species in 2012 and 2013, there were higher percentages of fish acclimated at depths >10 meters (>32.8 feet) for night- versus day-passed fish. Therefore, if operation of the FRE to control flooding occurred during the night, fish are assumed to be more likely to be able to handle passing through the hydraulic outlets at a deeper depth than those that approach the FRE during the day.

While it does appear juvenile salmonids are capable of acclimating to greater depths, Khan et al. (2012) found that juvenile Chinook Salmon and steelhead remained surface-oriented (i.e., above 10 meters [32.8 feet]) 62 percent of the time during the refill and full pool periods to 80 percent of the time during the flat elevation and fall release periods at the Lookout Point Dam on the Middle Fork Willamette River. During these periods, water temperatures from the surface to 5 meters (16.4 feet) ranged from 19.5ºC in August to 12.1ºC in November and were much cooler at depth, ranging from 11.7ºC in August to 10.6ºC in November, at 30 to 35 meters (98.4 to 114.8 feet) depth. Figure 3 shows the daily average surface elevation level of the forebay at the Lookout Point Dam from February 2010 to January 2011. The surface elevation level at the forebay paired with the water temperature may indicate why fish are more likely to remain surface-oriented versus diving deeper as typically when reservoir water temperatures are high in surface water, fish tend to move to deeper, cooler water. Regardless of temperature, the highest percentage of fish (30 to 60 percent) remained between 5 and 10 meters (16.4 and 32.8 feet) which was a prevalent behavior for juvenile salmonids.

Figure 3. Daily Average Surface Elevation (feet above mean sea level) of the Forebay at the Lookout Point Dam from February 2010 to January 2011



Source: Khan et al. (2012)

Lastly, Beeman et al. (2014) studied in-reservoir movements and dam passage of juvenile Chinook Salmon and steelhead at the Detroit Reservoir and Dam, near Detroit, Oregon. They found that the depths of tagged fish within 25 meters of the dam varied between species, reservoir elevation, and diel period. When the reservoir elevation was greater than the spillway ogee of 1,541 feet during the spring study period, the mean hourly depths of Chinook Salmon ranged from 10.4 to 29.1 feet and were slightly deeper during the day than during the night. When the reservoir elevation was less than 1,541 feet during the spring study period, which occurred as the reservoir was filling in March and April, Chinook Salmon showed a large variation in depth-distribution across a 24-hour period; however, only eight tagged fish were present during that condition. Their individual mean hourly depths ranged from 16.0 to 139.0 feet, with mean values of 104.5 feet during the day and 28.5 feet during the night. Steelhead depths were shallower and less variable than Chinook Salmon depths during the spring study period. Their mean hourly estimated depths ranged from the surface to 7.1 feet and were similar during the day and night.

4.3 Biological Mechanisms Influencing Fish Depth

To better understand why juvenile fish are distributed in the upper portions of the water column, biological mechanisms should also be reviewed. Juvenile fish activity is largely focused on survival and growth due to the limited physical resources they have in younger life stages (developing muscles, minimal fat stores). Bioenergetics is a research area that describes the balance of fish activity in a biological way.

Fish bioenergetics can be described as an energy budget where fish balance energy gained from ***I*** (ingestion: total energy gained) and lost through ***G*** (growth: increase in length and weight over time), ***A*** (activity: physical movements such as swimming, foraging, social interactions, evading predators, and search for suitable habitats), ***M*** (metabolism: chemical processes that convert food into energy in order to maintain life), ***R*** (reproduction: development of gonads: ovaries & testes and production of gametes: eggs & sperm), ***E*** (excretion: expelling or removal of metabolic waste through fecal matters, ammonia, urea, or uric acid), and ***SDA*** (specific dynamic action: digestive processes, nutrient absorption and assimilation; Mayfield and Cech 2004). A simplified bioenergetics equation is modeled below:

$$I = G + A + M + R + E + SDA$$

The bioenergetic demands of juvenile salmonids typically increase with activity level during foraging and searching for suitable habitats (Hartman & Hayward 2007). The presence of predators increases stress levels, as well as burst swimming to evade these predators lead to exhaustion which carries significant bioenergetic costs to juvenile salmonids. As a result, fish tend to inhabit waters with easily accessible and ample amounts of prey items for consumption to continue to have high amounts of stored energy for maintenance, growth, and reproduction to increase survival. This physiological ecology and response reflect the dynamic nature of adjustments aimed at optimizing the bioenergetic balance between consumption and expenditure across changing environmental conditions. More simply stated, bioenergetic success is represented by feeding with minimal effort.

The vertical habitat preferences of juvenile salmonids are generally driven by bioenergetics requirements that ensure that energy intake is maximized, and energy expenditure is minimized.

Since salmonids are primarily visual feeders, occupying the upper portions of water column maximizes energy intake relative to the cost of foraging. In addition, the upper water column tends to be better oxygenated, which supports aerobic metabolism and reduces the energy cost of respiration (Brett 1971, Quinn 2018). By remaining near the top of the water column where prey density is higher, juvenile salmonids can maximize foraging efficiency and achieve a positive energy balance that supports growth. Conversely, deeper portions of the water column often provide fewer prey resources and reduced light for visual feeding, which lowers potential for prey interaction and consumption. Additionally, deeper habitats may increase metabolic rates by swimming against stronger currents and respiratory demands if dissolved oxygen levels are reduced at depth (Gregory and Levings 1998). Vertical distribution of juvenile salmonids is not fixed, but instead reflects dynamic adjustments aimed at optimizing the bioenergetic balance between consumption and expenditure across changing environmental conditions.

The bioenergetics of salmon biology support that juvenile fish do not regularly invest in energetic activity to reach dark, less productive, water depths with little overall potential for benefit (i.e., feeding). Because impoundment of the dam is only expected to occur during flood events over short periods of time, high turbidity would be expected with low penetration of sunlight into the reservoir. With the photic zone (penetration of sunlight to support photosynthesis) being shallow, growth of primary producers (e.g., phytoplankton) and zooplankton at depth is limited, which limits food resources and habitat for macroinvertebrates. Therefore, juvenile fish would tend to occupy the upper water column near the surface to forage on macroinvertebrates associated with the presence of lower trophic level organisms.

While juveniles may infrequently occur at greater depths largely due to passive drift in larger rivers (undertow) or predator avoidance (being chased), the biological drivers behind their bioenergetic ‘budget’ of a juvenile salmon largely results in occupying shallower biologically productive water depths relative to the proposed project diversion.

5.0 Conclusion

Effects on juvenile fish outmigrating downstream in the Chehalis River are expected when flood retention operation occurs, and discharge from outlet gates is reduced to impound floodwater behind the FRE structure. During the portion of flood retention operations when the temporary inundation pool elevation is high the pool is evacuated using unscreened, high velocity hydraulic outlets. Pool evacuation using unscreened, high velocity outlets poses a risk of injury or death to juvenile outmigrants that may become entrained into these hydraulic outlets.

There is a depth at which the risk of fish entrainment is low enough to allow discharge through unscreened, high velocity outlets. It is critical to understand the vertical migratory behavior of fish as they approach the outlets so the hydraulic outlets can be design to operate to reduce risk to juvenile fish. Vertical migration is a typical phenomenon for salmonids and vertical distribution factors during downstream migration vary within reservoirs (e.g., species, diel changes, seasonally, annually, location, temperature, reservoir elevation). To reduce the risk to outmigrants, reservoir releases should occur via unscreened, hydraulic-only outlets at pool depths with low risk of entrainment or via outlets that exclude fish or provide safe downstream passage through hydraulically favorable conditions. The temporary reservoir elevation at which the depth above an active, unscreened, hydraulic-only outlet has an acceptably low risk of potential entrainment is shown in Figure 1 and described in Section 3 for a typical impoundment event.

In general, the research summarized in this document supports that juvenile salmonids (i.e., Chinook Salmon, Coho Salmon, and steelhead) typically prefer to stay in the top 20 feet of the water column as they migrate. However, study results vary, showing most fish observations from the surface down to maximum depths ranging from approximately 15 to 49 feet. The deeper depths at which are found to sound to are more likely to occur if fish are given time to acclimatize to deeper water columns. Fish are unlikely to acclimatize at the FRE given that storm events are sudden and the impoundment of water behind the FRE structure will be brief and infrequent. Ultimately, water depth preferences are driven largely by bioenergetics requirements, which dramatically reduce entrainment risk into the hydraulic outlets at depths greater than around approximately 20 to 30 feet with reducing risk as depth increases (Sections 4.1 and 4.2).

At a 30-foot depth, the differential ratio of the intake opening to the surface area near the dam is conservatively <0.01 percent. This mitigates much of the risk of entrainment, and even continues to decrease significantly at greater depths. However, an unknown but likely small percentage of fish could sound to depths greater than 30 feet if impoundment conditions persist long enough depending on species, specific life stages (e.g., fry, juvenile, etc.), water temperatures, time of day, and other factors. Additionally, flood retention operation is anticipated to occur about once every 4-to-5-years when the facility first begins operations and increase to once every 2-to-3-years based on recent climate projections. Further, operations are modeled to potentially occur between the months of November to February early in the life of the project and may occur between November and April by the year 2080. which would further increase juvenile salmonids' risk of entrainment. Most juvenile salmon and steelhead in the river will outmigrate after potential flood retention operations may occur early in the project's life (February to August), thus reducing exposure to potential entrainment even further. Exposure to potential entrainment may increase under future climate conditions, but would only increase potential exposure for two additional months of the seven month outmigration period.

HDR discussed the research and findings in this memo with NOAA Fisheries in 2025 (HDR 2025b; Appendix A). It was agreed that most juvenile salmonids likely would not sound deeper than 30 feet in a temporary inundation pool at the FRE structure and would have limited exposure to potential entrainment and flood operation conditions at the FRE. A hydraulic outlet that does not exclude fish or provide safe downstream passage through hydraulically favorable conditions must only discharge flow during flood retention operation when the water surface is 30 feet or more above the top of the same hydraulic outlet. Hydraulic outlets that discharge when the water depth is less than 30 feet must have a smooth inlet transition, such as curved entrances and radial gates. The design direction agreed upon in the meeting, summarized here, is consistent with and supported by the findings documented in this memo and will be incorporated into the project design.

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7.0 Acronyms

ºC	degrees Celsius
FRE	Flood Retention Expandable
HDR	HDR Engineering, Inc.
NOAA	National Oceanic and Atmospheric Administration
PDR	Preliminary Design Report
Proposed Project	Proposed Chehalis River Basin Flood Damage Reduction project
RM	river mile
RPDR	Revised Project Description Report
USFWS	United States Department of Fish and Wildlife
WDFW	Washington Department of Fish and Wildlife
WSEL	water surface elevation level

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Appendix C. Fishway Lighting TM

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Technical Memorandum

Date:	November 21, 2025
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	HDR
Subject:	**Fishway Lighting (Draft)**

1.0 Background

The Proposed Chehalis River Basin Flood Damage Reduction project (Proposed Project) objective is to implement a series of measures aimed at reducing damage to the communities of the Chehalis River Basin from Pe Ell to Centralia during major flood events. Among these measures is a proposed Flood Retention Expandable (FRE) structure on the Chehalis River, south of Pe Ell, Washington.

The Proposed Project's draft Preliminary Design Report (PDR) documents development of the preliminary design of the FRE facility and related elements. Development of the draft PDR began following submittal of the Revised Project Description Report (HDR Engineering, Inc. [HDR] 2024), which was used as the baseline for the draft PDR, submitted for information-only purposes on June 30, 2025 (HDR 2025). This draft PDR reflects design development that has occurred since submittal of the June 30, 2025, draft PDR.

The draft PDR documents the design basis for each Proposed Project element, including a record of design decisions, assumptions, and methods related to the development of the design of the FRE structure and related elements. The draft PDR also presents the technical details of the main features of the Proposed Project elements.

2.0 Introduction

The draft PDR also presents the technical details of the main features of the Proposed Project elements. The FRE structure includes the following fish passage components, designed to provide passage for a range of species and life stages:

- Flood Fish Passage Facility
- Outlet Works, including Fish Passage Structures
- Temporary Channels
- Permanent Channels

Both upstream and downstream passage are considered to include all life-stages of the species listed in Table 1 (Section 4.0).

As used in this Technical Memorandum, "fish passage structures" refers to the pathways designed for upstream and downstream fish passage in the facility. These may be dedicated fishways, the facility's primary or secondary conduits designed to accommodate fish passage, or other structures that accommodate fish passage. The broader term "fish passage structures" is used because the lighting concerns for these pathways are generally the same regardless of the type of pathway.

3.0 Fishway Lighting

The outlet works consist of conduits and fishways through the base of the FRE structure allowing the Chehalis River to pass through during normal flow-through operation (normal operation). The conduit and fishway gates are normally open for fish passage and only closed for flood retention. When the FRE structure operates to retain flood water (flood retention operation) the fishway gates are closed and the conduits are used for reservoir releases. During flood retention operation fish passage through the outlet works ceases. Fish passage during flood retention operation is described in Appendix I: Fish Passage Report (HDR 2025).

Artificial lighting of the fish passage structures, including pathways through the outlet works, was investigated as a potential mitigation strategy to improve fish passage throughout the year during normal operation. This technical memorandum includes a review of relevant literature to understand how lighting may be used to improve fish passage through the fish passage structures. The affected region of the Chehalis River Basin is characterized by migratory anadromous and other native fish species with reportedly varying levels of behavioral response to artificial light frequency and intensity. Given the varied responses of fish to light, knowledge gaps exist and need to be locally examined prior to final design recommendations. This technical memorandum offers a literature-informed review of artificial lighting impacts on fish passage, drawing from peer-reviewed studies and existing reports on species behavior and light sensitivity. While localized information and studies are key to understanding the benefit of lighting, the results of several studies provided herein highlight the potential outcomes of incorporating lighting to improve fish passage.

Artificial illumination around fish passage systems has been reported to assist and improve fish passage efficiency and restore longitudinal riverine connectivity. Several research and case studies emphasize the need for a holistic approach towards designing a functional fishway, including fish interactions with their environment. In a 2012 study, Vowles and Kemp argue that understanding the relationship between hydrodynamic cues and various environmental stimuli are critical towards implementing safe and successful lighting approaches (Vowles and Kemp 2012). However, there are mixed reviews on the effects of artificial light at night (ALAN) with researchers and industry members often noting an increased effect of predation on smolt or juvenile salmonids when exposed to high light levels at night. Other research studies have posted that varying light levels can act as an attractant or a deterrent (Table 2).

Evidence from Mueller and Simmons (2008), Tetard et al. (2019), Vowles and Kemp (2012), and others shows that juvenile salmonids may be attracted to low-intensity lighting (~0.25 lux, equivalent to moonlight) but startled or deterred by intensities above 400 lux. For some species (e.g., Topeka shiner, fathead minnow), studies found no significant behavioral change in response to culvert lighting, highlighting the need for site-specific observation (Table 3).

The 2022, National Oceanic and Atmospheric Administration (NOAA) Fisheries West Coast Region Anadromous Salmonid Design Manual (National Marine Fisheries Service [NMFS] 2022) states:

> *"Ambient lighting should be provided throughout the fishway, and abrupt lighting changes should be avoided (Bell 1991). In enclosed systems, such as transport tunnels, provisions for artificial lighting should be included. In cases where artificial lighting is required, lighting in the blue-green spectral range should be provided. Artificial lighting should be designed to operate under all environmental conditions at the installation. These lighting criteria are based in part on laboratory studies where a majority of Chinook and sockeye salmon and steelhead entered the lighted orifice when given a choice between a dark experimental orifice and a lighted control orifice where head was equal between the two orifices (Weaver et al. 1976)."*

NMFS (2022) recommendations also state that "lighting conditions upstream of a bypass entrance should be ambient and extend downstream to the structure or device controlling bypass flow."

Therefore, according to NMFS guidance, provisions for artificial lighting should be provided in transport tunnels, such as fish passage structures that pass through the base of the FRE structure, but does not require that artificial lighting be used. The recommendation to install provisions for artificial lighting but nor specifically recommending its use is consistent with the variability in outcomes noted in the studies described above and the need to understand the specific environmental conditions and potential impacts of lighting unique to each project and situation. Where artificial lighting is used, should be designed to mimic ambient light conditions, avoiding high-intensity illumination and minimizing abrupt light transitions. In applications such as orifice or fishway entry lighting, night-time light levels should not exceed 0.25–3.3 lux, depending on target species and context, as recommended by field-tested studies (Mueller and Simmons 2008; Tetard et al. 2019; Vowles and Kemp 2012).

Determining appropriate lighting conditions requires localized investigation. Fish behavior should be evaluated continuously across seasons and flow regimes, potentially including passive integrated transponder or acoustic telemetry, underwater cameras, or eDNA. These data are integral in building a species- and site-specific knowledge base. Developing and creating a system that provides light timing and intensity flexibility would allow for this monitoring to occur and adjustments to be made following construction of the facility. To avoid disrupting natural behavior, lighting should not be used to attract fish unless supported by empirical evidence local to the fishway. If used, lighting should be integrated thoughtfully with other components to enhance passage efficiency.

Table 1 lists target fish species and illustrates the varied response of species and life stage to different ambient lighting strategies across relevant studies as evidence to support the need for fishway lighting. While some reports reveal a negative (deterrent) response to artificial light, others show specific frequencies/wavelengths can assist fish passage by acting as an attractant.

Table 1. Target Fish Species and Life Stages Selected for Design Development

Species	Upstream	Downstream
Spring-run Chinook salmon	Adult, Juvenile	Juvenile
Fall-run Chinook salmon	Adult, Juvenile	Juvenile
Coho salmon	Adult, Juvenile	Juvenile
Winter-run Steelhead	Adult, Juvenile	Adult, Juvenile
Coastal cutthroat trout	Adult, Juvenile	Adult, Juvenile
Pacific lamprey	Adult	Ammocoetes, Macropthalmia
Western brook lamprey	Adult	Ammocoetes, Macropthalmia
Resident fish, including river lamprey, largescale sucker, Salish sucker, torrent sculpin, reticulate sculpin, riffle sculpin, prickly sculpin, speckled dace, longnose dace, peamouth, northern pikeminnow, redside shiner, rainbow trout, mountain whitefish	Adult	Adult

Table 2 documents behavioral responses of key native fish species to artificial lighting or shaded conditions across various life stages. Findings are paraphrased for clarity and based on peer-reviewed and agency reports. Table 3 provides observed responses of non-target or related fish species to artificial lighting or shaded environments (included for comparative context).

Table 2. Light Response of Target Fish Species

Family	Species	Life Stage	Key Finding	Citation
Cottidae	Torrent Sculpin, Reticulate Sculpin, Riffle Sculpin, Prickly Sculpin	Adult	No behavioral response to light recorded.	No Data
Cyprinidae	Northern Pikeminnow, Speckled Dace, Longnose Dace, Northern Pikeminnow, Peamouth, Redside Shiner	Adult/ Other	Behavioral changes under artificial light, including altered passage or detection. No significant behavioral avoidance to reduced light conditions in culverts.	Celedonia et al. 2008; Kozarek et al. 2017
Salmonidae	Coastal Cutthroat Trout, Mountain Whitefish, Rainbow trout, Winter-run Steelhead, Brown Trout	Juvenile	Context-dependent responses to artificial light in that they were often attracted to low-intensity light (<50 lux) but startled by or avoided high-intensity light (>100 lux). Behavior included increased aggregation near illuminated structures, delayed migration, altered diel patterns, and elevated stress under continuous exposure. Some studies also observed optimal swimming and welfare at moderate light levels.	Mueller and Simmons 2008; Tétard et al. 2019; Kemp et al. 2006; Liu et al. 2025; Tabor et al. 2004; Jensen 2023
Salmonidae	Chinook, Coho, and Sockeye Salmon	All	Light influenced movement or habitat selection across life stages. Avoidance of high-velocity acceleration zones under light may reflect stress or risk sensitivity.	Celedonia et al. 2008; Jensen 2023; Kemp et al. 2006; Mueller and Simmons 2008; Tabor et al. 2004; Tetard et al. 2019
Salmonidae	Juvenile Salmonids	Smolt	Experienced delays or disrupted movement under ALAN.	Mueller and Simmons 2008
Salmonidae	Steelhead trout	Smolt	Higher passage under light; larger fish favored short weir under light	Kemp et al. 2006

Table 3. Light Response of Related Fish Species

Family	Species	Life Stage	Key Finding	Citation
Anguillidae	European Eel (*Anguilla anguilla*)	Silver eel	Tended to avoid illuminated areas, possibly to reduce predation risk.	Vega et al. 2024
Centrarchidae	Carnivorous Fish (e.g., *Micropterus salmoides*)	Mixed	Carnivorous species had higher mean detection rate and relative read abundance under ALAN; *Micropterus salmoides* only detected under ALAN.	Oyabu et al. 2023
Cyprinidae	European Gudgeon (*Gobio gobio*)	Adult	Experienced delays or disrupted movement under artificial light exposure	Tarena et al. 2024
Cyprinidae	Italian Riffle Dace (*Telestes muticellus*)	Adult	Showed no significant behavioral response to light or shade.	Tarena et al. 2024
Cyprinidae	Himalayan trout *Schizothorax waltoni*	Adult	Strong attraction to green and blue light, repulsion from red and yellow light. Suggests green/blue for guidance to safe areas, red/yellow for deterrence.	Xu et al. 2022
Gadidae	Cod (*Gadus morhua*)	Juvenile	Light reduces upper codend entry only at night; No effect of illumination during the day.	O'Neill et al. 2022
Gadidae	Haddock (*Melanogrammus aeglefinus*)	Juvenile	Fewer enter upper codend under illumination and at night; Illumination and diel cycle reduce the proportion entering upper codend. Significant length interaction observed.	O'Neill et al. 2022
Salmonidae	Atlantic Salmon and European Eel (*Salmo salar; Anguilla anguilla*)	Fry; Migratory	Experienced delays or disrupted movement under artificial light exposure.	Vega et al. 2024; Riley et al. 2013
Salmonidae	Atlantic Salmon (*Salmo salar*)	Adult	Despite expectations, successfully navigated a dark, low-velocity tunnel without lighting. Upstream migration confirmed via resistivity counter, even under sub-optimal hydraulic condition.	Rogers and Cane 1979

Family	Species	Life Stage	Key Finding	Citation
Salmonidae	Atlantic Salmon (*Salmo salar*)	Smolt (Early Migration)	Reduced entry into lit bypass zone, but increased passage rate; experienced delays or disrupted movement under artificial light exposure.	Tétard et al. 2019; Vega et al. 2024
Cyprinidae	Fathead Minnow, Topeka Shiner (*Pimephales promelas*; *Notropis topeka*)	Adult	No statistically significant trend in selection or movement through shaded versus unshaded areas.	Kozarek et al. 2017
Salmonidae	Sea Trout (*Salmo trutta*)	Adult	Successfully passed through the long, dark tunnel. Performance not improved by lighting; illumination deemed unnecessary.	Rogers and Cane 1979

4.0 Conclusion and Recommendations

Ultimately, this memo concludes that lighting is beneficial only under certain circumstances. Therefore, lighting is not proposed as a stand-alone solution for fishways. Instead, it should serve as a supportive element within a broader passage design. The design should allow for lighting to be installed post-construction, so that as literature and knowledge on this subject evolve, lighting can be added based on demonstrated need.

There is a body of evidence from empirical research to suggest positive benefits and describe a need for fishway lighting, but only under specific conditions. However, the evidence also suggests that artificial lighting used in inappropriate conditions can negatively impact fish behavior. NMFS (2022) specifically states the need for ambient lighting provisions throughout a fish passage. In instances where rates of passage are recorded, or otherwise known, to be sub-optimal, ambient fishway lighting should be included based on best available practices and NOAA guidelines. In these instances, adaptive lighting and management plans should be strongly considered, and a fish passage monitoring program established. To avoid disruption in natural fish behavior, fishway lighting to attract fish when there is no data to support this need, should be avoided. The goal is for lighting to be one of many fishway system components that act in concert to optimize and regulate fish passage for critical periods such as out-migration and should only be used when a conduit or tunnel system is disallowing or detracting fish away from traveling through the system.

Due to the equivocal benefit of lighting unless it is tailored to specific locales, fish populations, and conditions, ambient fishway lighting will be considered during design of the FRE passage conduits and fishways to ensure lighting solutions can be reasonably added post-construction. An integrated monitoring plan should be prepared to assess the need for artificial ambient lighting. While lighting is not currently proposed, the design should allow for lighting to be added if future monitoring or evolving literature demonstrates a need. If lighting is installed, its effectiveness and potential adverse effects will be evaluated. This issue can be addressed through permitting as knowledge on the subject continues to develop. Lighting conditions should be expected to fluctuate annually. Understanding water velocity rates in conjunction with the light intensity during specific times of year to monitor and manipulate light presence and intensity, is integral for facilitating effective fish passage.

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6.0 Acronyms/Abbreviations

ALAN	artificial light at night
HDR	HDR Engineering, Inc.
FRE	Flood Retention Expandable
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PDR	Preliminary Design Report

Appendix D. Backwater Analysis Pool Frequency with Conduit Gates Open (Draft) TM

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Technical Memorandum

Date:	January 9, 2026
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	HDR
Subject:	**Backwater Analysis Pool Frequency with Conduit Gates Open (Draft)**

1.0 Background

The Proposed Chehalis River Basin Flood Damage Reduction project (Proposed Project) objective is to implement a series of measures aimed at reducing damage to the communities of the Chehalis River Basin from Pe Ell to Centralia during major flood events. Among these measures is a proposed Flood Retention Expandable (FRE) structure on the Chehalis River, south of Pe Ell, Washington.

The Chehalis River Basin Flood Damage Reduction, draft Preliminary Design Report (PDR) documents development of the preliminary design of the FRE facility and related elements. Development of the draft PDR began following submittal of the Revised Project Description Report (HDR Engineering, Inc. [HDR] 2024), which was used as the baseline for the draft PDR. This draft PDR reflects design development that has occurred since submittal of the June 30, 2025 draft PDR (HDR 2025).

The draft PDR documents the design basis for each Proposed Project element, including a record of design decisions, assumptions, and methods related to the development of the design of the FRE structure and related elements. The draft PDR also presents the technical details of the main features of the Proposed Project elements.

2.0 Introduction and Purpose

The Chehalis Basin Flood Control Zone District is proposing to construct a new flood retention structure to reduce damage to life and property along the Chehalis River (Proposed Project). Design of the proposed FRE structure is at a preliminary level of development.

This Technical Memorandum documents the hydraulic analysis of the frequency and time duration of when a backwater is created, with the conduit gates fully open, when river flows exceed 13,700 cubic feet per second (cfs).

3.0 Level Pool Routing

River flow data was analyzed from 1982 to 2022 for when river flows exceeded 13,700 cfs. The conduits begin to flow full and create a backwater at flows greater than 13,700 cfs. Dates identified where the gates were triggered to close for flood retention were not included in this analysis. A level pool routing analysis was conducted for each time the river flow exceeded 13,700 cfs. Figure 1 shows the estimated conduit capacity with the gates fully open. Figure 2 shows the storage volume upstream in relation to when the conduits begin to create a backwater. Using the river flow as the inflow and the conduit capacity as the outflow, the change in storage was, or backwater, evaluated, and the time required for the backwater to dissipate was calculated. Table 1 shows the results of the level pool routing for each event that exceeds 13,700 cfs. The duration between the 12 events range from 1.2 hour to 6.5 hours, with the average being 3.6 hours.

Figure 1. Estimated Conduit Capacity with Gates Fully Open

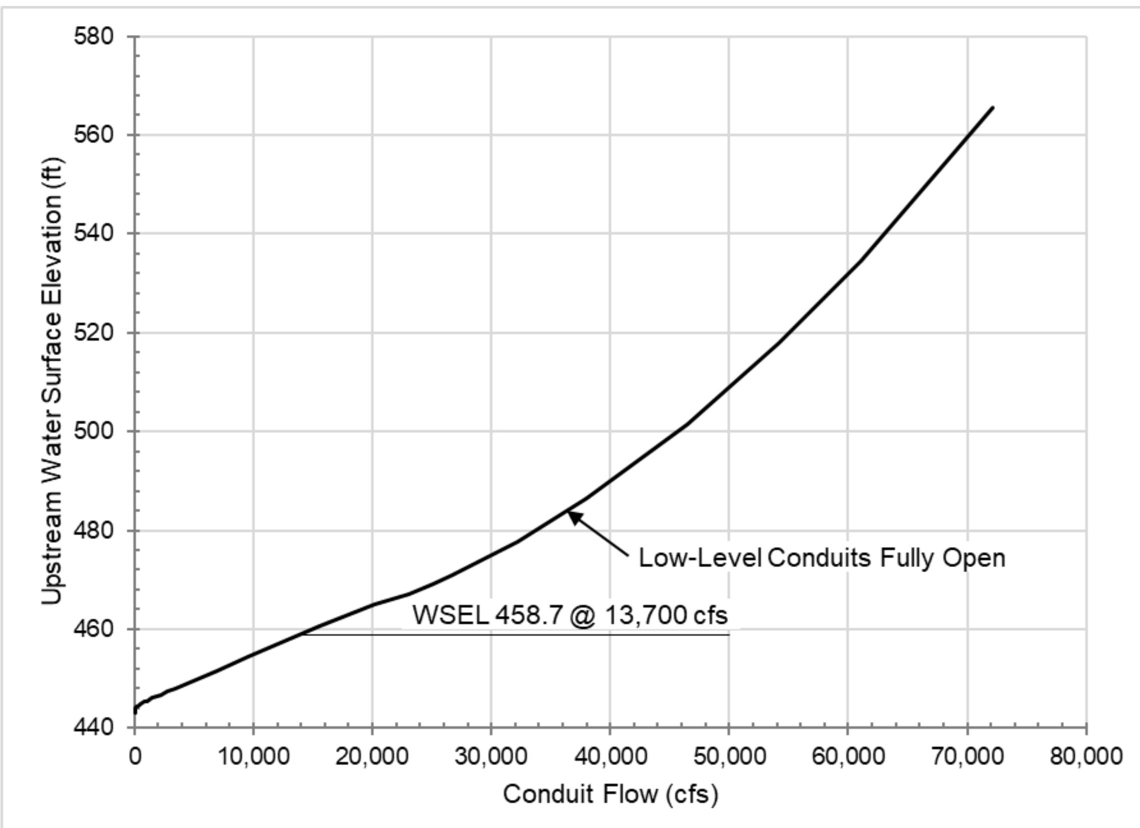

Figure 2. Storage Volume in Relation to Conduit Capacity at 13,700 cfs

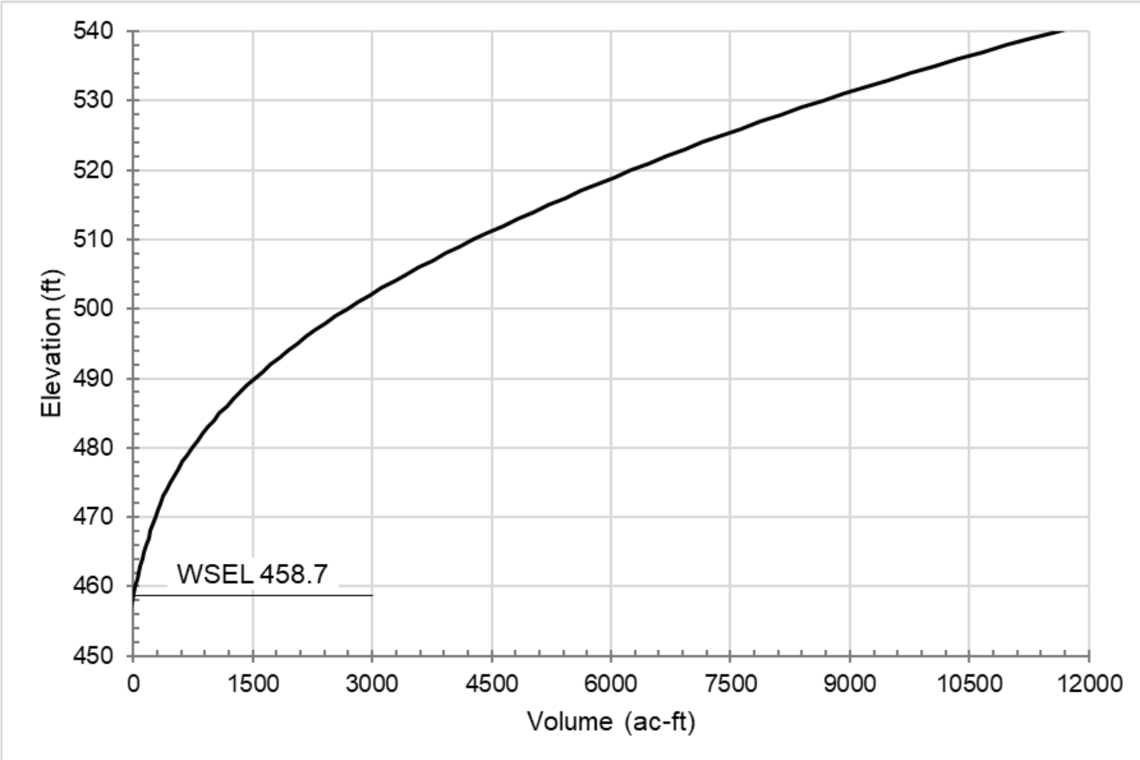

Table 1. Routing Results for each Flow Condition Exceeding 13,700 cfs

Starting Date	Duration (hours)	Peak Inflow (cfs)	Max River Elevation (feet)	Max Storage (ac-ft)	Max Additional Area Due to Storage (ac)
2/23/1986	1.2	13,909	458.9	3.3	0.3
11/25/1998	2.5	14,335	459.3	11.8	0.7
11/14/2001	3.8	16,075	461.1	46.8	2.4
1/17/2005	6.5	16,297	461.3	51.8	2.7
12/14/2006	1.6	14,152	459.1	7.2	0.5
11/12/2008	1.2	13,765	458.8	1.0	0.1
11/19/2012	5.1	14,764	459.8	21.0	1.1
1/5/2015	5.8	16,326	461.3	52.7	2.7
10/31/2015	4.7	16,427	461.4	55.0	2.8
11/13/2015	3.5	15,900	460.9	42.9	2.3
2/9/2017	3.4	14,792	459.8	20.7	1.1
12/19/2019	3.7	14,053	459.1	6.5	0.5

ac = acre; ac-ft = acre-feet

4.0 References

HDR Engineering, Inc. (HDR)

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2025 *Draft Preliminary Design Report: Flood Retention Expandable Structure*, Chehalis River Basin Flood Damage Reduction Project, Lewis County, Washington*,* June 30, 2025.

5.0 Acronyms/Abbreviations

ac	acre
ac-ft	acre-feet
cfs	cubic feet per second
FRE	Flood Retention Expandable
HDR	HDR Engineering, Inc.
PDR	Preliminary Design Report
Proposed Project	Proposed Chehalis River Basin Flood Damage Reduction project